

Drought risk analysis -a state of the art-

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Environmental Hydrological Systems

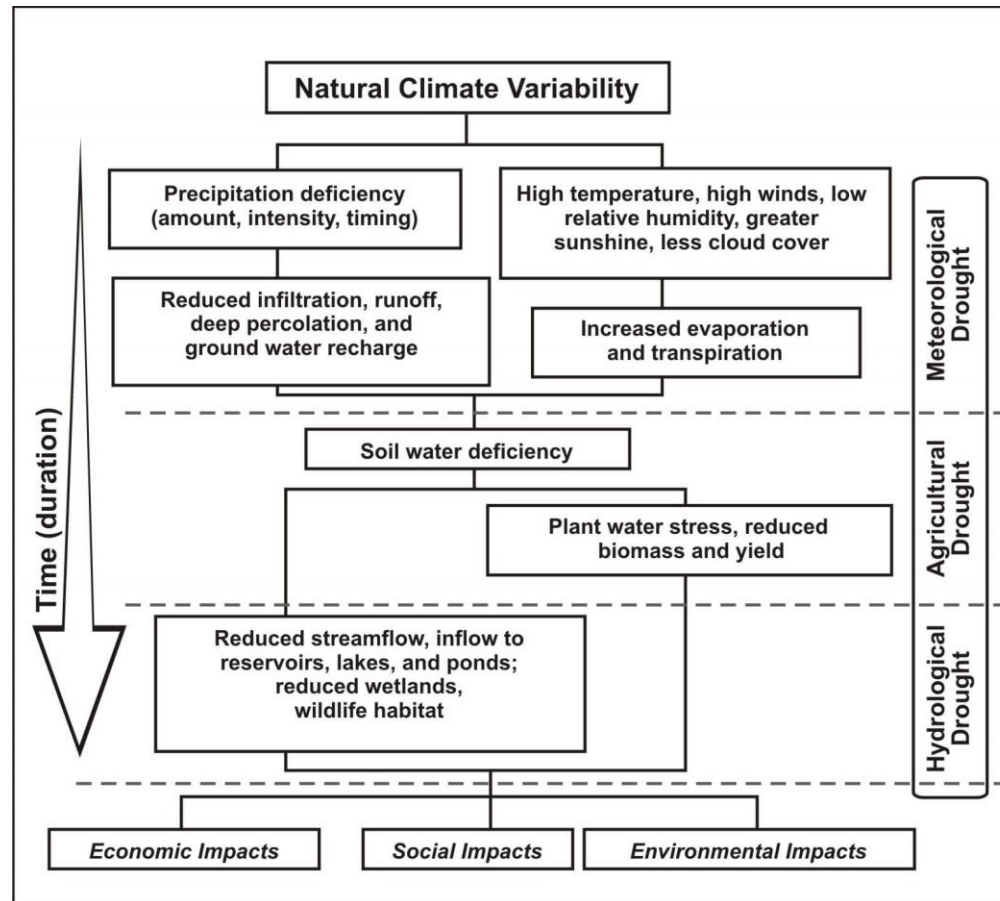
Albert-Ludwigs-Universität Freiburg



UNI
FREIBURG



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

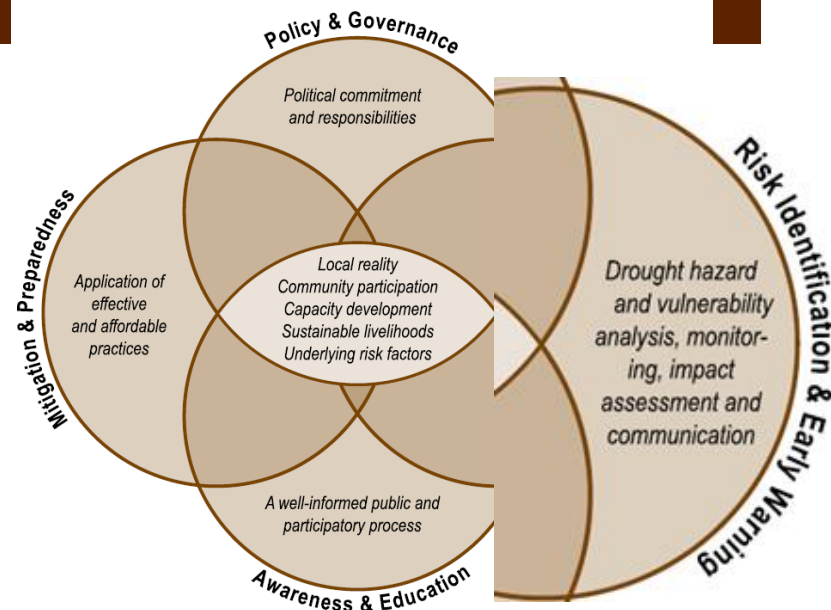
Drought risk is not: frequency and severity of the hazard

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



International Strategy for Disaster Reduction

Drought Risk Reduction Framework and Practices



Picturing drought – impacts globally



HYDROLOGY



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

Drought risk = $f(\text{hazard} \times \text{vulnerability})$

Foci of the review

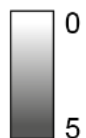
- Location
- Focus
- Spatial scale
- Temporal scale
- Paradigms of analysis
- Data applied
- Visualisation of risk via maps

Drought risk analyses around the globe

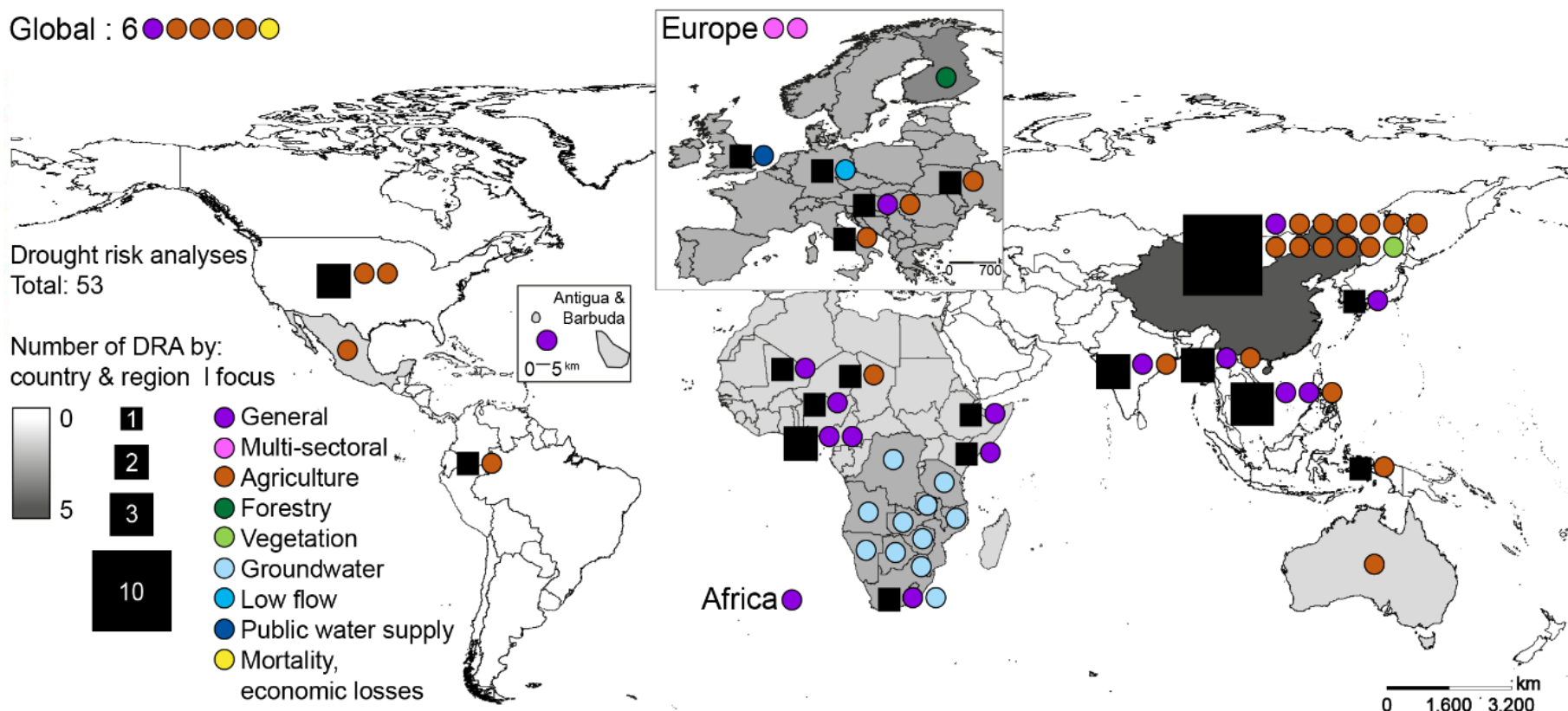
Global : 6 ●●●●●●

Drought risk analyses
Total: 53

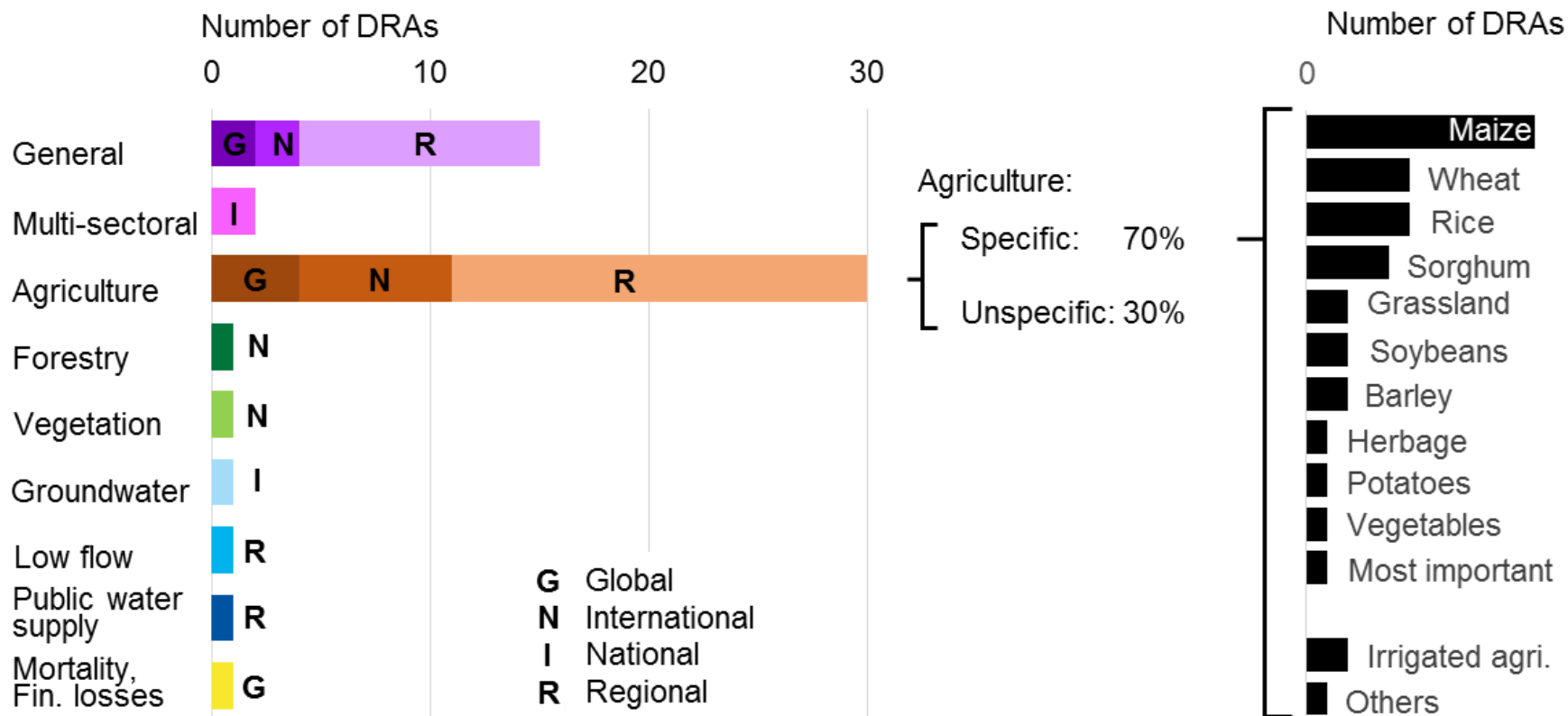
Number of DRA by:
country & region | focus



- General
- Multi-sectoral
- Agriculture
- Forestry
- Vegetation
- Groundwater
- Low flow
- Public water supply
- Mortality, economic losses



Sectors & scales of DRAs



Data approach

Drought risk
 $f(\text{hazard, vulnerability})$

Combination method

Drought risk
 $f(\text{hazard} \times \text{VULNERABILITY})$

Impact approach

Impacts as proxy of past vulnerability

Natural sciences

Quantification of risk based on the linkage between drought indices and impacts (as a proxy for vulnerability)

Risk analysis

Factor approach

(weighted) combination of different factors characterising vulnerability

Social sciences

Assessment of vulnerability by a combination of 'relevant', **vulnerability factors** stemming from epistemic fundi

Vulnerability assessment

Drought risk
 $f(\text{hazard} \times \mathbf{VULNERABILITY})$

Impact approach

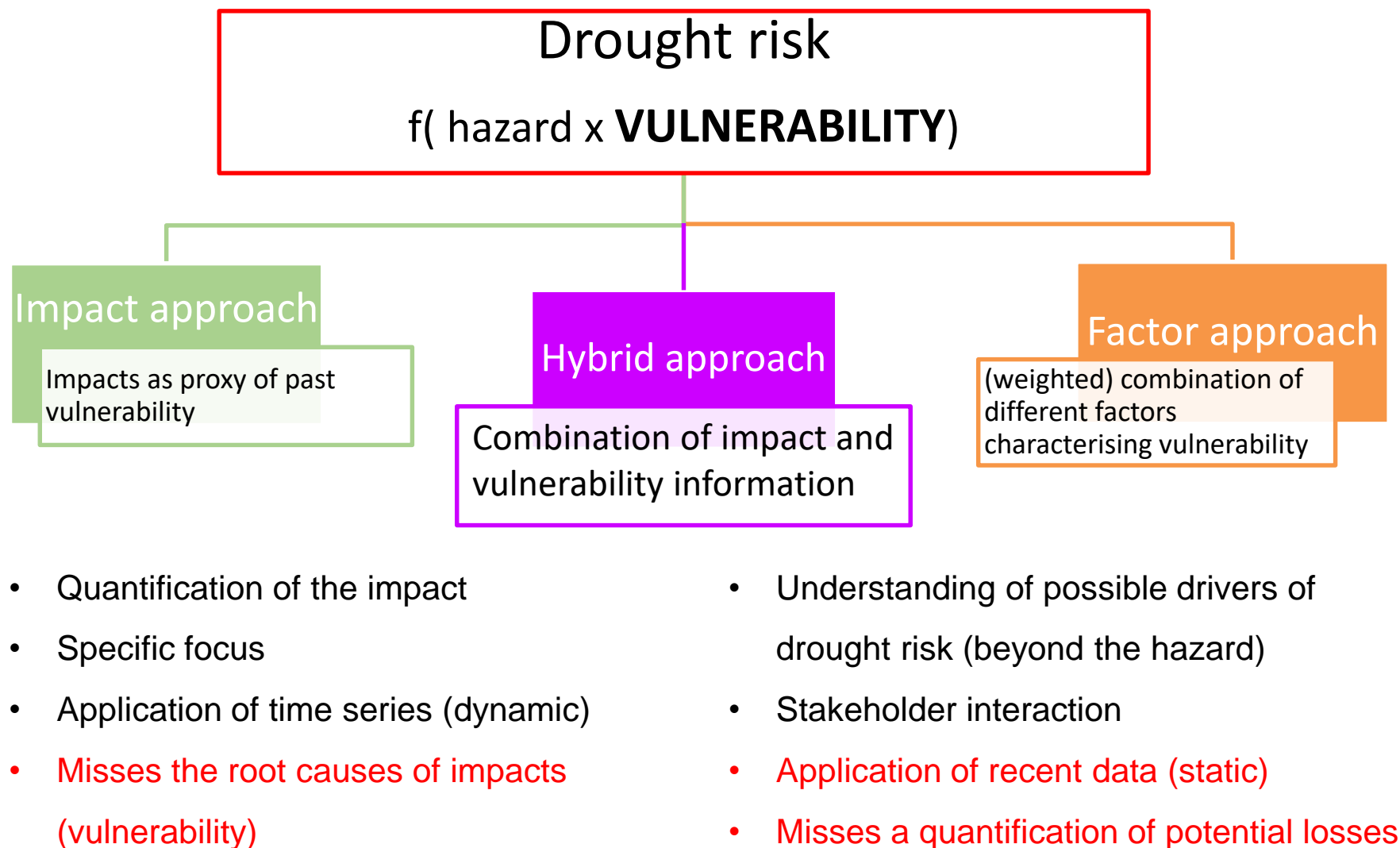
Impacts as proxy of past vulnerability

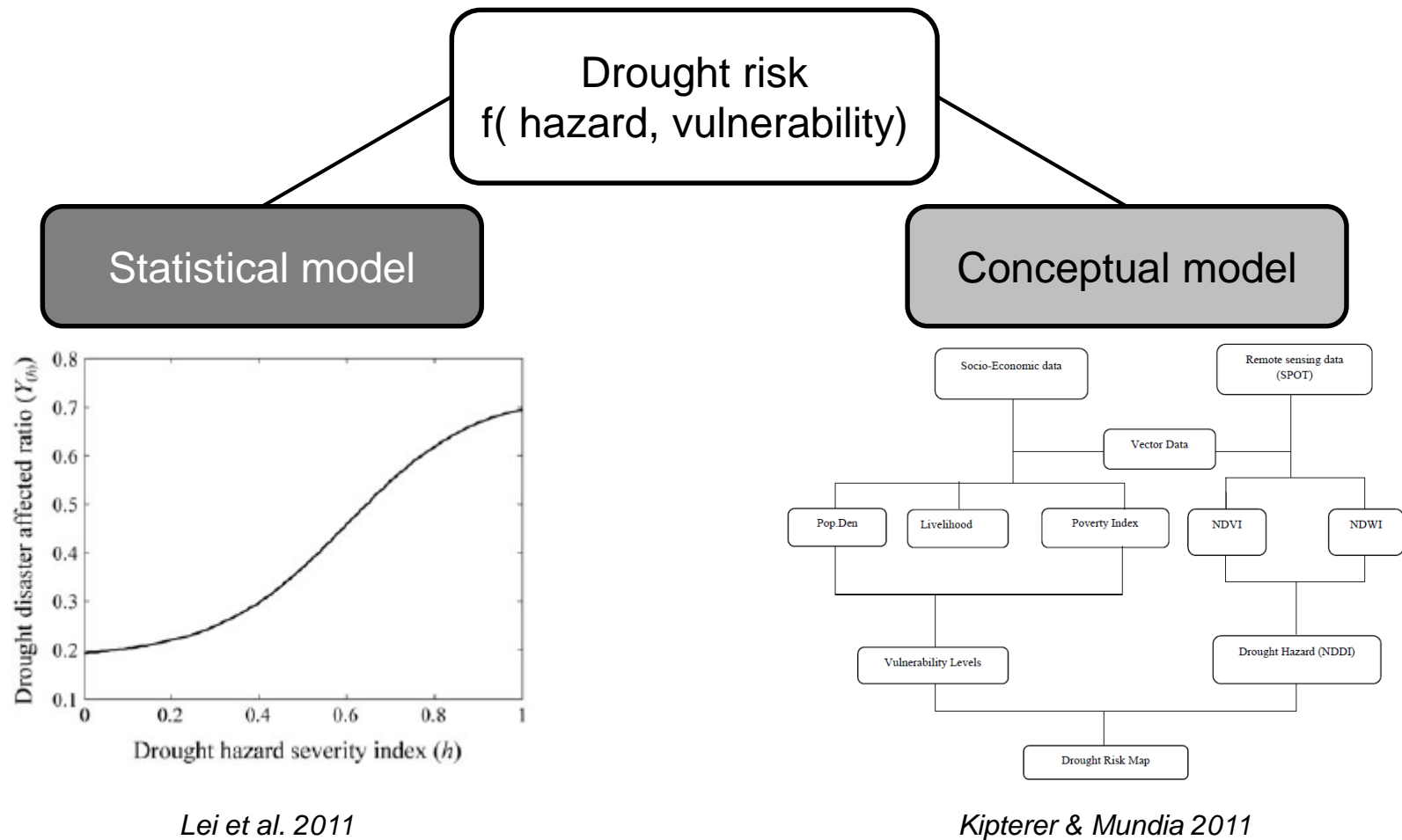
- Agricultural yields
- Financial losses
- Energy production
- Reported drought impacts

Factor approach

(weighted) combination of different factors characterising vulnerability

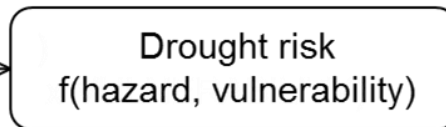
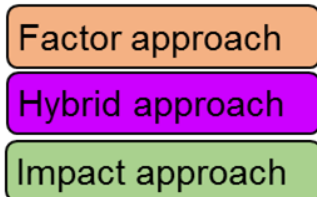
- Landuse
- Population density
- GDP
- Water Management plans
-



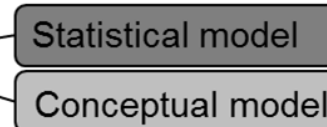


- Statistics are reliable and transparent
- Intransparent weighting and verification procedures

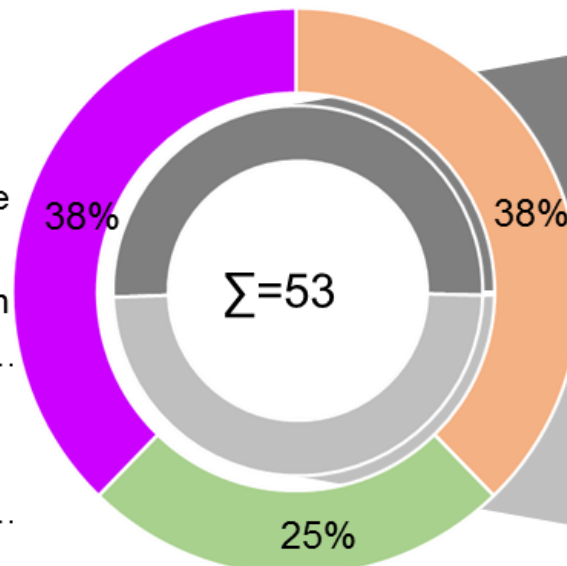
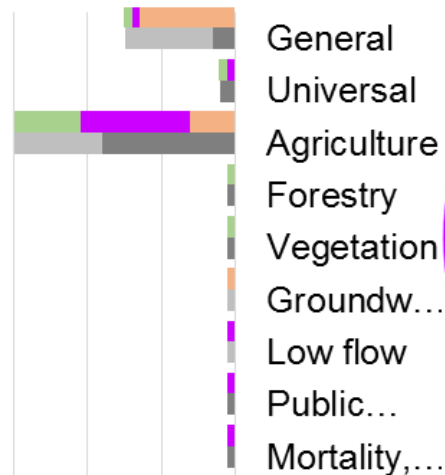
Data approach



Combination method



30 20 10 0



| | |
|---|----|
| Damage functions / production rates | 25 |
| Regression model | 2 |
| Weighted by EK | 13 |
| Weighted equally | 3 |
| Analytical hierarchy process & comprehensive weights approach | 2 |
| Analytical hierarchy process | 1 |
| Data Envelopment Analysis | 1 |
| Entropy weight method | 1 |
| Expert rankings | 1 |
| Grey correlation method | 1 |
| Variety | 1 |
| Weighted sum overlay approach | 1 |
| Counting system: properties met, summed to risk index | 1 |

→ Impact information: statistical model

→ Vulnerability information: conceptual models

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*

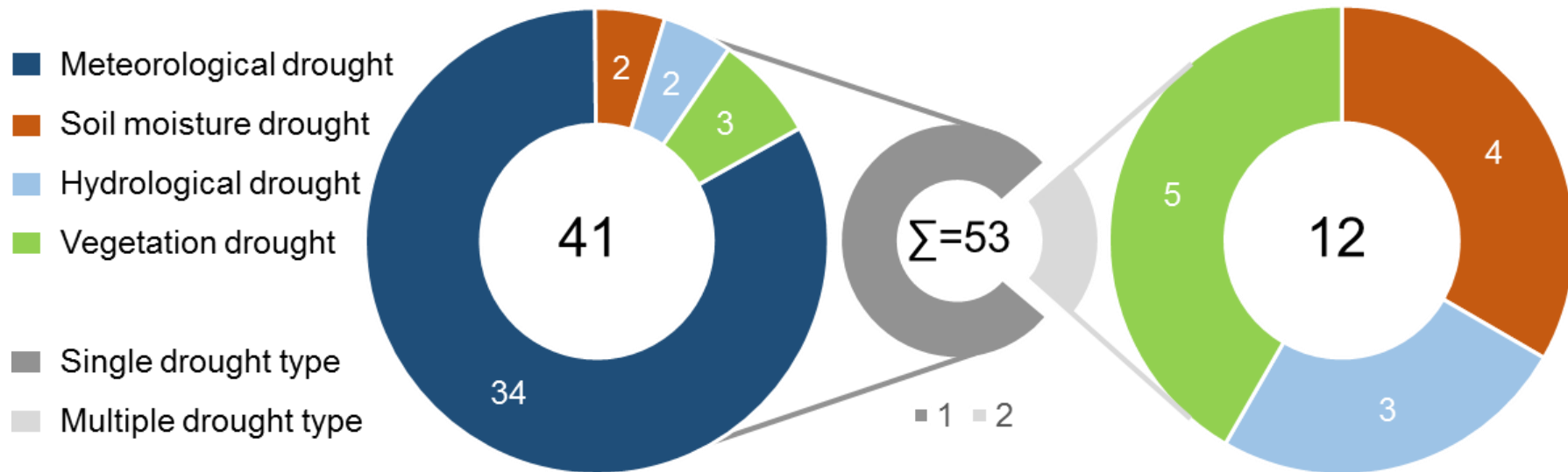
Risk:

Hazard

Vulnerability

Impact

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



Hit list:

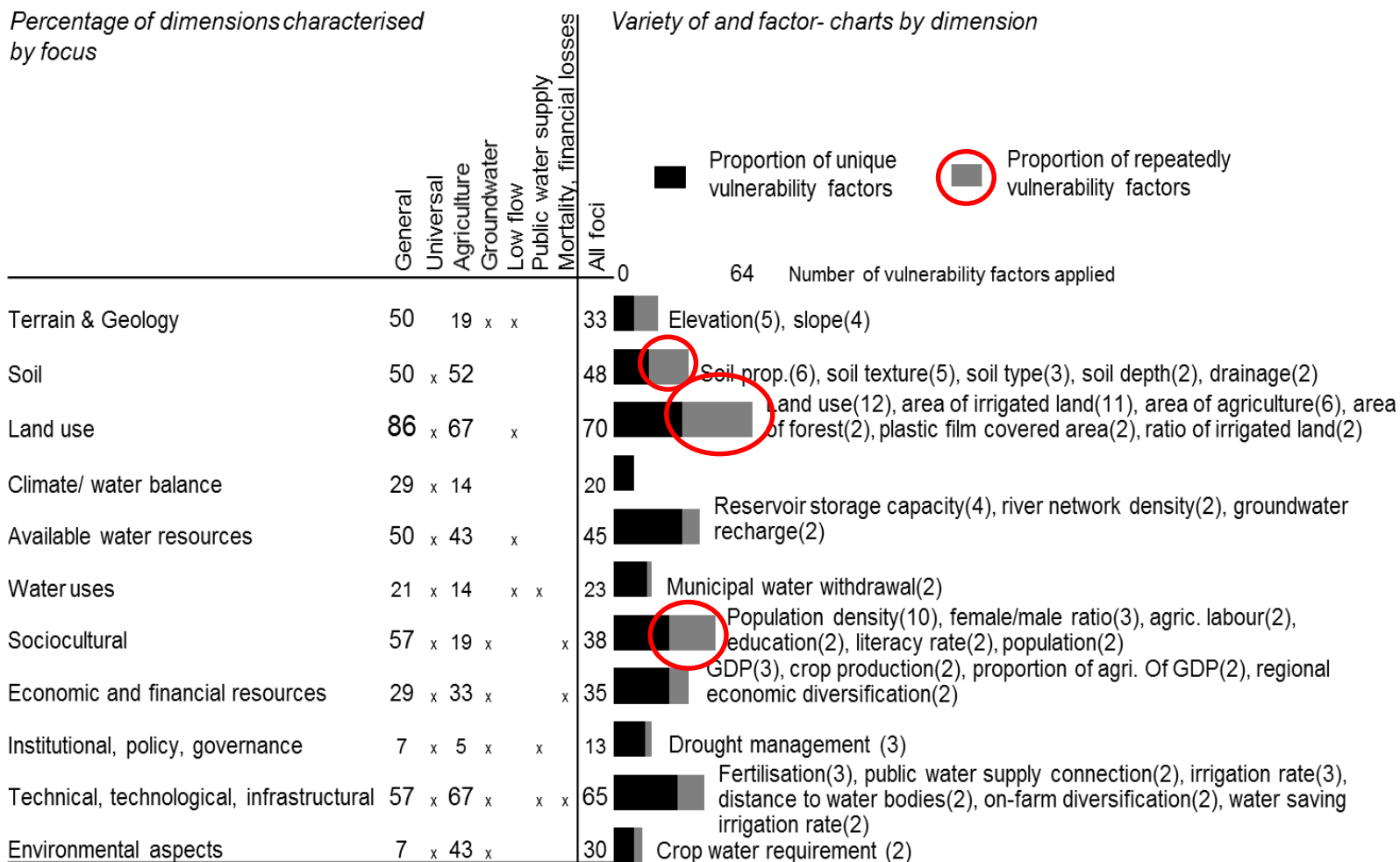
| | |
|------|---------------|
| SPI | 7 application |
| NDVI | 5 application |
| SPEI | 4 application |

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

Vulnerability factors (75% of DRAs)

Percentage of dimensions characterised by focus

Variety of and factor- charts by dimension



| 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% |
| <u>224 unique vulnerability factors</u> | |

- *Hugh variety*
- *Lack of common standards*
- *Prevalence of landuse and technological/ infrastructural information*

- > 60% of DRAs apply impact information
- Modelled and observed information
- Sources of 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 | Σ |
|---------------------|-----|-----|--------------|----------|
| 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 |
| Σ | 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*

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.

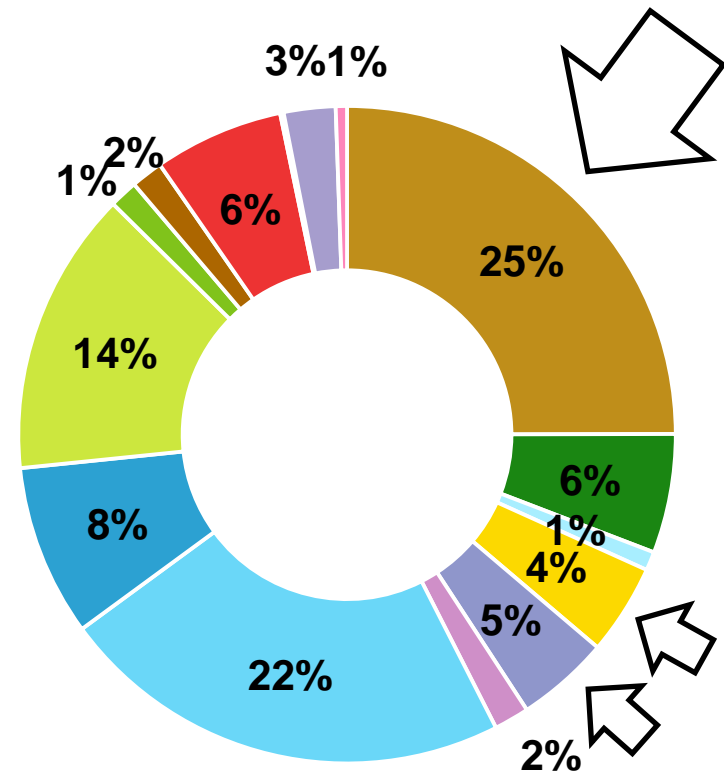
Information on drought impact tell the story of past drought risk and therefore should be the basis of an appropriate risk analysis. Furthermore, they are key to verify predictors selection.



Insights to the vulnerability to drought are essential to understand the drivers of impacts beyond the hazard, and thus essential to develop drought management strategies. Assessments should preferably be based on statistics, 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.

Affected sectors in Europe

- 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



Likelihood of impact occurrence :

Impacts

15 impact
Categories
(annual impacts)

x

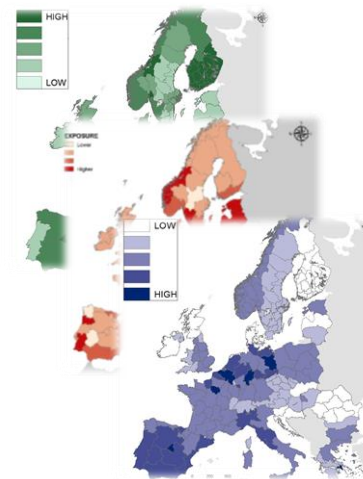
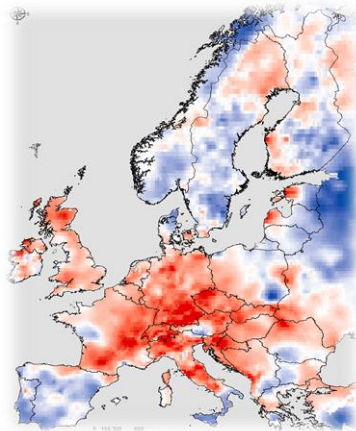
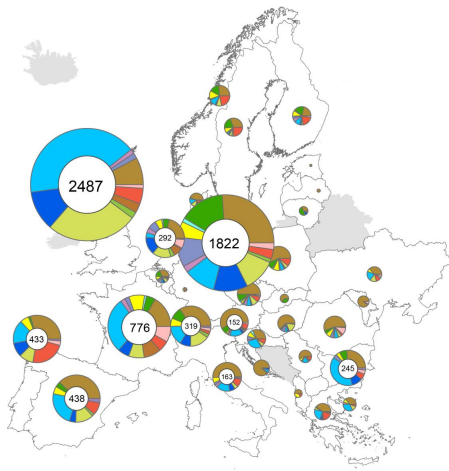
Hazard

x

5 indices (different
timescales, months)

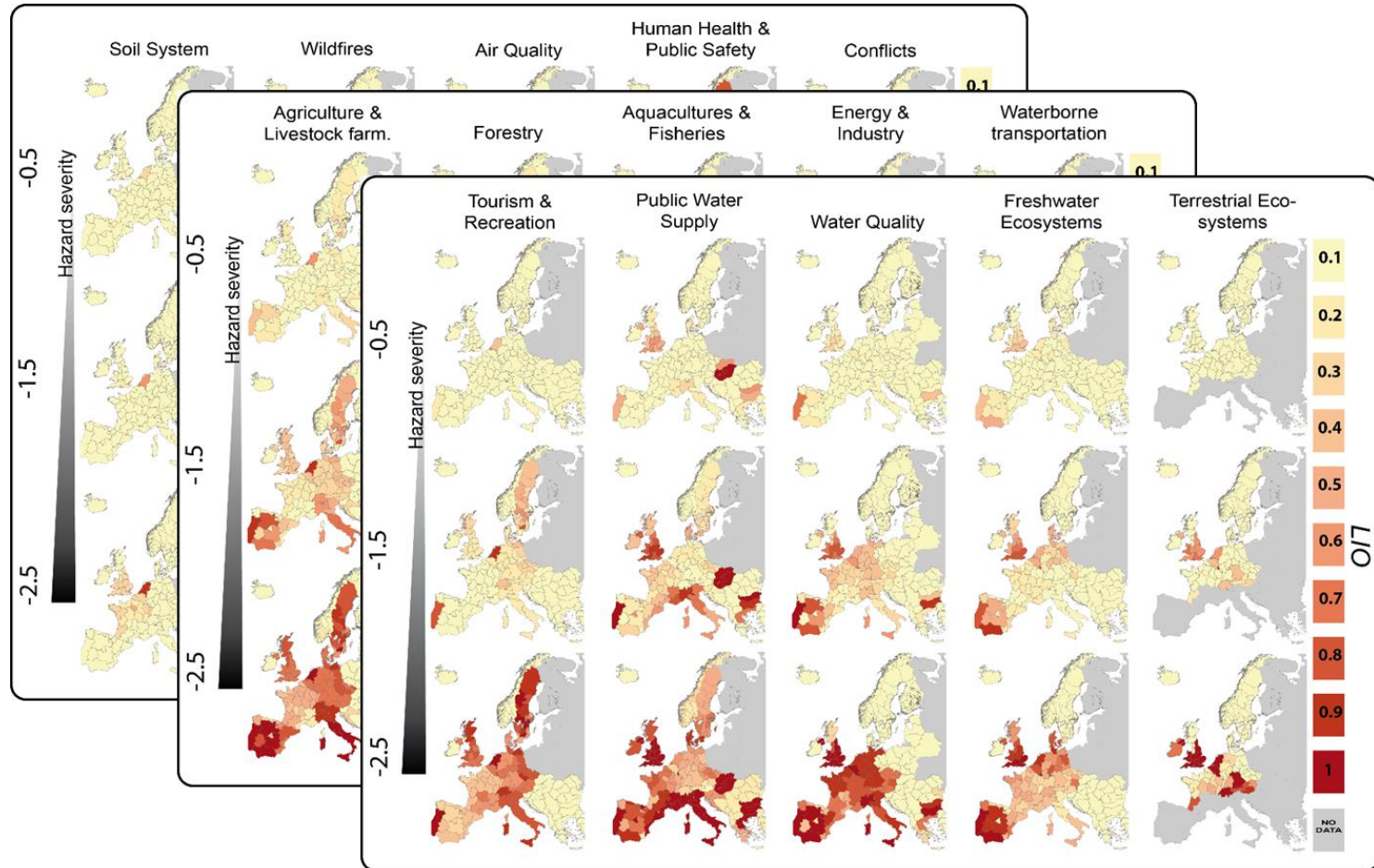
Vulnerability Factors = Risk

81 vulnerability factors

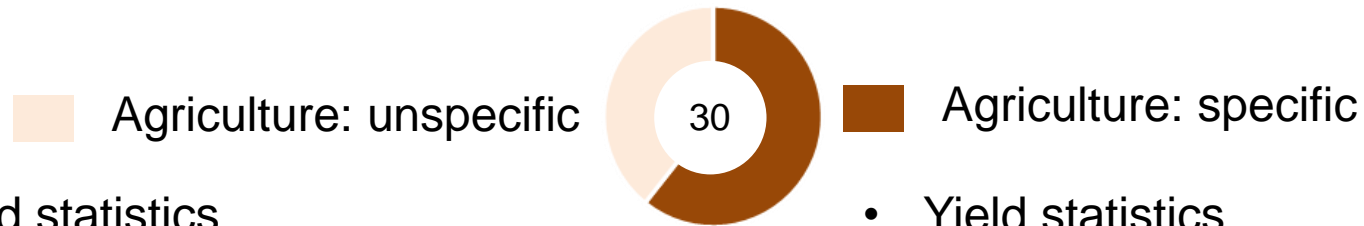


- Region and sector specific identification of relevant drought indices
- Region and sector specific identification of relevant vulnerability factors
- Combination of best performing hazard indices and vulnerability factors
 - → Region & sector specific **likelihood of impact occurrence**

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

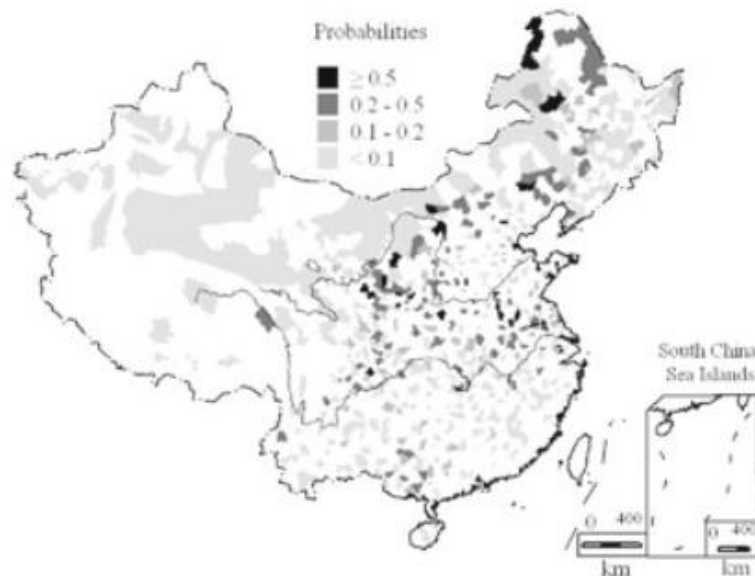


(Blauhut et al. 2016)

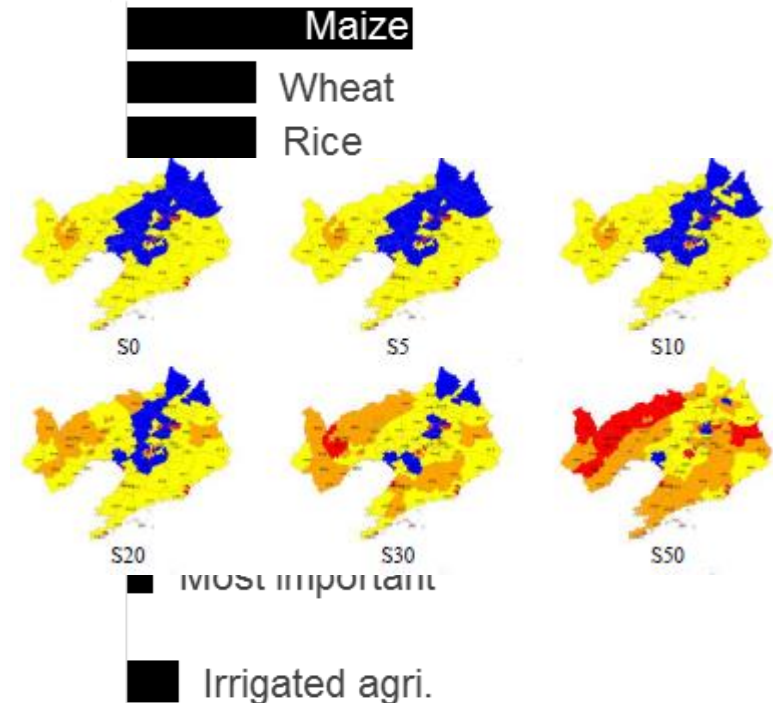


- Yield statistics
- Agricultural impact reports

- Yield statistics
- Modelled yields



Probability of drought disaster occurrence by agricultural disaster survey data, China
Hao et al. 2011

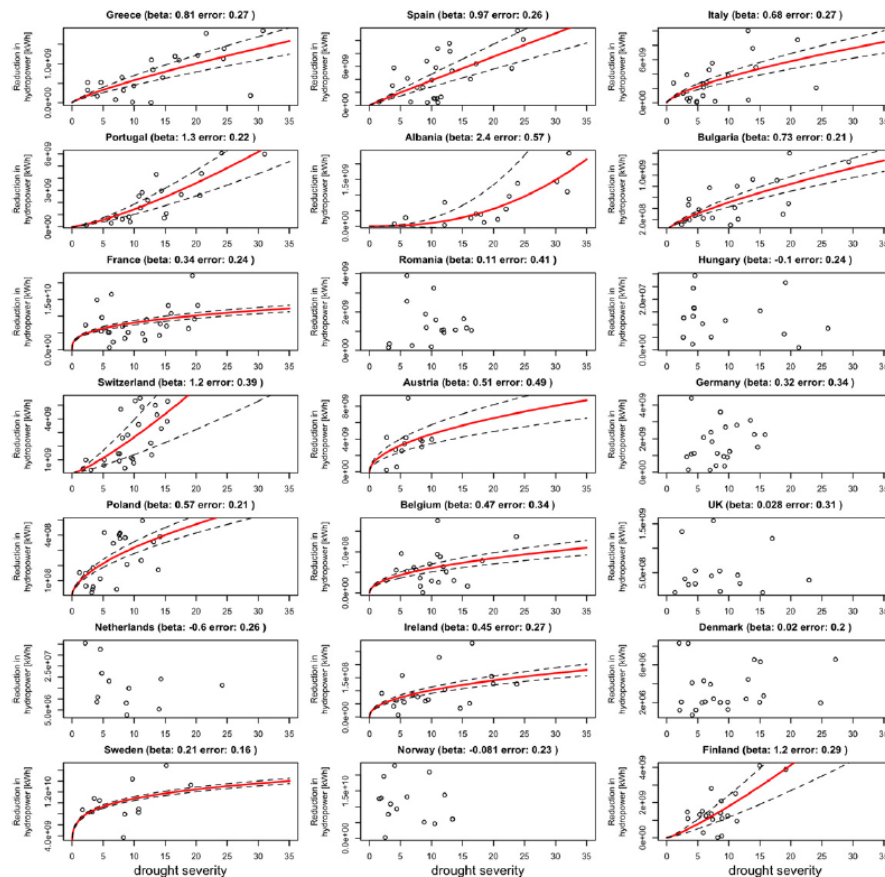


DeNiro et al. 2017
DeComposition, maize losses due to days without rainfall, Liaoning province
Sun et al. 2017

User to address: supra-regional agencies

Hydropower production

Country scale

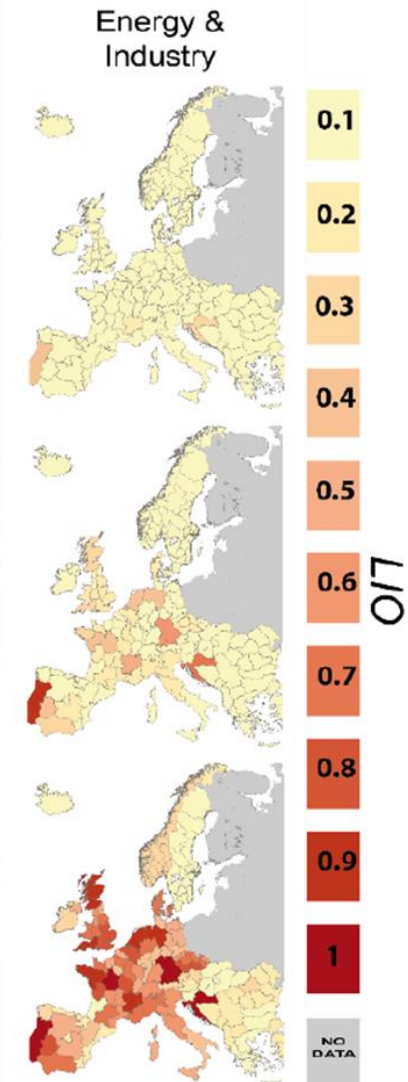


Spinoni et al. 2015

County scale

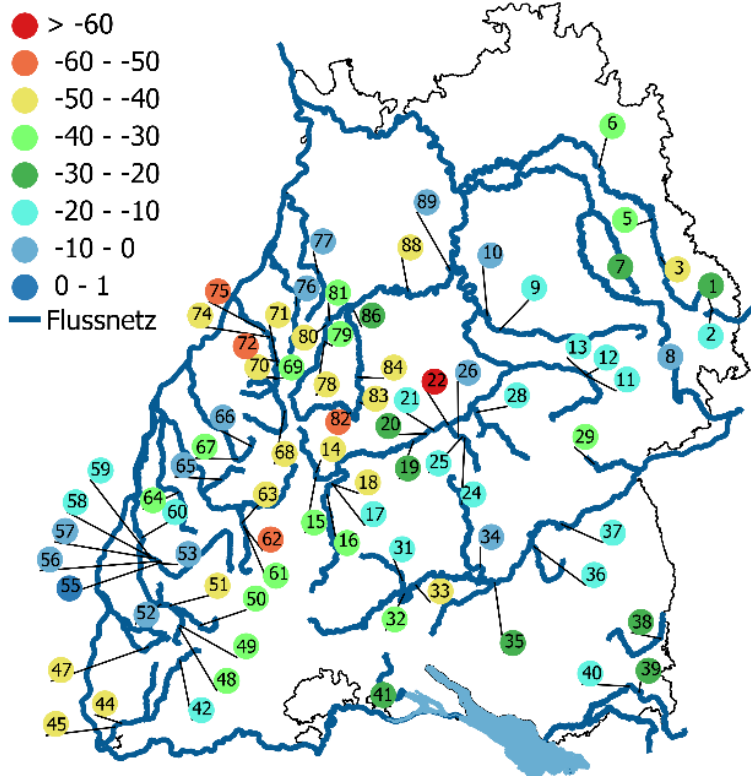
-0.5
-1.5
-2.5

Hazard severity



Blauhut et al. 2016

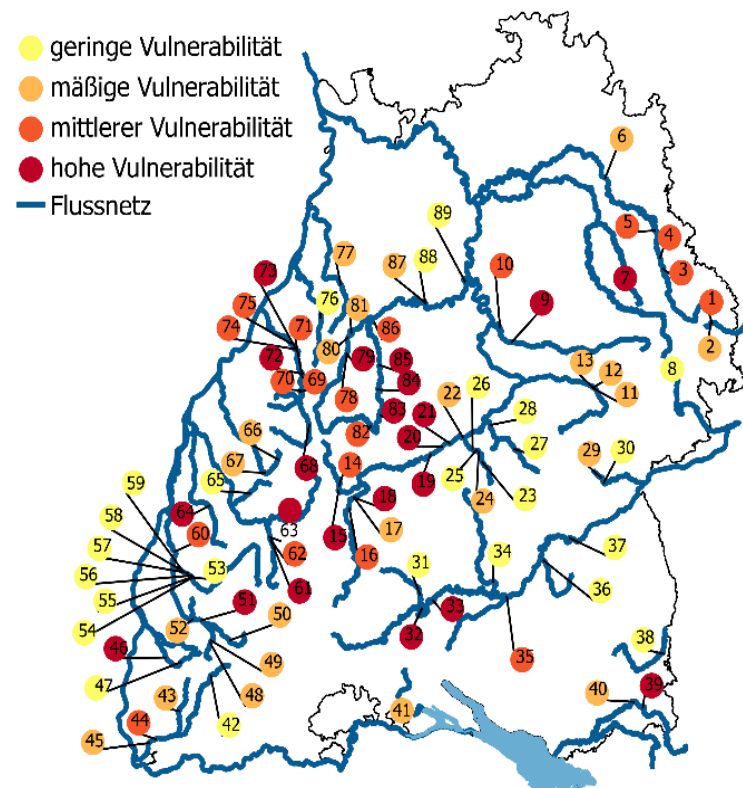
Drought risk of hydropower production



Annual loss in energy production in percentage to average production

Energy production = $f(\text{density of water, earth acceleration, degree of efficiency, drop height, usable runoff})$

Vulnerability of hydropower stations



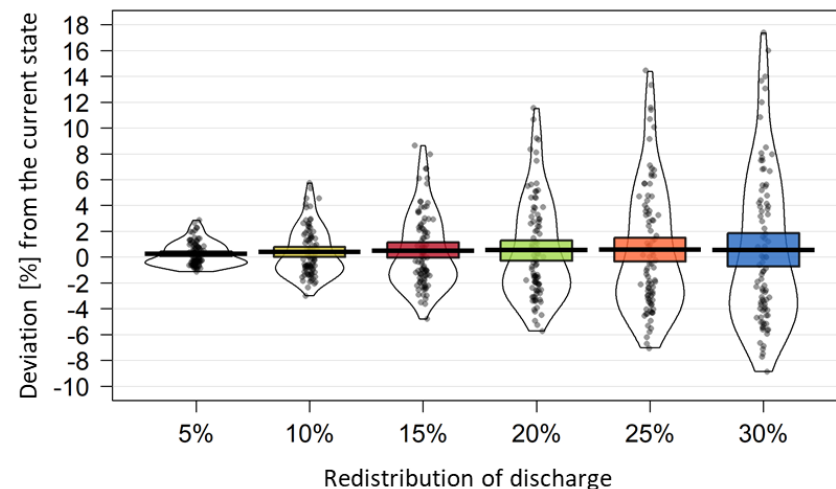
Vulnerability to drought index based on questionnaire & physical factors

User to address: local operators

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 |
| | | discharge variability | +++ |
| | physical factors | 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 |

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 than 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

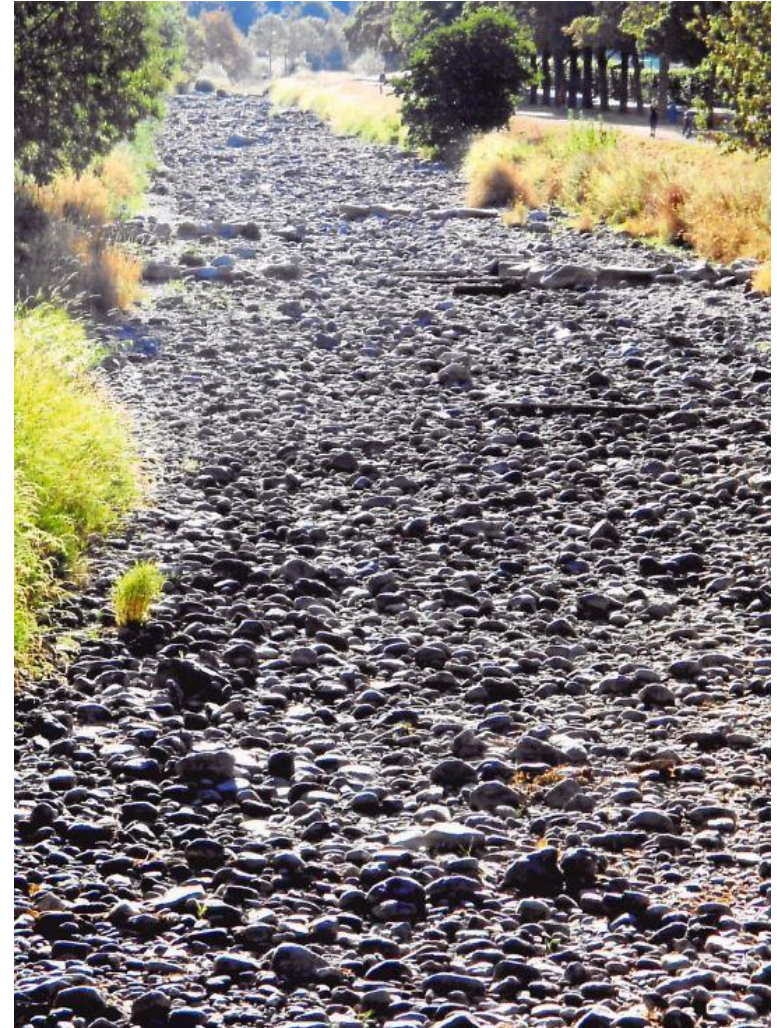
- **Guidance on drought risk analysis: drought risk analysis catalogue?**



Thank you



Picture by Alexander Gerst, Aug. 2018



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