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A spatially explicit assessment of drought risk for irrigated and rainfed agricultural systems at the global scale

- Meza, I., Siebert, S., Döll, P., Kusche, J., Herbert, C., Eyshi Rezaei, E., Nouri, H., Gerdener, H., Popat, E., Frischen, J., Naumann, G., Vogt, J. V., Walz, Y., Sebesvari, Z., and Hagenlocher, M.

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Introduction

- Droughts continue to affect ecosystems, communities, and entire economies (UNDRR, 2019; FAO 2018).

- **Agriculture** bears much of the impact, and in many countries it is the **most heavily affected sector** (FAO, 2018).

- Over the past decades, efforts have been made to assess drought risk at different spatial scales. Few at global scale (Carrão et al., 2016; Dilley et al., 2005) but not yet **focused on agricultural systems**.

- We present for the **first time an integrated assessment of drought risk** for both irrigated and rain-fed agricultural systems at the global scale. Bringing together data from different sources and disciplines for **rain-fed and irrigated agricultural systems** considering relevant drought **hazard indicators, exposure and vulnerability at the global scale**.

Overall workflow of the assessment: Drought risk assessment for agricultural systems at global-scale

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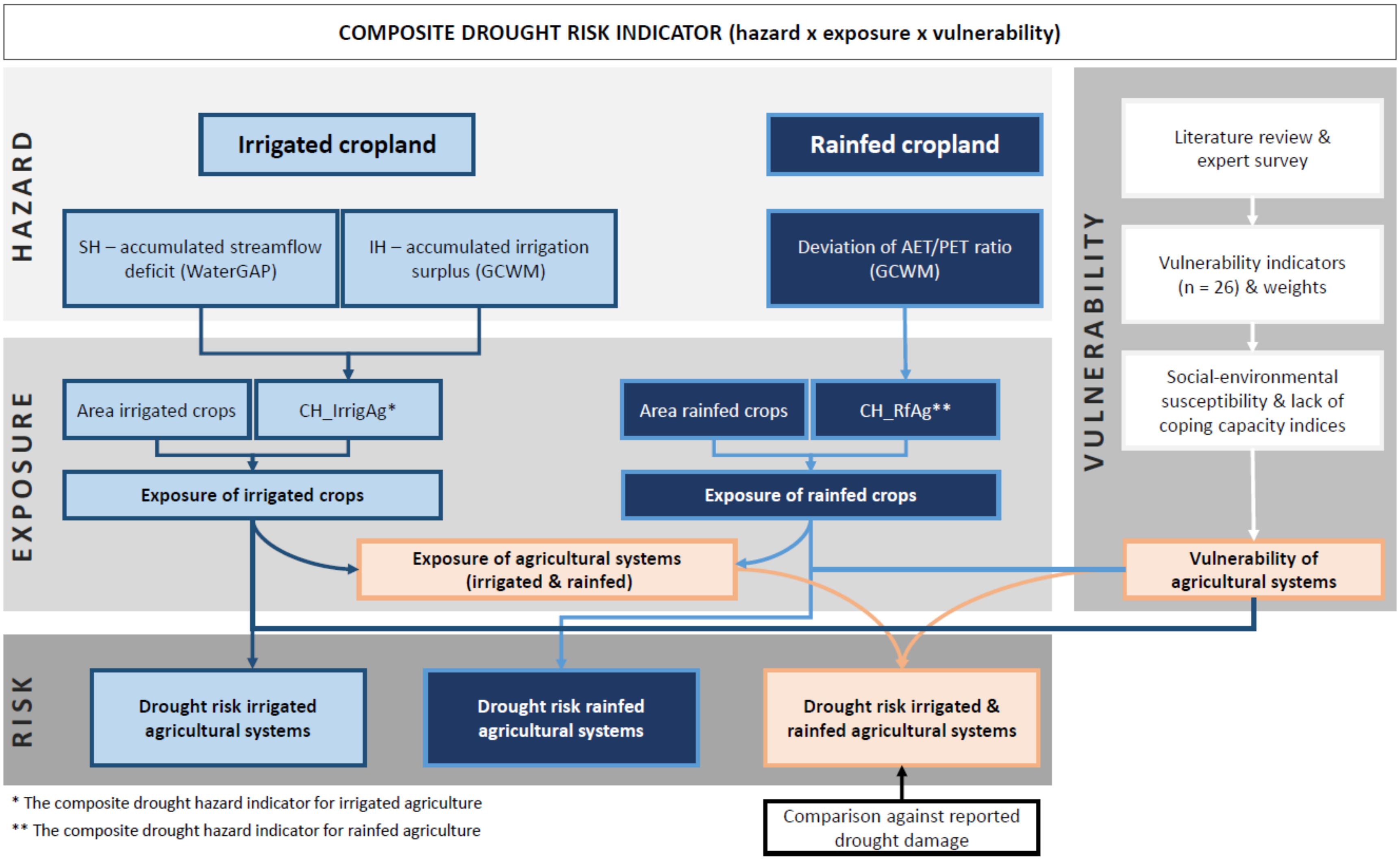

* The composite drought hazard indicator for irrigated agriculture

** The composite drought hazard indicator for rainfed agriculture

Source: Meza et al. (2020) – *NHESS*

Methodology:
Drought hazard & exposure analysis

Risk component	Composite indicator	Indicator	Processed data
Drought hazard	Irrigated	Accumulated streamflow deficit	WaterGAP (1980-2016) with climate forcing WFDEI-GPCC. Streamflow monthly time series.
		Accumulated irrigation surplus	GCWM (1980-2016) with climate forcing CRU TS3.25. Monthly time series of net irrigation requirements
	Rainfed	AET/PET deviation ratio	GCWM (1980-2016) with climate forcing CRU TS3.25. Annual time series of the deviation of the ratio AET / PET from the long-term (1986-2015) median of the ratio AET / PET
Exposed elements	Rainfed & irrigated	Aggregation of pixel level data to national scale	MIRCA 2000 dataset was used to compute harvested area weighted averages of the indicators

- Terrestrial hydrology (WaterGAP)
- Crop water use (GCWM)

Methodology:
Drought vulnerability assessment

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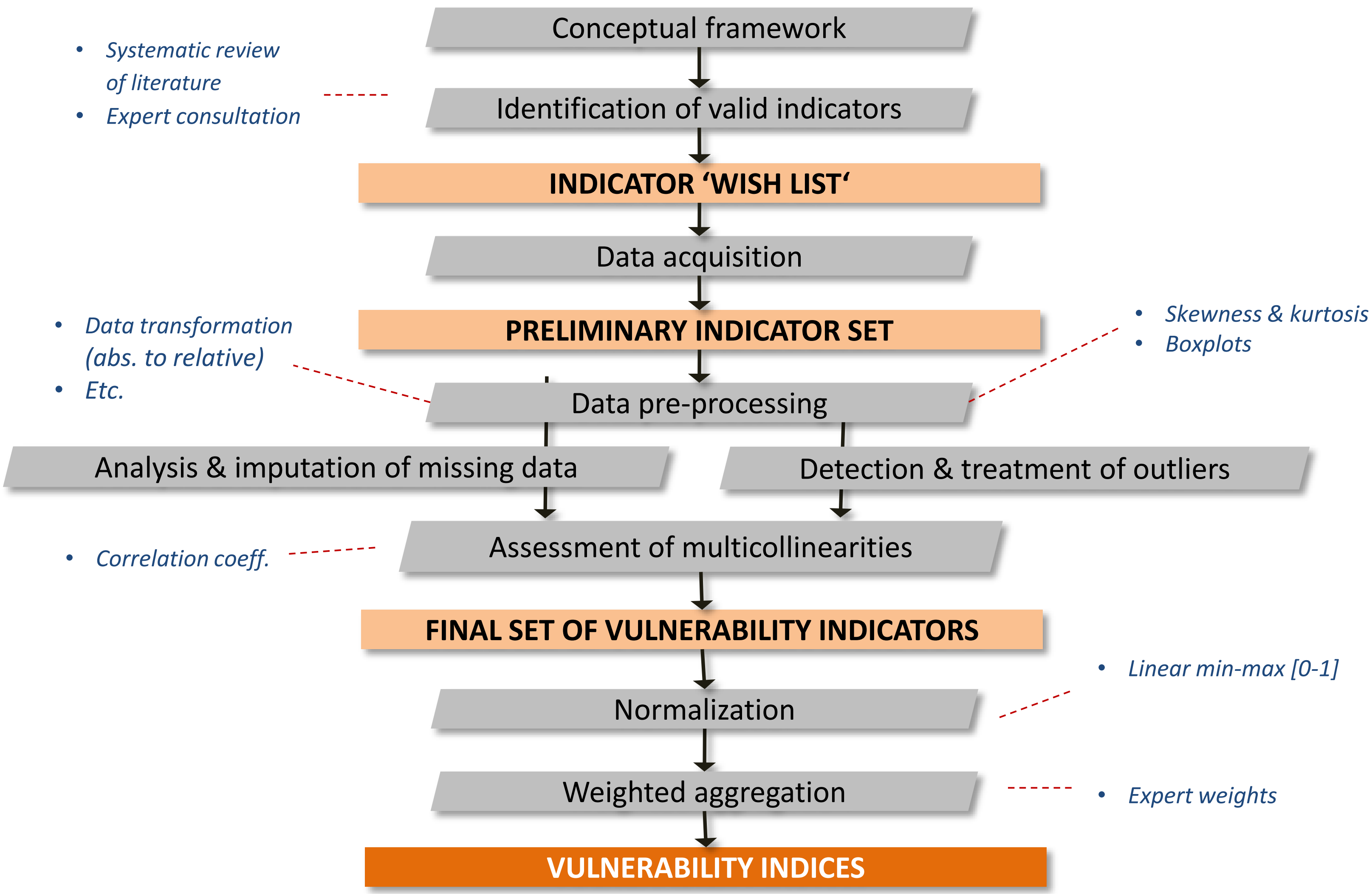
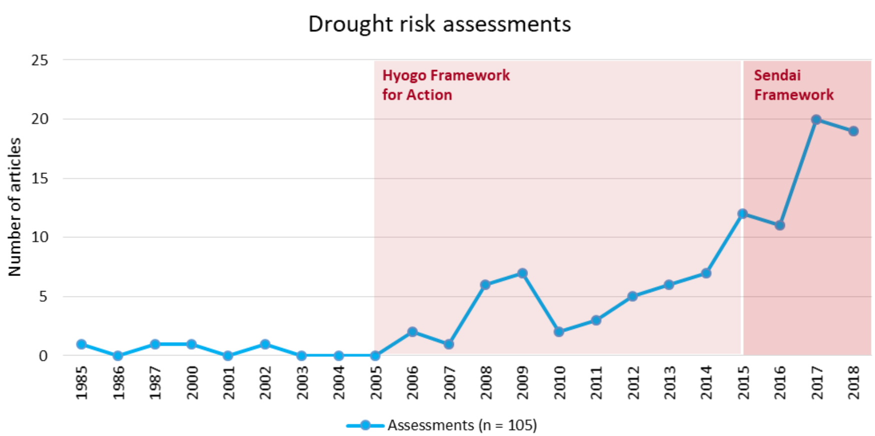
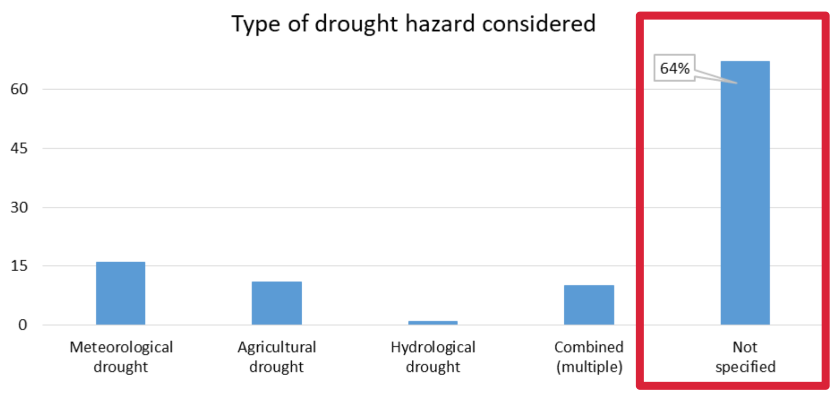


Source: adapted from OECD (2008)

Identifing drivers of risk:
Literature review

- **Systematic review** of **105** peer-reviewed **drought risk assessments** using **Web of Science** and **Scopus**





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Drought vulnerability and risk assessments: state of the art, persistent gaps, and research agenda

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Supplementary material for this article is available online

Abstract

Reducing the social, environmental, and economic impacts of droughts and identifying pathways towards drought resilient societies remains a global priority. A common understanding of the drivers of drought risk and ways in which drought impacts materialize is crucial for improved assessments and for the identification and (spatial) planning of targeted drought risk reduction and adaptation options. Over the past two decades, we have witnessed an increase in drought risk assessments across spatial and temporal scales drawing on a multitude of conceptual foundations and methodological approaches. Recognizing the diversity of approaches in science and practice as well as the associated opportunities and challenges, we present the outcomes of a systematic literature review of the state of the art of people-centered drought vulnerability and risk conceptualization and assessments, and identify persisting gaps. Our analysis shows that, of the reviewed assessments, (i) more than 60% do not explicitly specify the type of drought hazard that is addressed, (ii) 42% do not provide a clear definition of drought risk, (iii) 62% apply static, index-based approaches, (iv) 57% of the indicator-based assessments do not specify their weighting methods, (v) only 11% conduct any form of validation, (vi) only ten percent develop future scenarios of drought risk, and (vii) only about 40% of the assessments establish a direct link to drought risk reduction or adaptation strategies, i.e. consider solutions. We discuss the challenges associated with these findings for both assessment and identification of drought risk reduction measures, and identify research needs to inform future research and policy agendas in order to advance the understanding of drought risk and support pathways towards more drought resilient societies.

1. Introduction

Droughts are recurring slow-onset hazards that can potentially have major direct and indirect impacts on human and natural systems, including terrestrial and freshwater ecosystems, agricultural systems, public health, water supply, water quality, food security, energy, or economies (e.g. through tourism, transport on waterways, forestry) (Schwalm *et al* 2017). While drought generally refers to a lack of water compared to normal conditions (Van Loon *et al* 2016), droughts are commonly grouped into four major types, including (i) meteorological or climatological, (ii) hydrological, (iii) agricultural or soil moisture, and (iv) socio-economic drought (Wilhite and Glantz 1985). They are characterized in terms of their frequency, severity, duration, and extent (Zargar *et al* 2011). According to existing conceptual models (Wilhite and Glantz 1985, Van Loon *et al* 2016), these drought types generally occur in a particular sequence: climate variability leads to a precipitation deficit that instigates a meteorological drought, which when combined with high potential evapotranspiration leads to an agricultural or soil moisture drought. Hydrological droughts occur as a

- **64 indicators** for drought vulnerability were identified

Identifing drivers of risk:
Global expert survey

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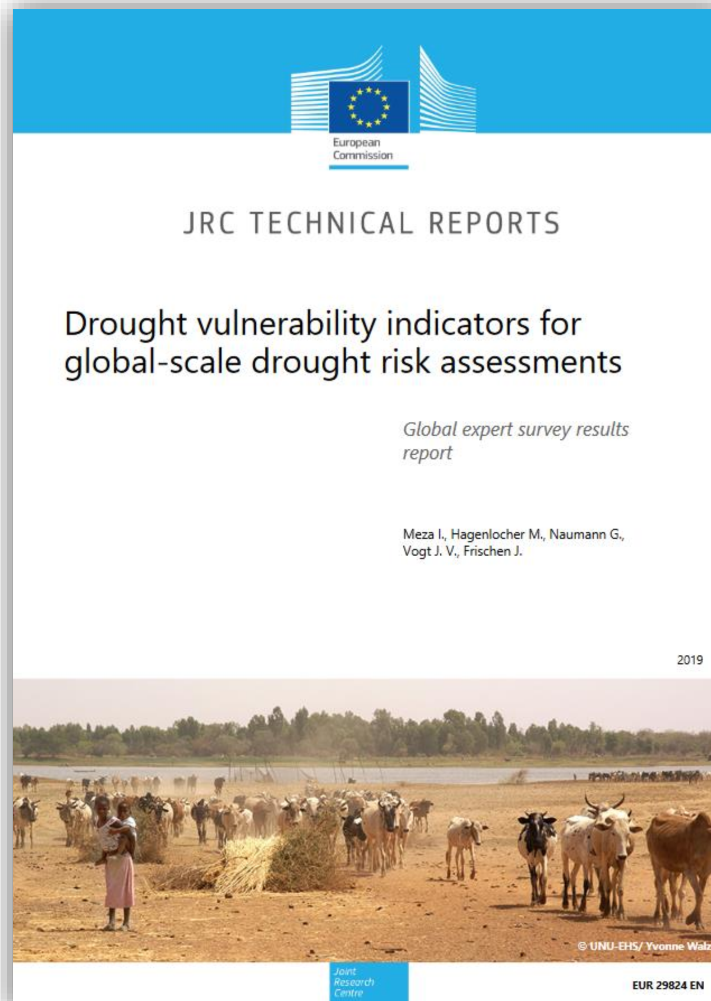
- Joint effort with JRC/GDO
- **64 indicators were weighted** for agricultural systems and domestic water supply
- Sent to **124 selected experts** (based on publications & expertise)
- **63%** participated in the survey (incl. 45 complete & 33 partial responses)
- To inform the global-level vulnerability analysis:
  - 45 indicators for agricultural systems
  - 35 indicators for water supply



Vulnerability indicators used in the analysis and their related expert-weights*

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Indicator	Data source	Weight*
Social susceptibility (SOC_SUS)		
Share of GDP from agr., forestry and fishing in USD (%)	FAO (2016a)	0.96
Rural population (% of total population)	World Bank (2011–2017)	0.85
Prevalence of undernourishment (% of population)	World Bank (2015e)	0.82
Literacy rate, adult total (% of people ages 15 and above)	World Bank (2015d)	0.80
Prevalence of conflict and/or insecurity (crime and theft, index: 0–30)	World Bank (2017a)	0.76
Proportion of population living below the national poverty line (%)	SDG indicators (2015–2017)	0.75
Access to improved water sources (% of total population with access)	World Bank/FAO (2015a)	0.66
DALYs (disability-adjusted life years; DALYs per 100 000; rate)	GBD (2016)	0.65
GINI index	World Bank (2017b)	0.64
Insecticides and pesticides used ($t\,ha^{-1}$)	FAO (2016b)	0.63
Gender inequality index	UNDP (2018)	0.62
Electricity production from hydroelectric sources (% of total)	World Bank (2015b)	0.62
Unemployment, total (% of total labor force; national estimate)	World Bank (2017)	0.60
Dependency ratio (population ages 15–64 – % of total population)	World Bank (2011–2016)	0.60
Population using at least basic sanitation services (%)	WHO (2015)	0.60
Healthy life expectancy (HALE) at birth (years)	WHO (2014)	0.56
Ecological susceptibility (ECO_SUS)		
Average land degradation in GLASOD erosion degree	FAO (1991a)	0.92
Fertilizer consumption (kilograms per hectare of arable land)	World Bank (2015c)	0.74
Average soil erosion	FAO (1991b)	0.72
Terrestrial and marine protected areas (% of total territorial area)	World Bank (2016–2017)	0.63
Lack of coping capacity (COP)		
Saved any money in the past year (% age 15+)	Global FINDEX (2014–2017)	0.87
Government effectiveness: percentile rank	World Bank (2017)	0.85
Total dam storage capacity per capita. Unit: m^3 per inhab.	FAO (2017)	0.82
Total renewable water resources per capita (m^3 per inhab. per year)	FAO (2014)	0.76
Corruption perception index (CPI)	Transparency International (2017)	0.68
Travel time to cities ≤ 30 min (population; %)	JRC (2015)	0.65

Results:
Drought risk (irrigated systems)

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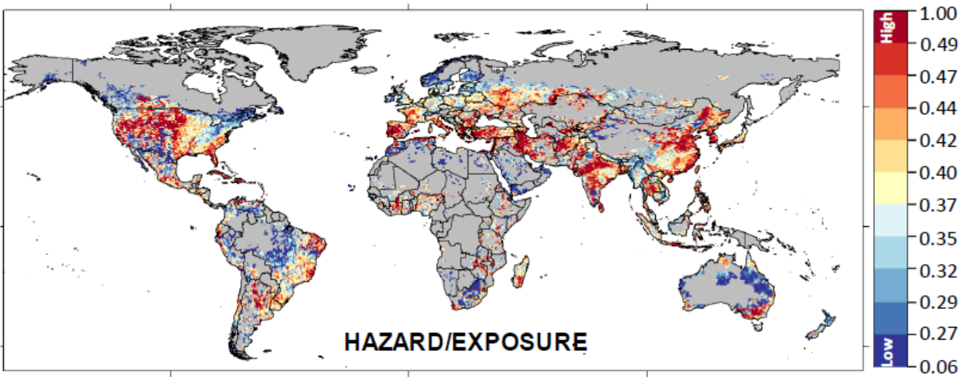
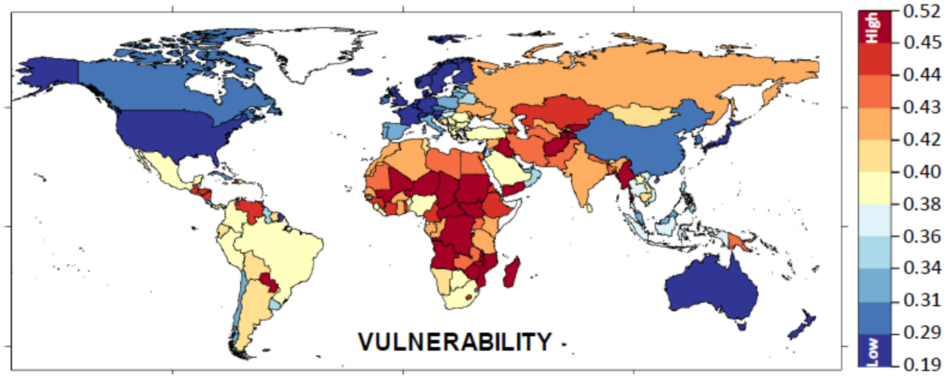
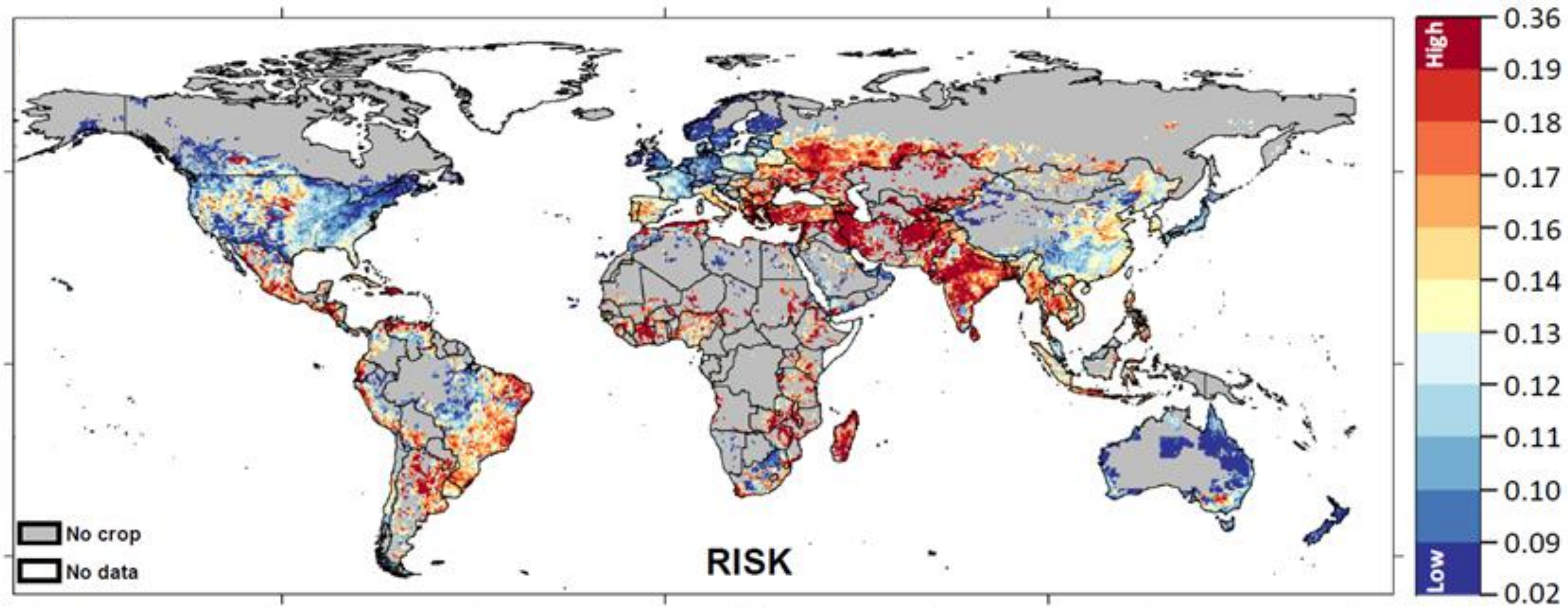
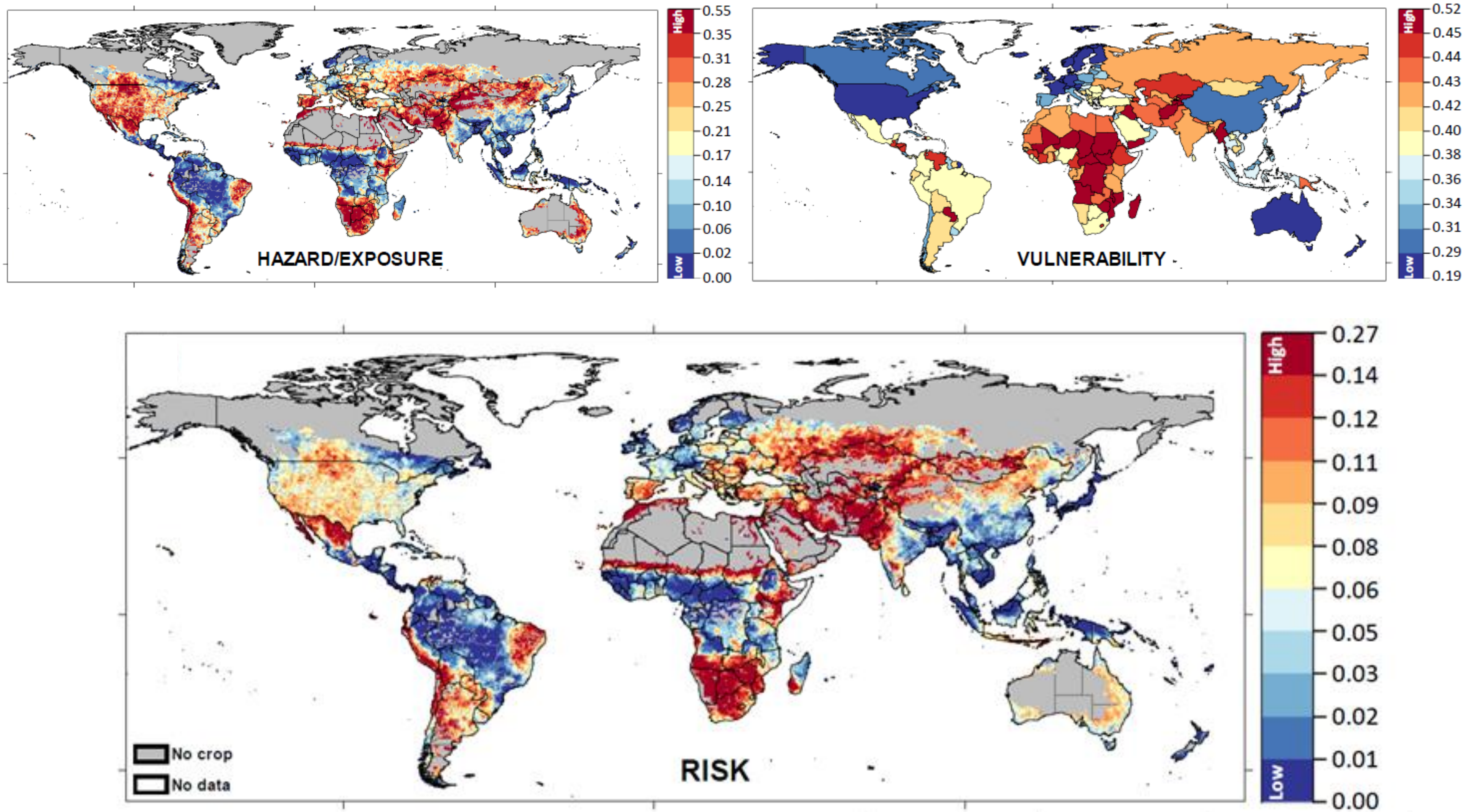






Results:
Drought risk (rainfed systems)



Results:
Drought risk (rainfed & irrigated systems)

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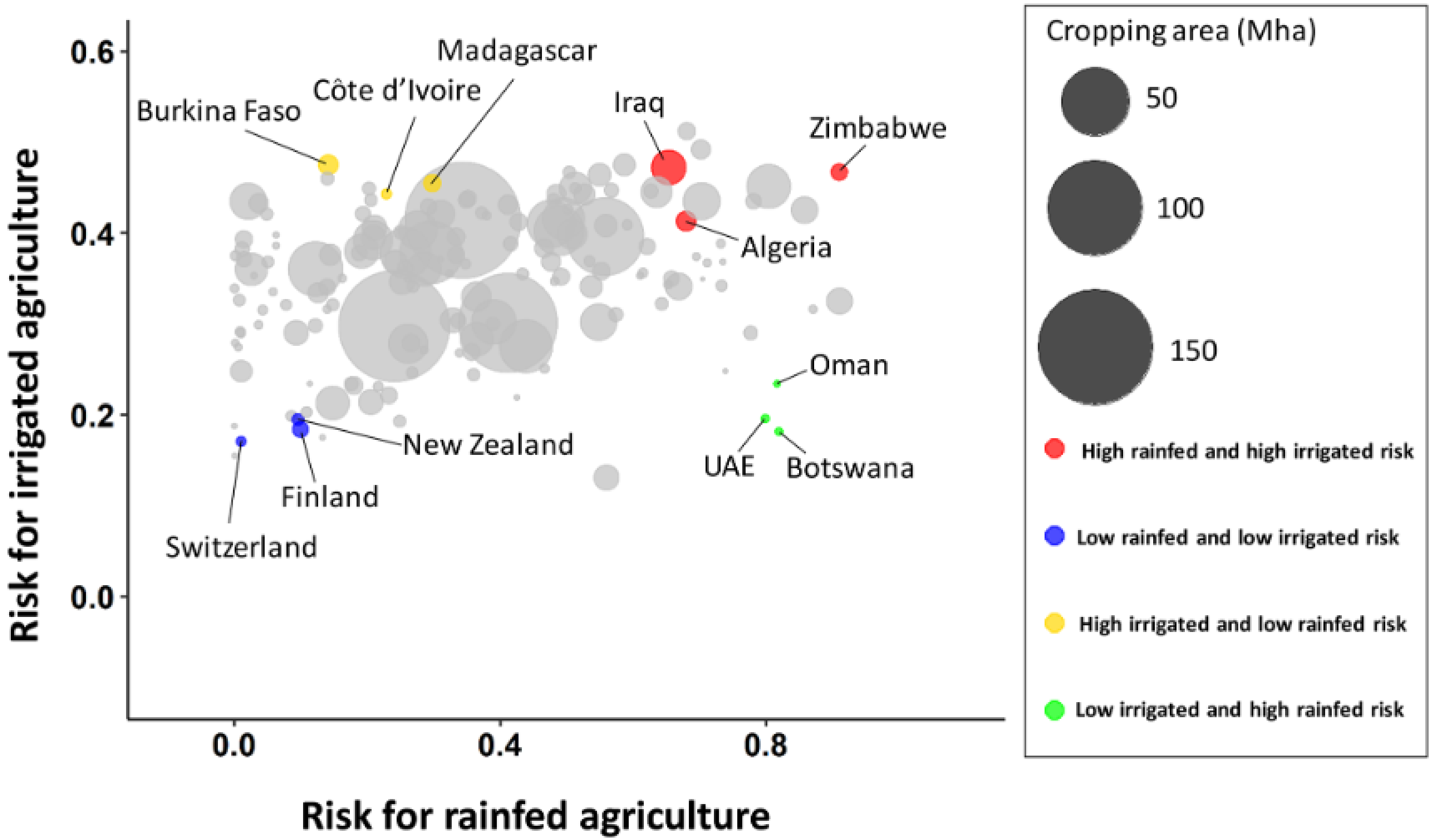

Conclusions

- Regions with **low hazard and exposure** of AS to drought → tend to be tropical and subarctic regions (e.g. northern parts of LA and Central Africa)
- In general, countries with **higher drought risk** have a high amount of **exposed crops** (e.g. Zimbabwe)
- High hazard variation due to varying climatic conditions in large countries
- **Socio-ecological susceptibility** and **coping capacity** of a country are key in the level of drought risk and for resilience-building (e.g. soil degradation, poverty levels, total renewable water resources)
- Risk assessments should be **impact/sector-specific**

Persisting gaps (selection) & outlook

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- **Human-environmental interaction** is increasingly attributed to the occurrence of droughts, but not yet well conceptualized in drought vulnerability & risk assessments
- Assessments often use the same set of **vulnerability indicators for different sectors, context, and scales**, neglecting inherent differences
- Lack of **data** at **high spatio-temporal resolution** (notably vulnerability & impact data)
- **Emerging risks, systemic risk** (cascading effects) & **globally networked risks**
- Few drought risk assessments conduct any form of **validation**
- **'Science to action'** (e.g. entry points for risk reduction, risk transfer or adaptation)

Further reading

- Meza, I., Siebert, S., Döll, P., Kusche, J., Herbert, C., Eyshi Rezaei, E., Nouri, H., Gerdener, H., Popat, E., Frischen, J., Naumann, G., Vogt, J. V., Walz, Y., Sebesvari, Z., Hagenlocher, M. (2020). Global-scale drought risk assessment for agricultural systems. *Natural Hazards and Earth System Sciences 20*, 695–712, DOI:10.5194/nhess-20-695-2020.

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Thank you!

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Antonio Guterres
Secretary-General, United Nations

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