Indicators for vulnerability and risk assessment. Emphasis on environmental components

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Outline

✓Part 1: Basic concepts and application

- Introduction to indicators
- Case study floods in Germany
- Case Study in West Africa

✓Part 2: Focus on ecosystem component

- Brief introduction to ecosystem services
- The Global Delta Risk Index

Part 1
Introduction to indicators

Indicators: definitions

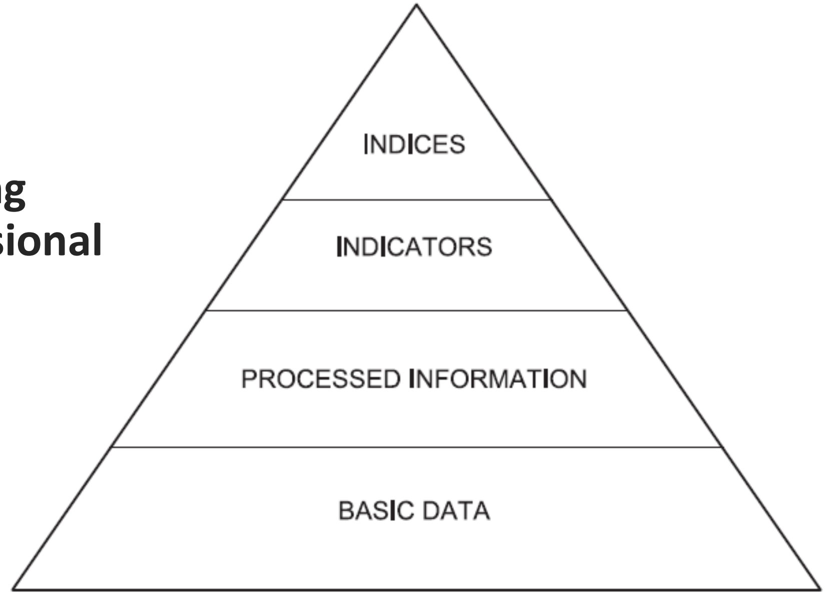
“a **quantitative** or **qualitative measure** derived from a series of observed facts that can reveal **relative positions in a given area**. An indicator can point out the direction of change across **different units** and **through time**”

“a **composite indicator** is formed when individual indicators are compiled into a single **index** on the basis of an underlying model. It ideally measures **multi-dimensional concepts** which cannot be captured by a single indicator alone”

(Nardo et al. 2005; OECD 2008)

Indicator vs. Index

- Indicator vs index (composite indicator)
  - "a **quantitative or qualitative measure** derived from a series of observed facts that can **reveal relative positions in a given area**. An indicator can point out the **direction of change** across different units and through time"
  - "a **composite indicator** is formed when individual indicators are compiled into a single **index** on the basis of an **underlying model**. It ideally measures **multi-dimensional concepts** which cannot be captured by a single indicator alone"



Sources: Nardo et al. (2005); OECD (2008); Adriaanse (1994); Damm (2010)

Indicators: purposes

A central element of defining an indicator should be the **vision or goal** behind the indicator development process rather than having an interest in an indicator itself

Indicators as “**symbolic representations** designed to **communicate** a property or trend in a **complex system** or entity”

Criteria for Indicator Development 1/2

Indicators should respect the following criteria:

- ✓ **Validity and accuracy**: The indicator has to give a true reflection of the issue under consideration and must be developed in a consistent analytical framework
- ✓ **Relevance**: The indicator has to clearly relate to the topic and goal of the analysis
- ✓ **Reproducibility**: The indicator should be reproducible within defined and acceptable limits for data collection over time and space
- ✓ **Sensitivity**: The indicator should respond to a broad range of conditions or perturbations within an appropriate time frame and geographic scale
- ✓ **Understandability**: An important and often neglected prerequisite for the usefulness (and acceptance) of indicators is that the users must understand them

Criteria for Indicator Development 2/2

Indicators should respect the following criteria:

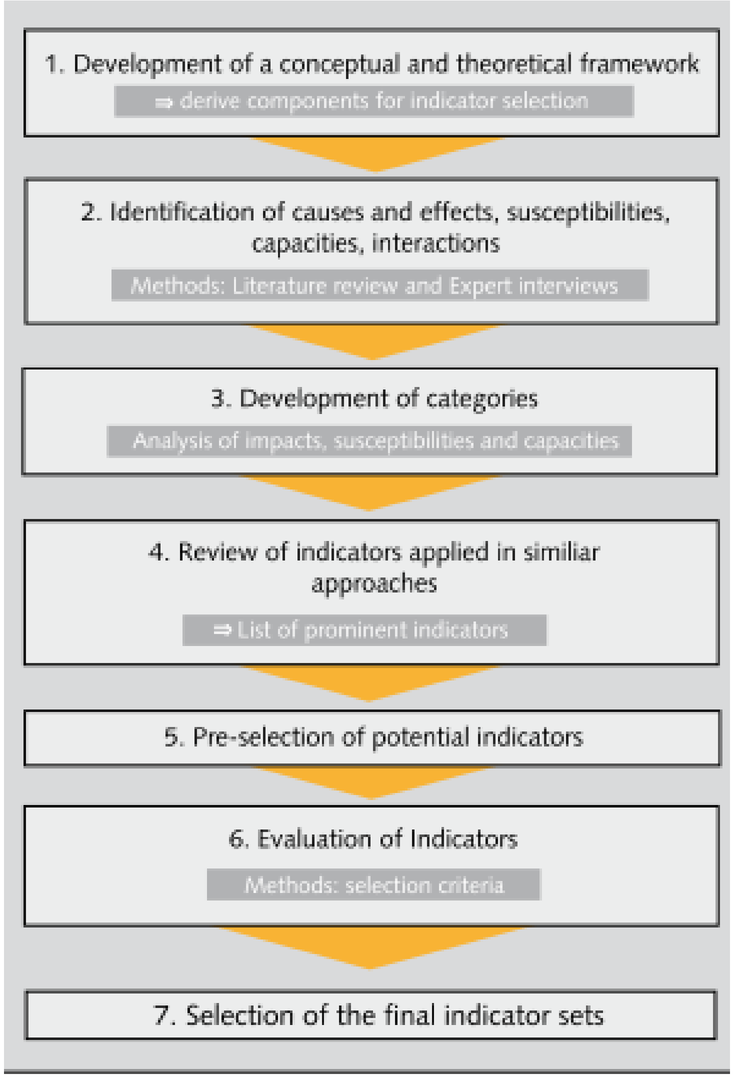
✓**Ease of interpretation**: The interpretation of data must be simple and publicly appealing. The indicator should inform clearly about the extent of the issues represented

✓**Data availability**: Data must be either available or should be obtainable through measurement

✓**Policy relevant**: An indicator has to monitor the key outcomes, inform on any progress, measure processes, and provide specific information

Adapted from Damm (2010): Mapping Social-Ecological Vulnerability to Flooding. Graduate Research Series No. 3, UNU-EHS (http://www.ehs.unu.edu/file/get/8056)

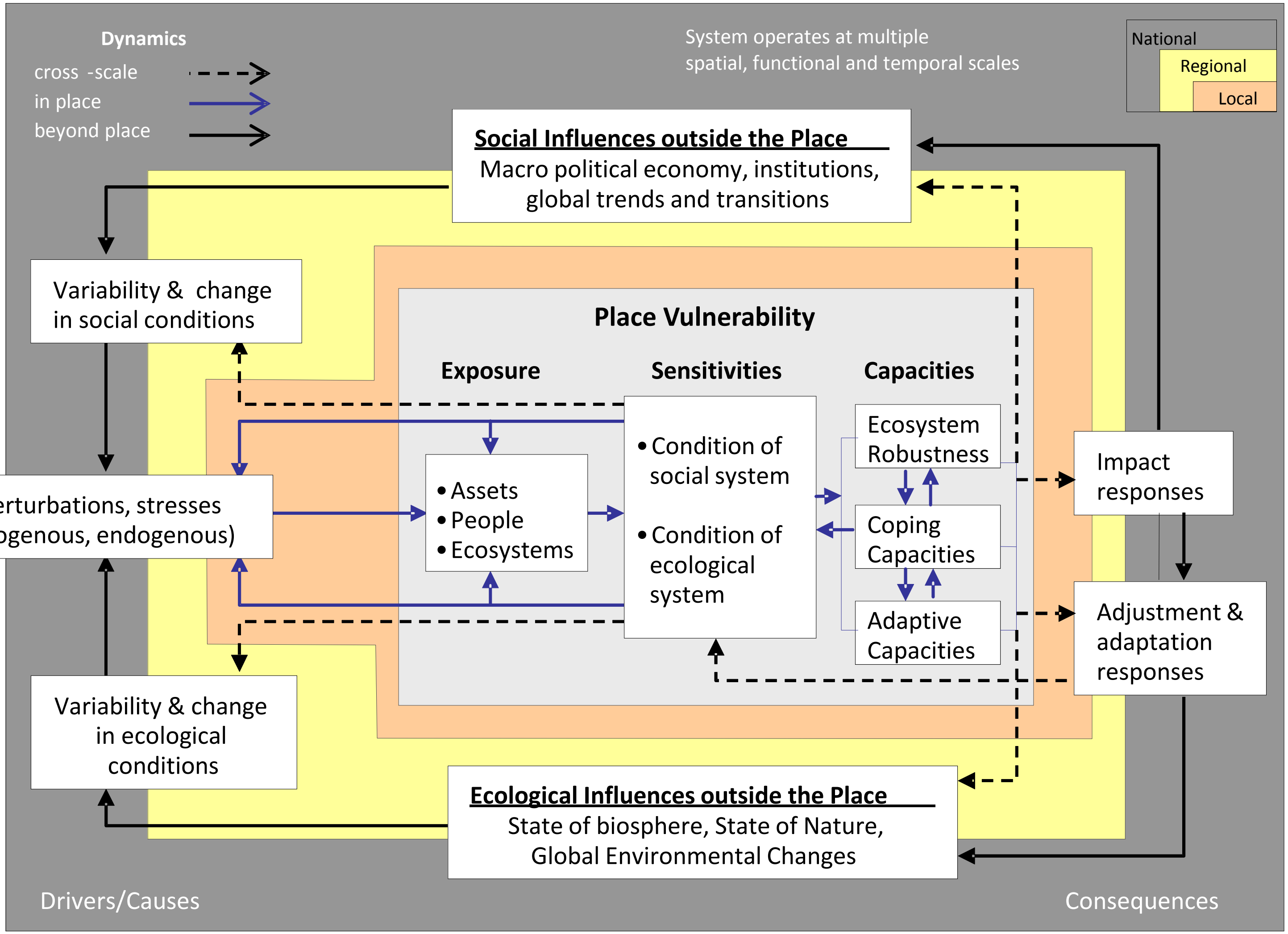
Procedure for the Development of Indicators



Damm (2010): Mapping Social-Ecological Vulnerability to Flooding. Graduate Research Series No. 3, UNU-EHS (http://www.ehs.unu.edu/file/get/8056)

Part 1
Flood case study, Germany

Vulnerability Assessment – Modified SUST Model

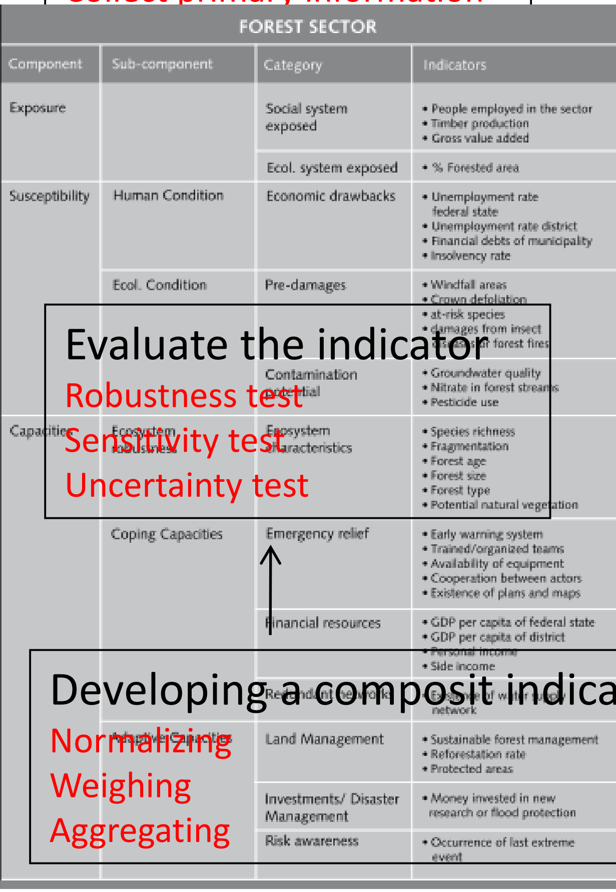


Source: Turner II et al. 2003. A framework for vulnerability analysis in sustainability science. *PNAS 100:8074-8079*. MODIFIED – Marion Damm (2010) Mapping Social-Ecological Vulnerability to flooding: A sub-national approach to Germany. Graduate Research Series Vol 3, UNU-EHS, Bonn

Indicator development process

Expert interviews

Collect primary information



FOREST SECTOR

Component	Sub-component	Category	Indicators
Exposure		Social system exposed	• People employed in the sector • Timber production • Gross value added
		Ecol. system exposed	• % Forested area
Susceptibility	Human Condition	Economic drawbacks	• Unemployment rate federal state • Unemployment rate district • Financial debts of municipality • Insolvency rate
	Ecol. Condition	Pre-damages	• Windfall areas • Crown defoliation • at-risk species • damages from insect • forest fires
		Contamination potential	• Groundwater quality • Nitrate in forest streams • Pesticide use
Capacities	Ecosystem robustness	Ecosystem characteristics	• Species richness • Fragmentation • Forest age • Forest size • Forest type • Potential natural vegetation
	Coping Capacities	Emergency relief	• Early warning system • Trained/organized teams • Availability of equipment • Cooperation between actors • Existence of plans and maps
		Financial resources	• GDP per capita of federal state • GDP per capita of district • Personal income • Side income
		Redundant networks	• Existence of water supply network
	Adaptive Capacities	Land Management	• Sustainable forest management • Reforestation rate • Protected areas
		Investments/ Disaster Management	• Money invested in new research or flood protection
		Risk awareness	• Occurrence of last extreme event

Analysis of expert interviews and literature

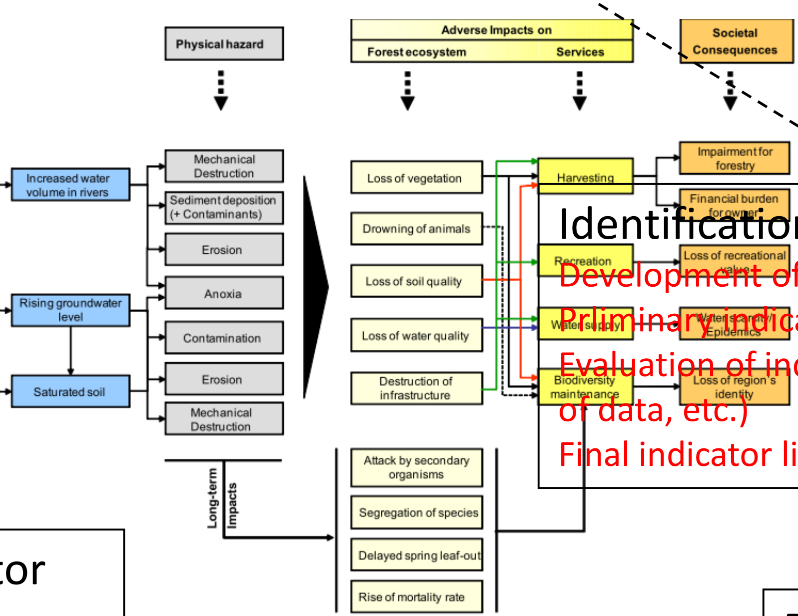
Analysis of flood impact on sectors

Analysis of susceptibility

Analysis of capacities component

Review of indicators

Determination of prominant indicators



Identification of an indicator set

Development of vulnerability categories

Prliminary indicator set

Evaluation of indicators (validity, availability of data, etc.)

Final indicator list

Data analysis

e.g. Cross-correlation

Developing a composit indicator

Normalizing

Weighing

Aggregating

Evaluate the indicator

Robustness test

Sensitivity test

Uncertainty test

Adapted from Damm (2010): Mapping Social-Ecological Vulnerability to Flooding. Graduate Research Series No. 3, UNU-EHS (http://www.ehs.unu.edu/file/get/8056)

Selecting Indicators

Indicators Forest	Validity	Understandability	Data availability/data quality	Reproducibility
People employed in F.S.	xx	xx	xx	xx
Timber production	x	xx	o	o
Gross value added	xx	xx	xx	xx
Forested area	xx	xx	xx	xx
Unemployment rate F.S.	xx	xo	xx	xx
Unemployment rate district	xx	xo	xx	xx
Financial debts of municip.	x	x	o	o
Insolvency rate	x	xx	o	o
Windfall areas	xx	xx	xo	xo
Mean crown defoliation	xx	xx	xx	xx

Damm (2010): Mapping Social-Ecological Vulnerability to Flooding. Graduate Research Series No. 3, UNU-EHS (http://www.ehs.unu.edu/file/get/8056)

Use of SUST for specific sectors
Indicators

Agricultural Sector

Exposure (E)

- % farmland (e_1)
- % employees (e_2)

Sensitivity (S)

- unemployment rate of district (sh)

- contamination potential (se_1)
- erosion potential (se_2)
- water quality index (se_3)

Capacities (C)

- Water storage capacity (er_1)
- Filter/buffer capacity (er_2)
- % perm. grasslands (er_3)

- GDP per capita district (c_1)
- GDP per capita FS (c_2)
- side business income (c_3)

- % organic farms (a_1)
- % protected areas (a_2)

Forest Sector

Exposure (E)

- % forested area (e_1)
- % employees (e_2)

Sensitivity (S)

- unemployment rate of district (sh)

- % pre-damaged forest (se_1)
- water quality index (se_2)

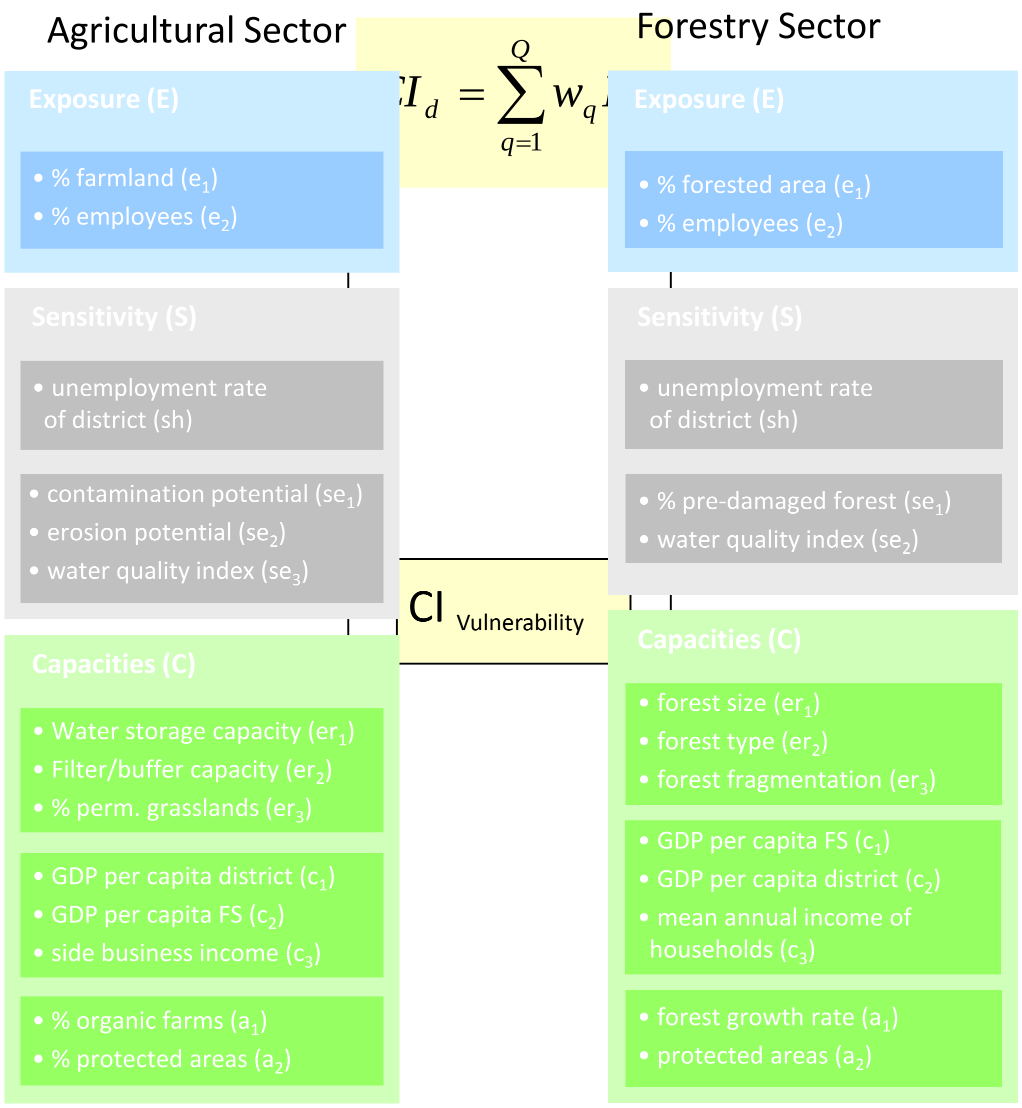
Capacities (C)

- forest size (er_1)
- forest type (er_2)
- forest fragmentation (er_3)

- GDP per capita FS (c_1)
- GDP per capita district (c_2)
- mean annual income of households (c_3)

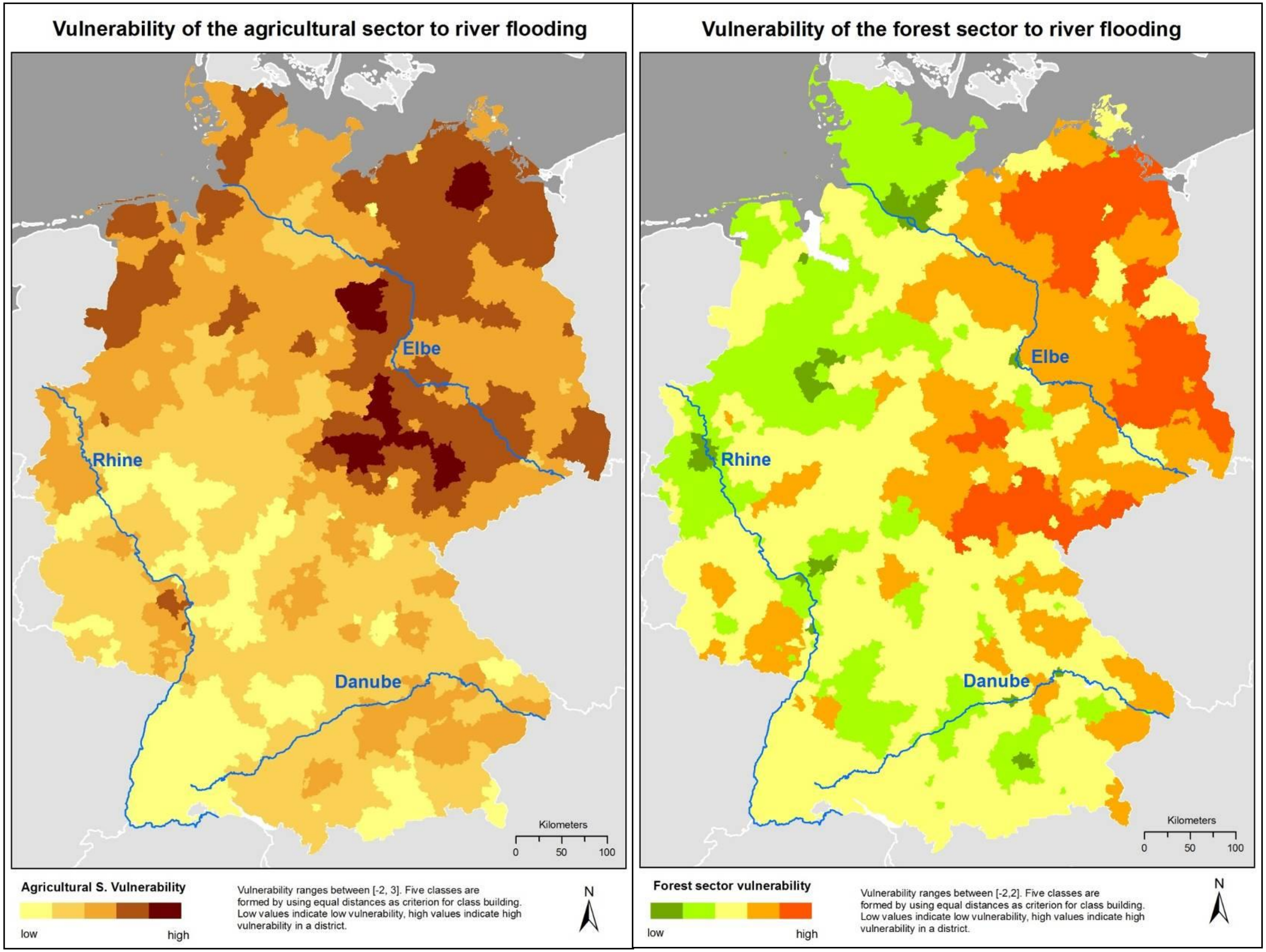
- forest growth rate (a_1)
- protected areas (a_2)

Weights and Aggregation



Adapted from Damm (2010): Mapping Social-Ecological Vulnerability to Flooding. Graduate Research Series No. 3, UNU-EHS (http://www.ehs.unu.edu/file/get/8056)

Vulnerability Maps



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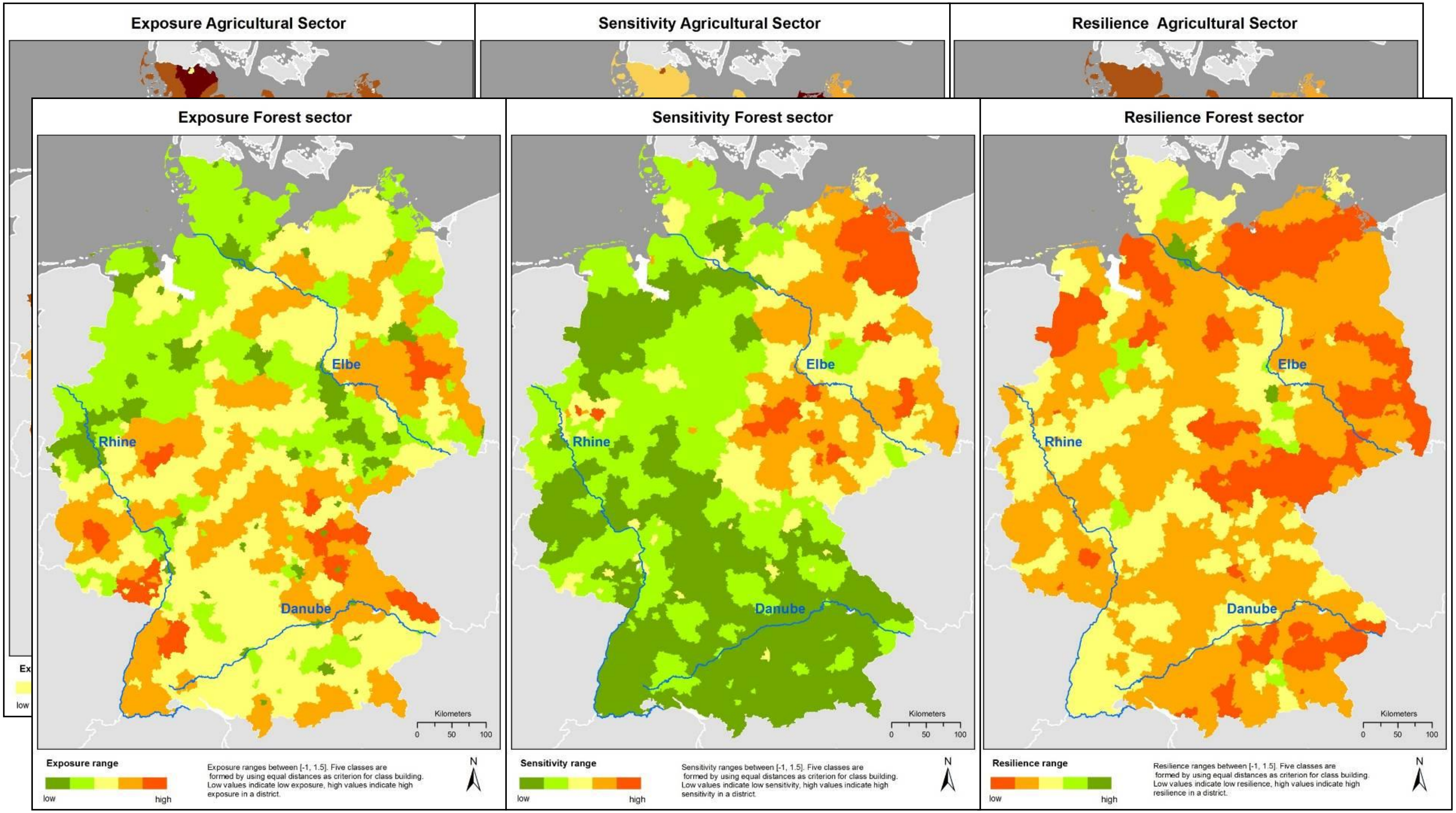
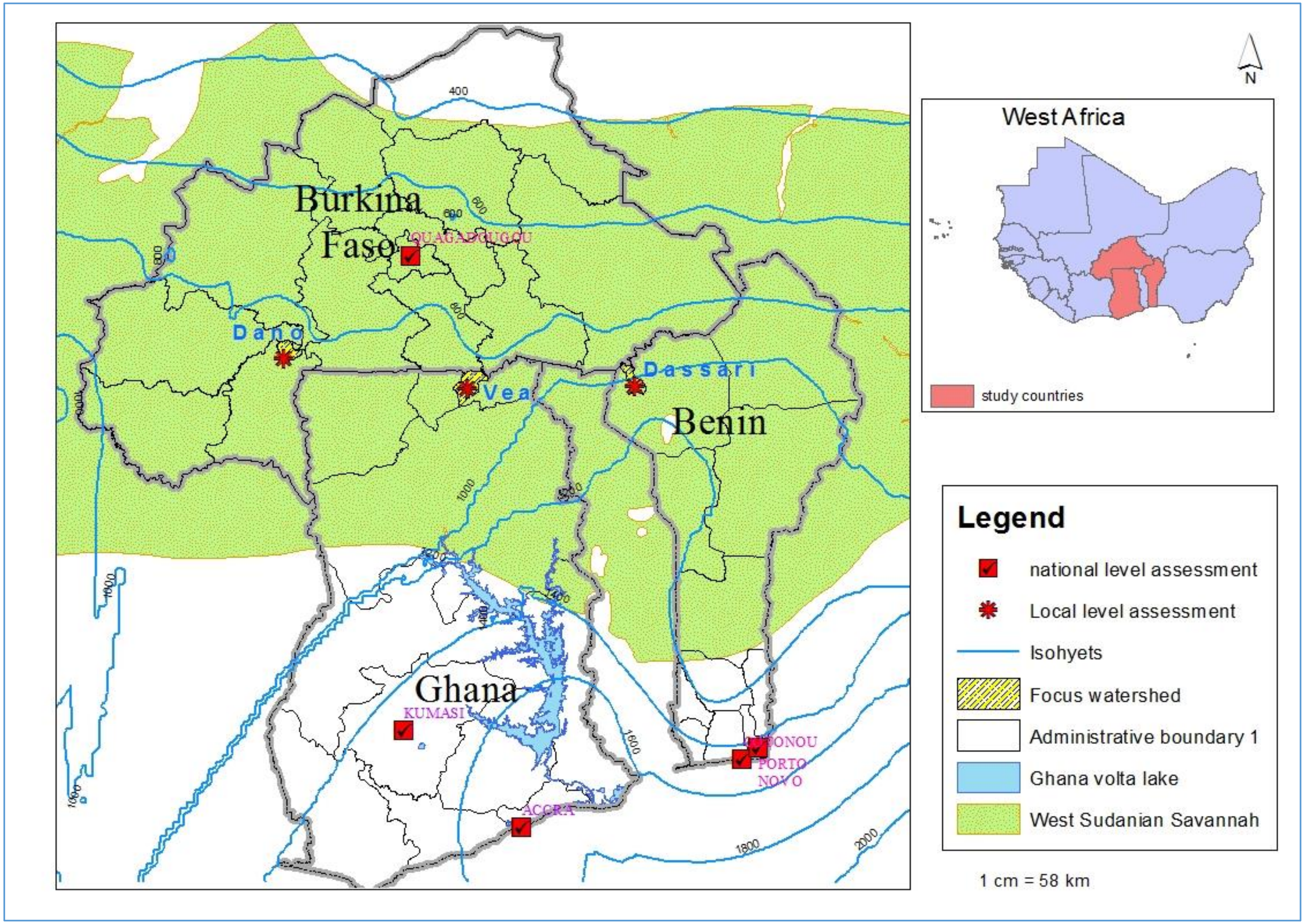


Adapted from Damm (2010): Mapping Social-Ecological Vulnerability to Flooding. Graduate Research Series No. 3, UNU-EHS (http://www.ehs.unu.edu/file/get/8056)

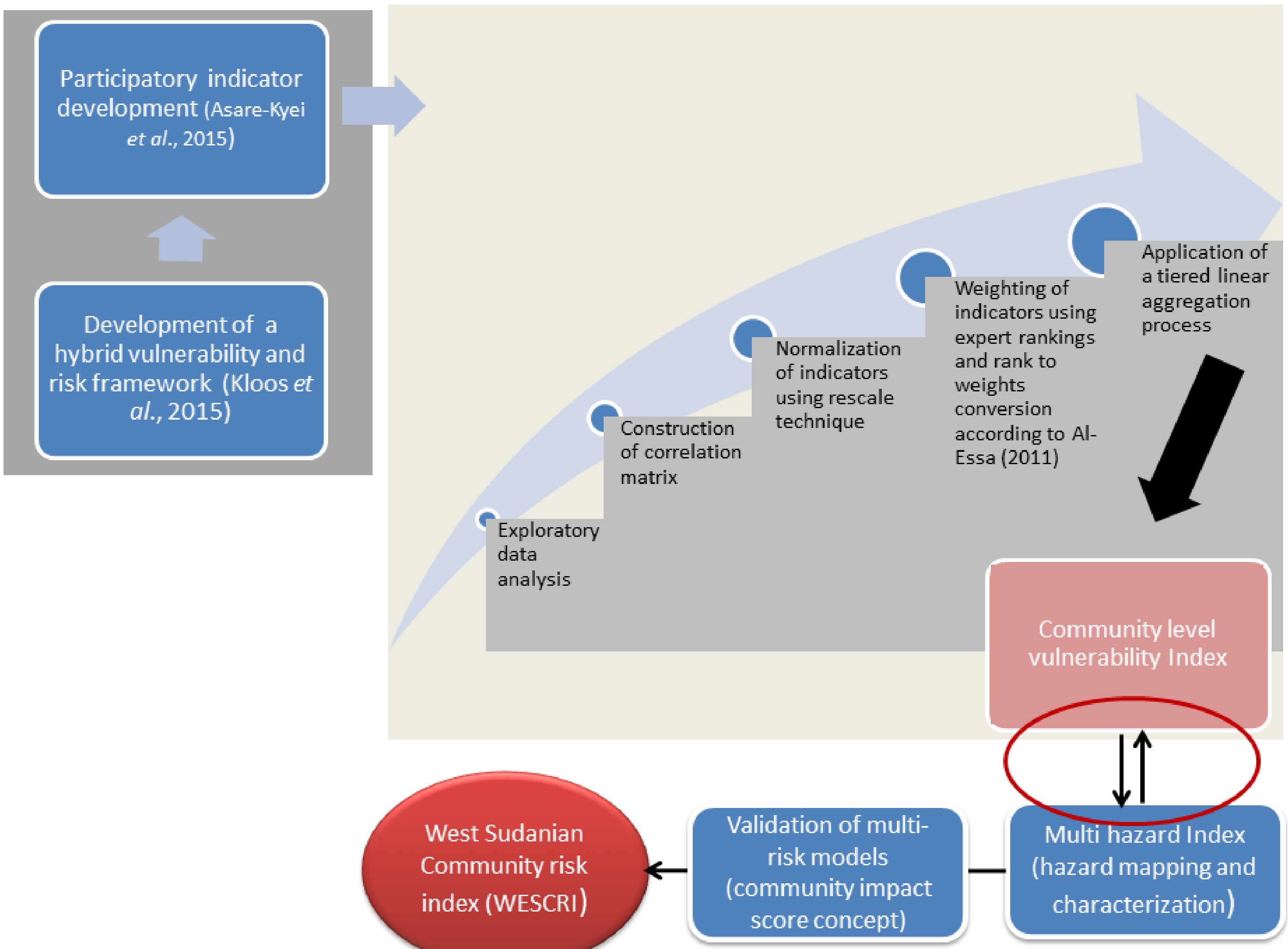
Part 1
Community-based risk assessment in West Africa

Research area



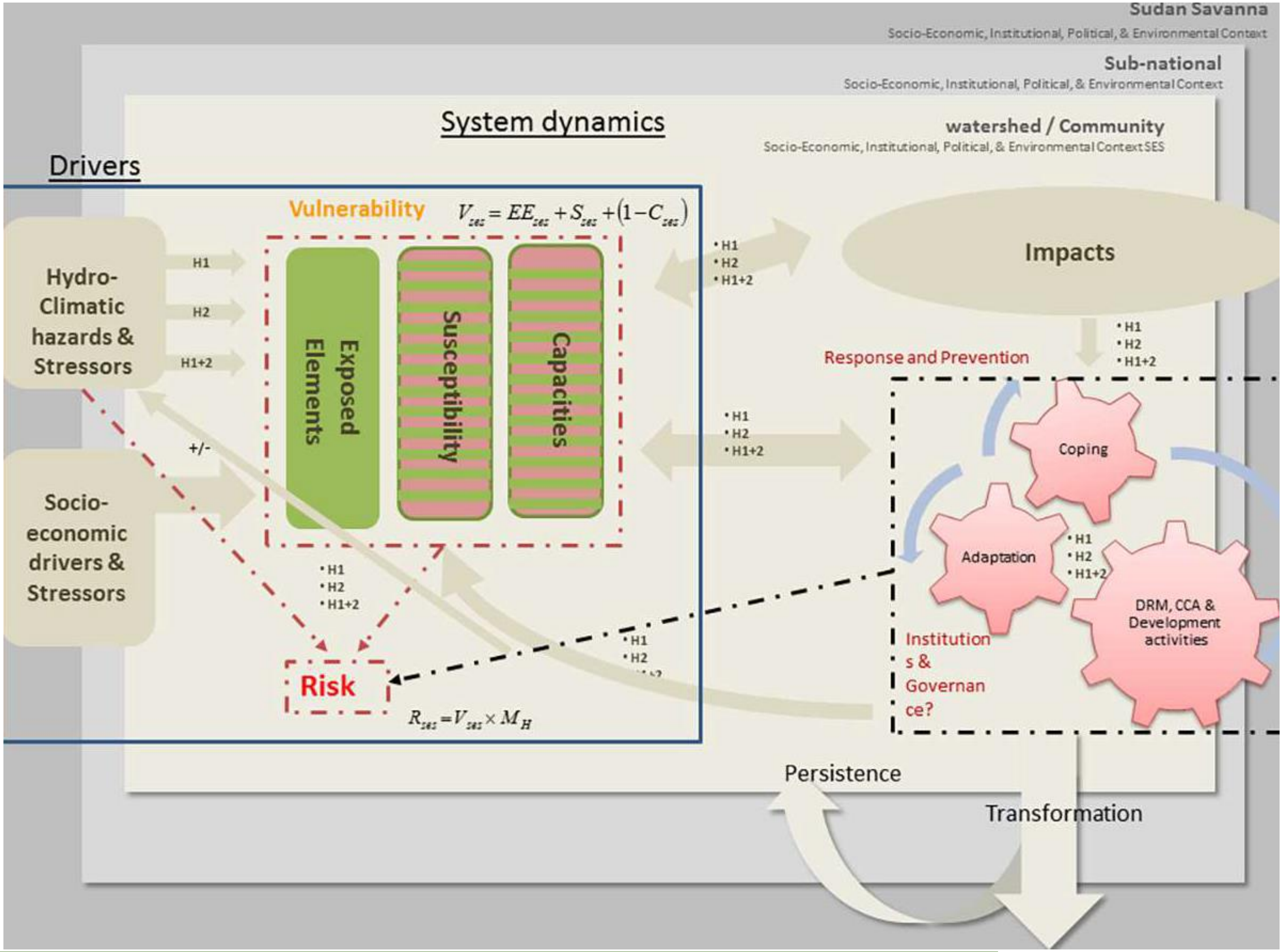
Asare-Kyei et al (2016): PLoS ONE 12(3): e0171921. doi:10.1371/journal.pone.0171921

Stepwise process of risk assessment



Asare-Kyei et al (2016): PLoS ONE 12(3): e0171921. doi:10.1371/journal.pone.0171921

Conceptual framework



Asare-Kyei et al (2016): PLoS ONE 12(3): e0171921. doi:10.1371/journal.pone.0171921. Bssed on Kloos et al (2015)

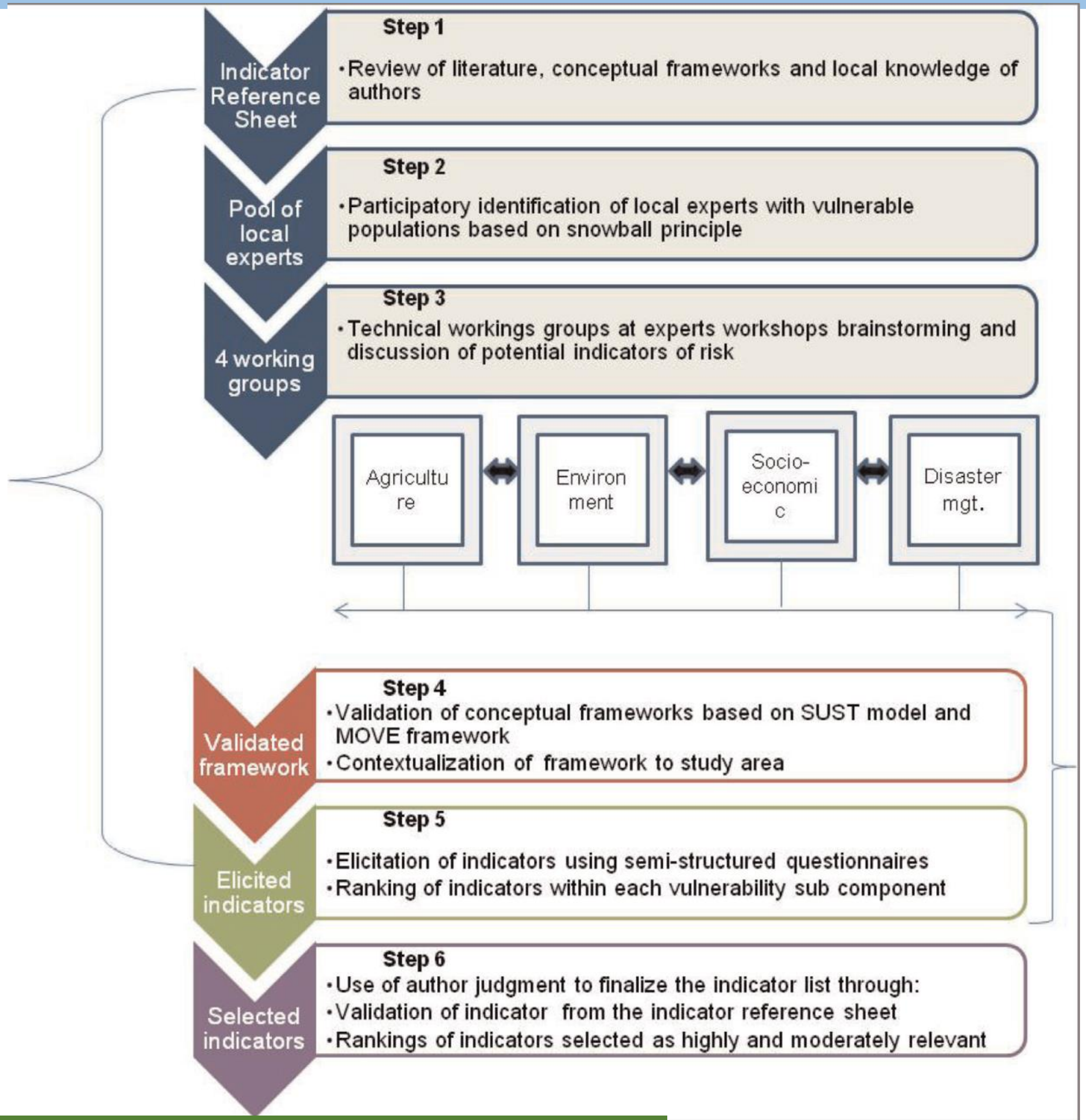
Approach to indicator development

- ✓The indicator development looks at appropriate Participatory Action Research (PAR) methods that could be used to involve local communities and at risk populations in developing the indicators.

- ✓This indicator development phase is a crucial first step in understanding the vulnerability and risk of exposed populations.

Asare-Kyei et al (2016): PLoS ONE 12(3): e0171921. doi:10.1371/journal.pone.0171921

Participatory indicator development



Asare-Kyei et al (2015): International Journal of Disaster Risk Reduction 11:13–34

Number of indicators elicited and validated

Country	Scale of assessment	
	Local level	National level
Ghana	37 (5*)	25 (8*)
Burkina Faso	34 (6*)	22 (3*)
Benin	37 (4*)	25 (6*)

* ***Number of indicators that are unique to each country***

Asare-Kyei et al (2015): International Journal of Disaster Risk Reduction 11:13–34

Unique indicators

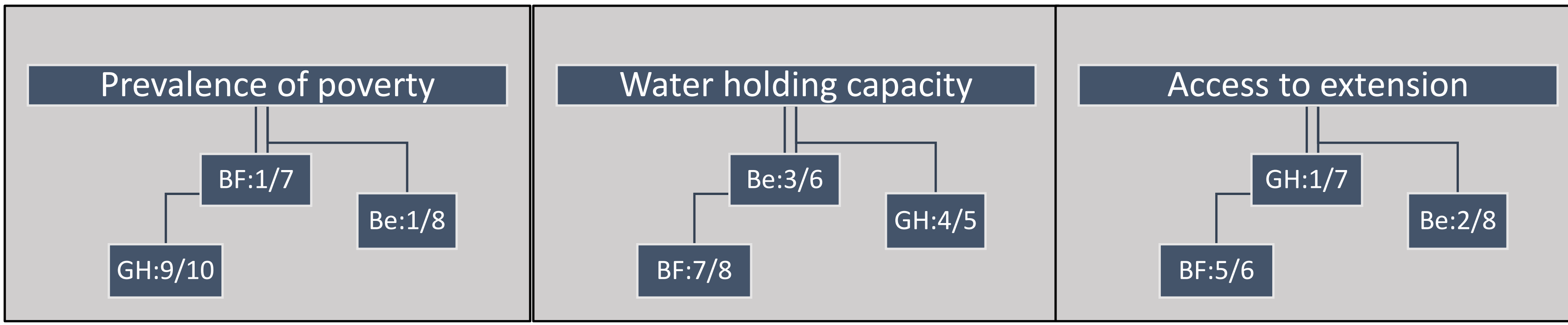
Ghana	Vulnerability component	Burkina Faso	Vulnerability component	Benin	Vulnerability component
Crop type	Sus.ES	Household size	Sus.Ss	Forested area	Eco. robust
Unimproved drinking water source	Sus.SS	Agroforestry cover	Eco-robust	Erosion rates	Sus-Es
Physical infrastructure	Exp. assets	Soil depth	Eco-robust	Land ownership	Adaptive capacity
Population density	Sus.ss	Number of bas-fonds (small reservoirs)	Eco. robust	Total soil nitrogen	Eco. robust
Female headed households	Sus.Ss	NDVI	Eco-robust		
		Early warning system	Coping capacity		

Unique indicators have good bearings with realities on the ground

Asare-Kyei et al (2015): International Journal of Disaster Risk Reduction 11:13–34

Differential ranking of indicators

Even for indicators that were common and run through all the 3 countries, they differ in their rankings.

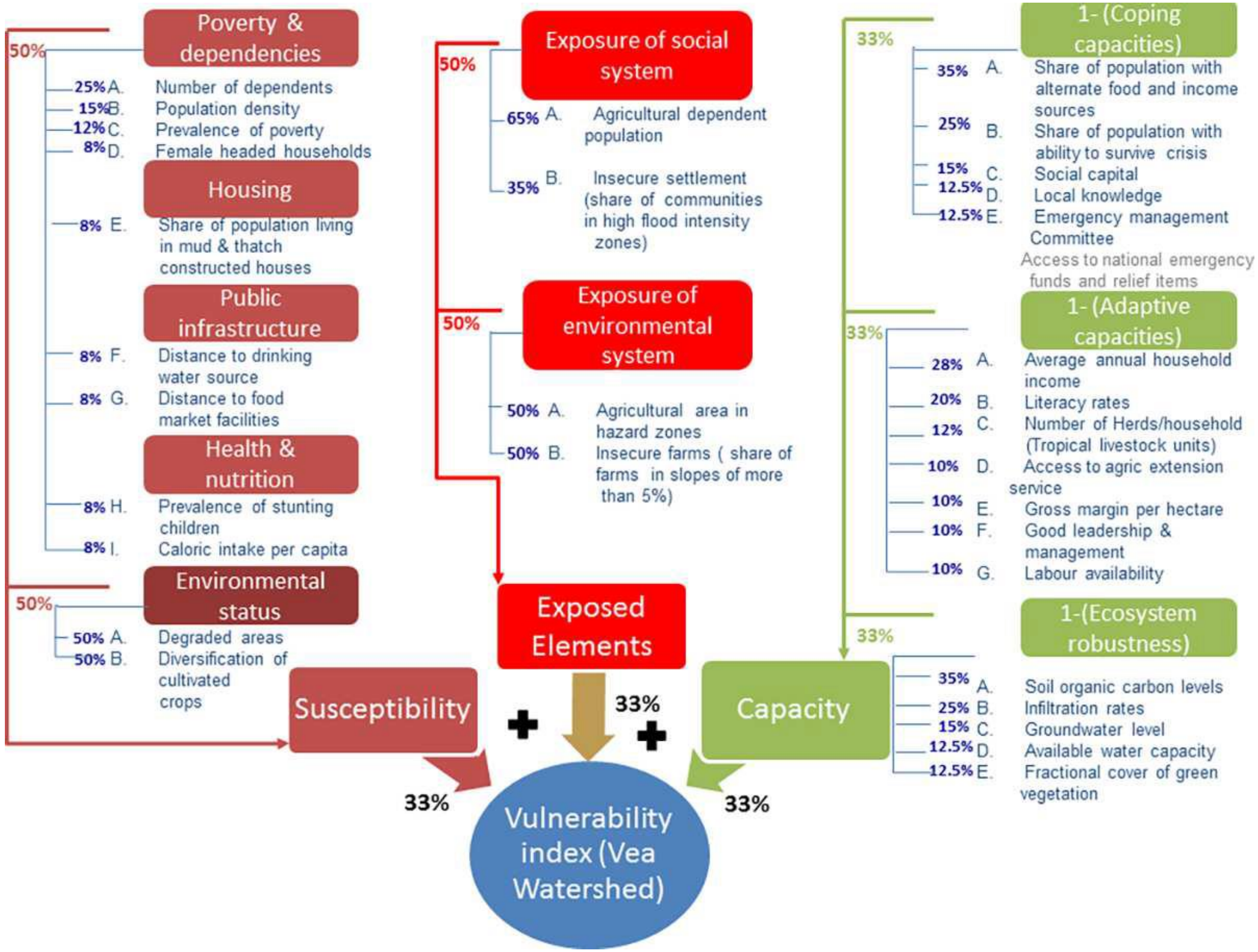


This differential ranking has significant implications for weighting during risk estimations and hence the risk faced by people in different societies

And it arises from differences in perceptions of risks, cultural, political and socio-economic disparities in different countries

Asare-Kyei et al (2015): International Journal of Disaster Risk Reduction 11:13–34

Vulnerability index



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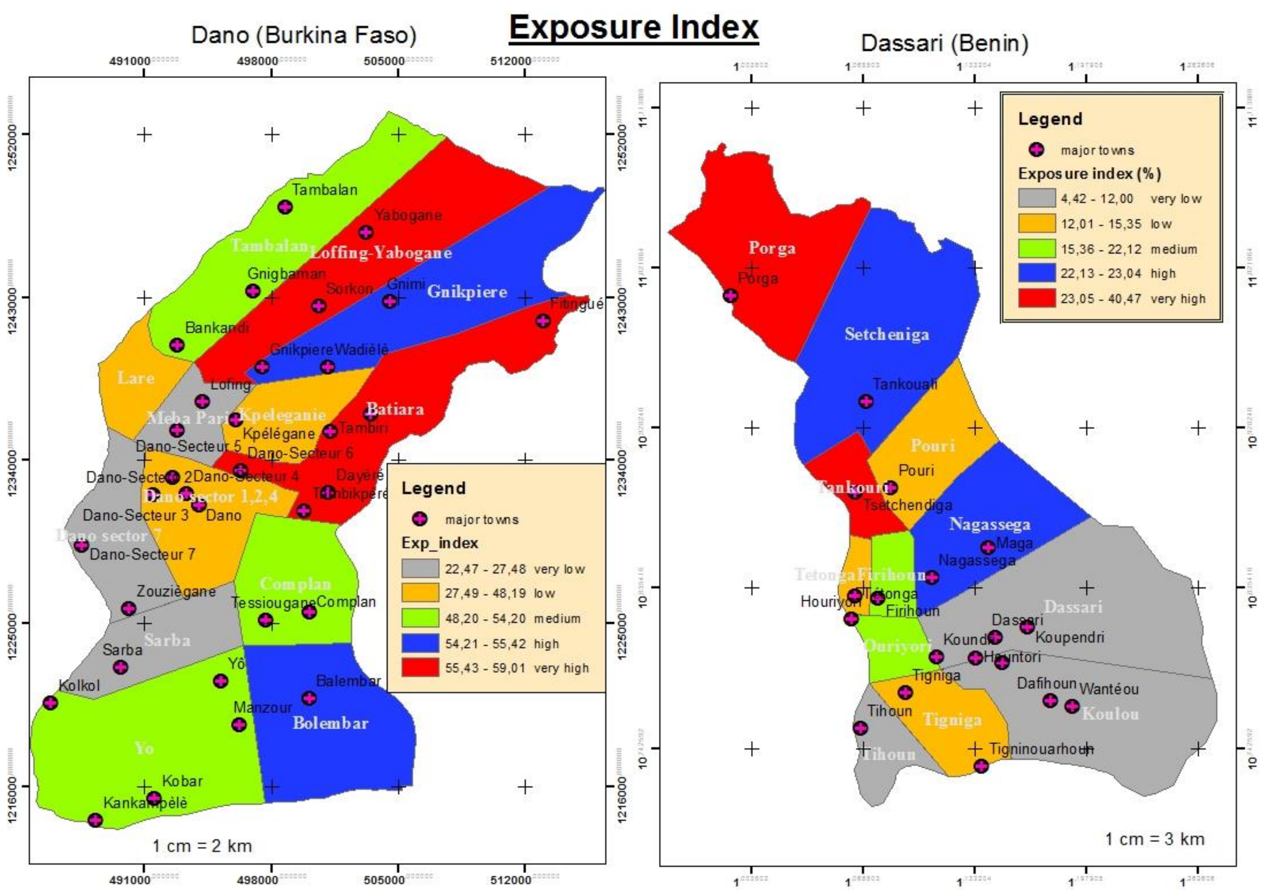
Exposure profiles

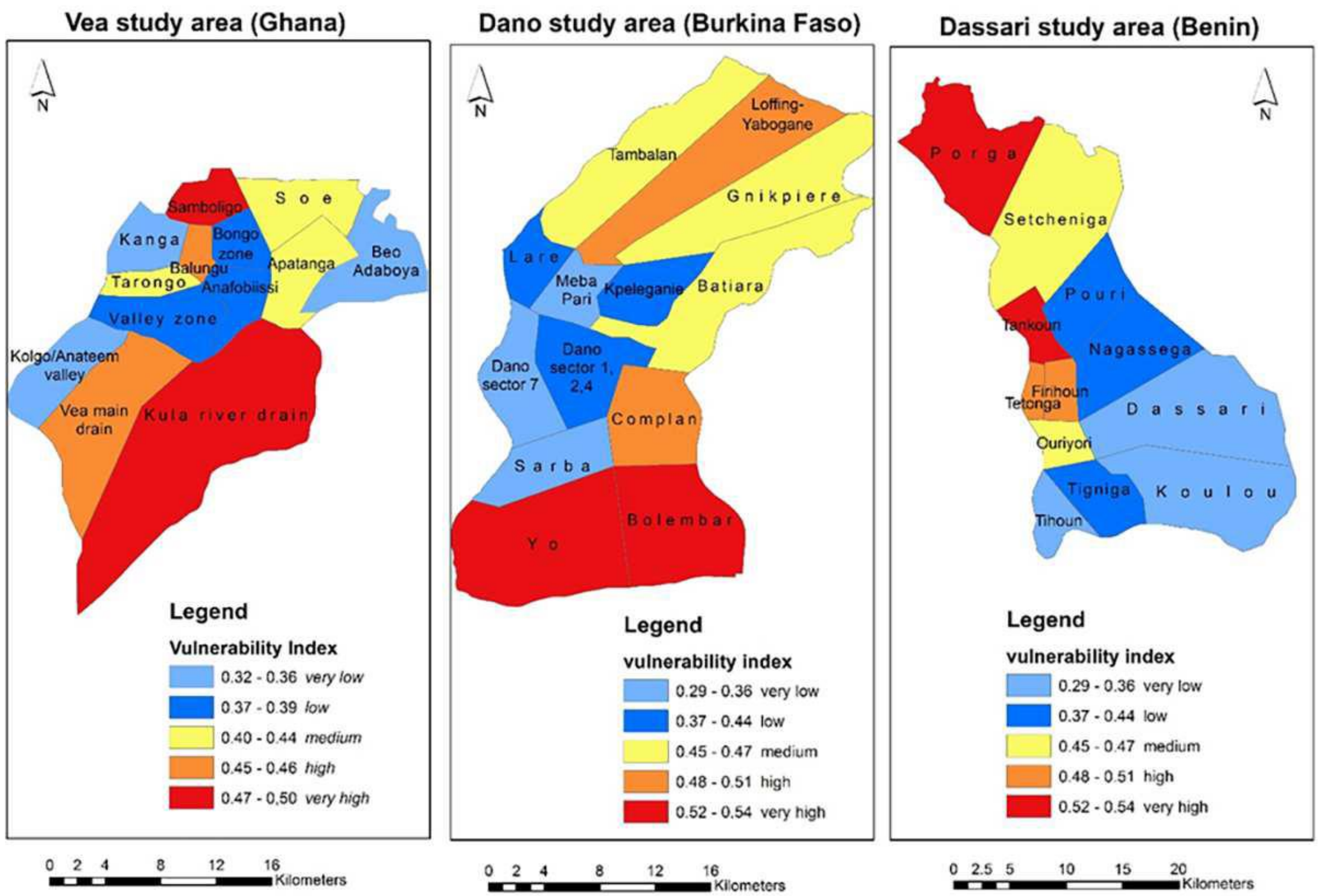


Community ranking of exposure of the SES to droughts and floods

	Vea study area (Ghana)		Dano study area (Burkina faso)		Dassari study area (Benin)	
Rank	Community cluster	Exposure (%)	Community cluster	Exposure (%)	Community cluster	Exposure (%)
1	Kula river drain	58.14	Loffing-Yabogane	59.01	Porga	40.47
2	Vea main drain	49.55	Batiara	58.45	Tankouri	26.93
3	Valley zone	34.85	Bolembar	55.42	Setchendiga	23.04
4	Balungu	34.14	Gnikpiere	55.06	Nagassega	22.36
5	Kolgo-Anateem	31.31	Yo	54.20	Ouriyori	22.12
6	Anafobiisi	29.98	Complan	53.54	Firihoun	19.19
7	Apatanga	29.73	Tambalan	52.31	Pouri	15.35
8	Samboligo	29.70	Dano sector 1,2,4	48.19	Tetonga	13.85
9	Soe	29.54	Kpeleganie	46.24	Tigniga	12.07
10	Tarongo	19.54	Lare	28.34	Tihoun	12.00
11	Beo Adaboya	19.29	Sarba	27.48	Dassari	11.32
12	Bongo zone	16.42	Dano sector 7	23.59	Koulou	4.42
13	Kanga	13.44	Meba Pari	22.47		

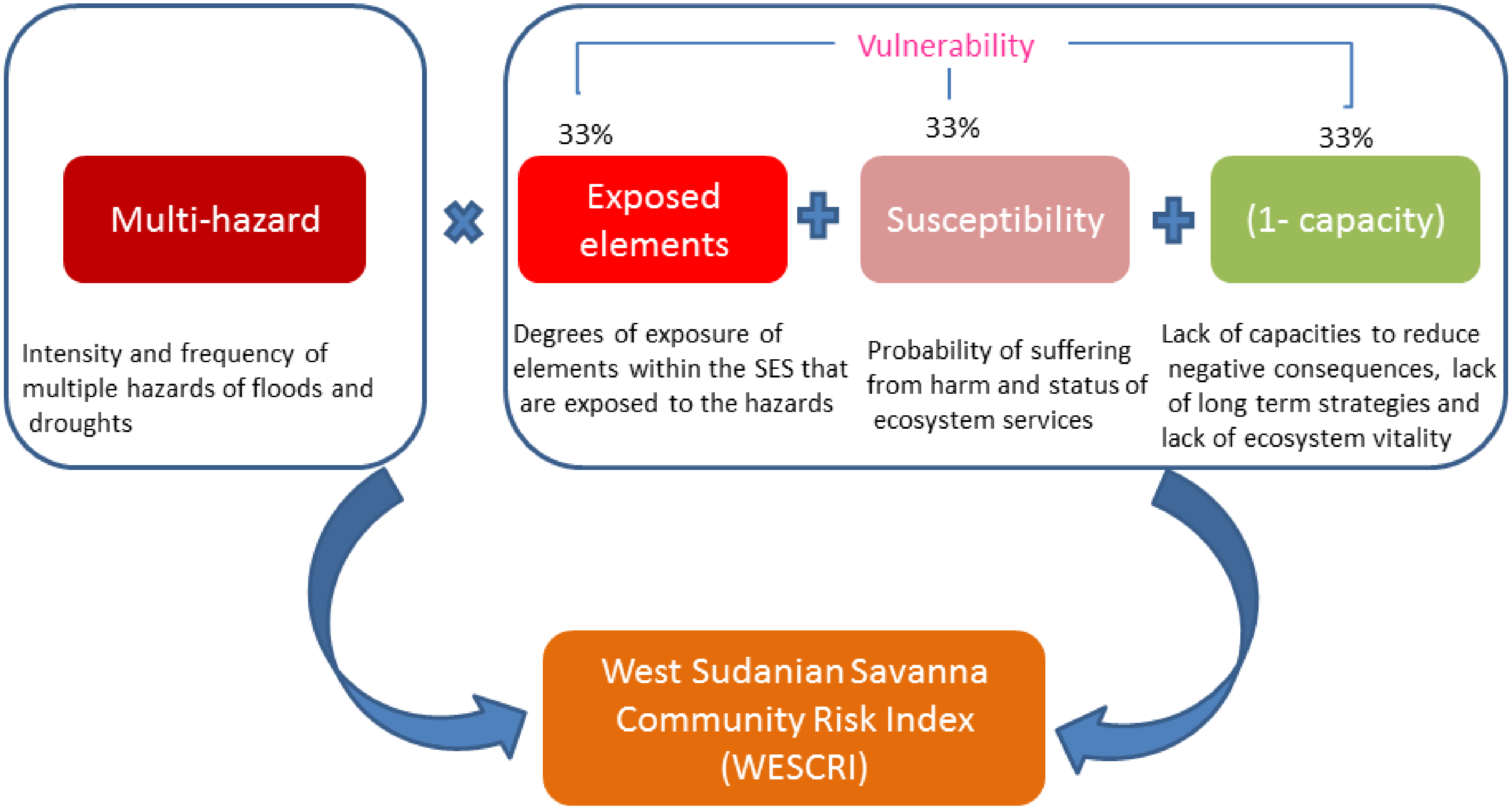
Slide prepared by Asare-Kyei (UNU-EHS)

Composite community vulnerability index



Asare-Kyei et al (2016): PLoS ONE 12(3): e0171921. doi:10.1371/journal.pone.0171921

West Sudanian Savanna Community Risk Index (WESCRI): Computation



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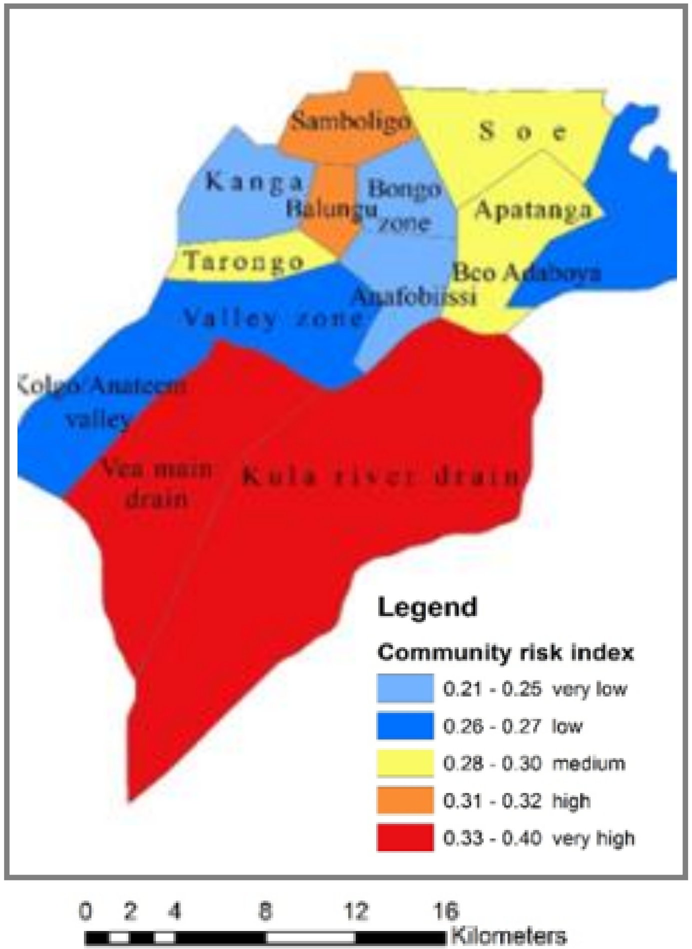
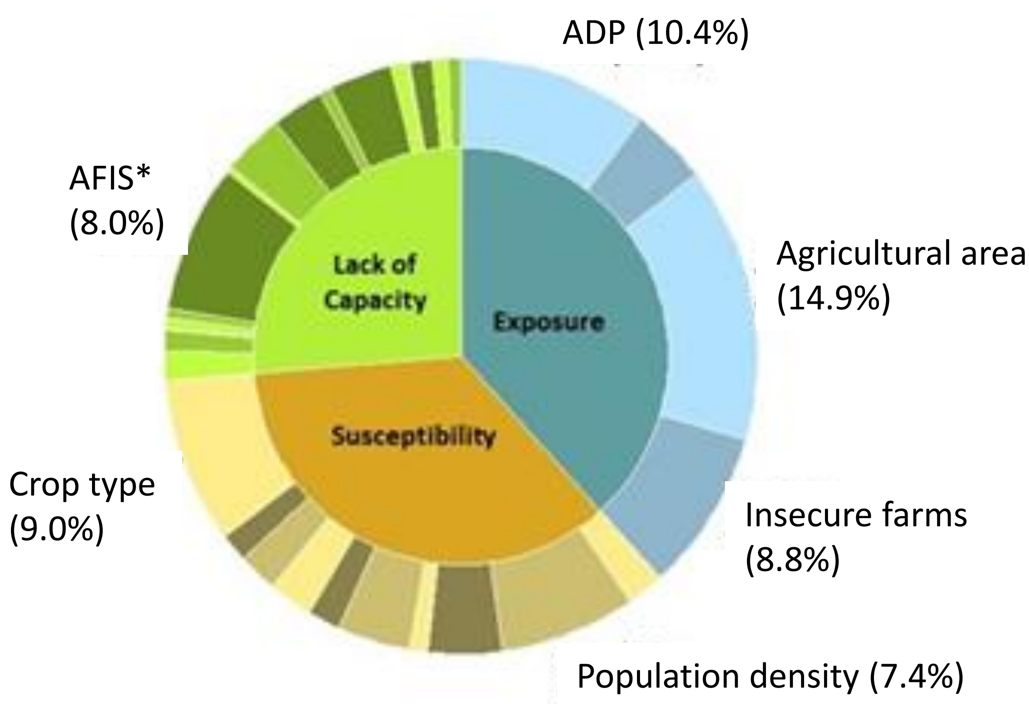
Risk and vulnerability profiles 1/2

Risk



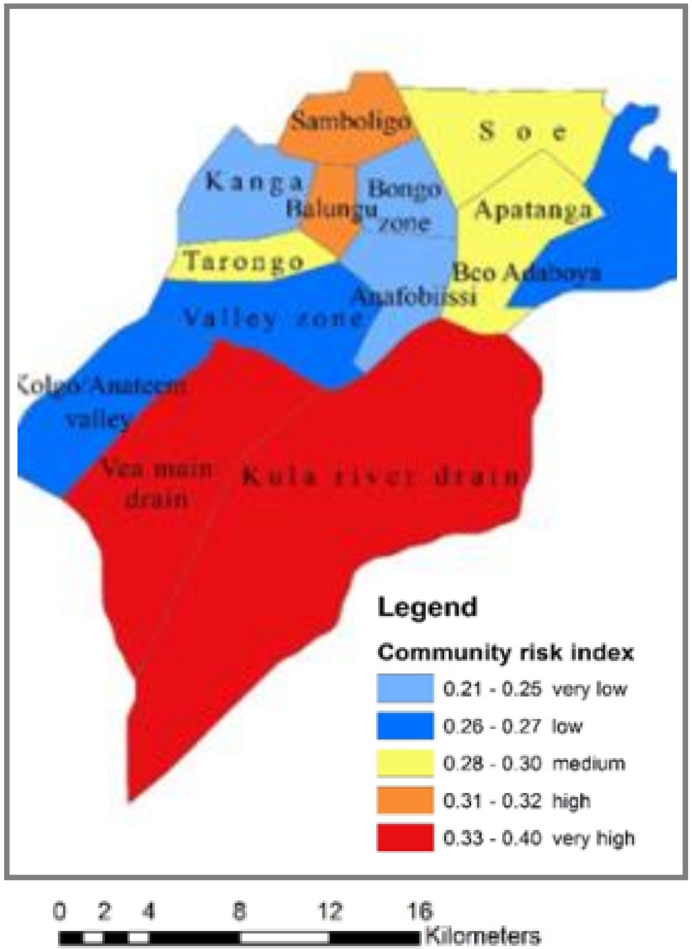
Vulnerability profile of
Kula river drain community



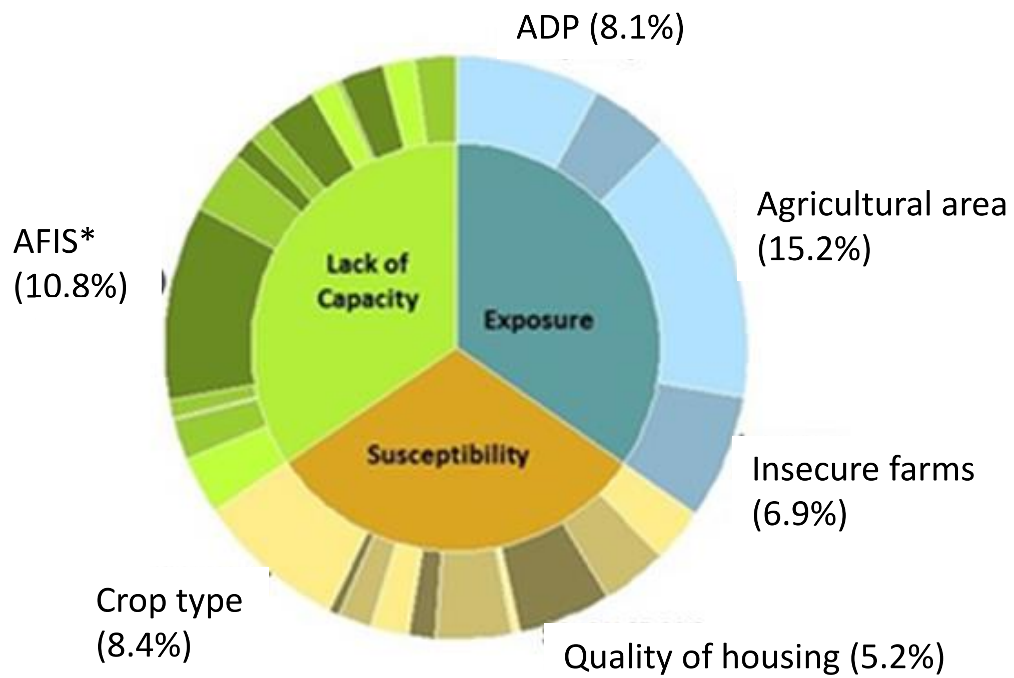
*Alternate food and income source

Risk and vulnerability profiles 2/2

Risk



Vulnerability profile of
Vea main drain community



*Alternate food and income source

Summary

Opportunities

- Can summarize complex, multi-dimensional phenomena with a view to supporting decision makers
- Easier to interpret than a battery of indicators
- Comparative analysis & identification of hotspots
- Monitoring of trends
- Facilitate communication with decision makers, practitioners and the public

Challenges / limitations

- Data (availability, quality)
- "Subjectiveness" of indicator choice
- Validation
- May send misleading policy messages if poorly constructed or misinterpreted
- May invite simplistic policy conclusions
- Technocratic → may fail to consider the actual root causes of vulnerability

Part 2
Brief introduction to Eco-DRR ecosystem services

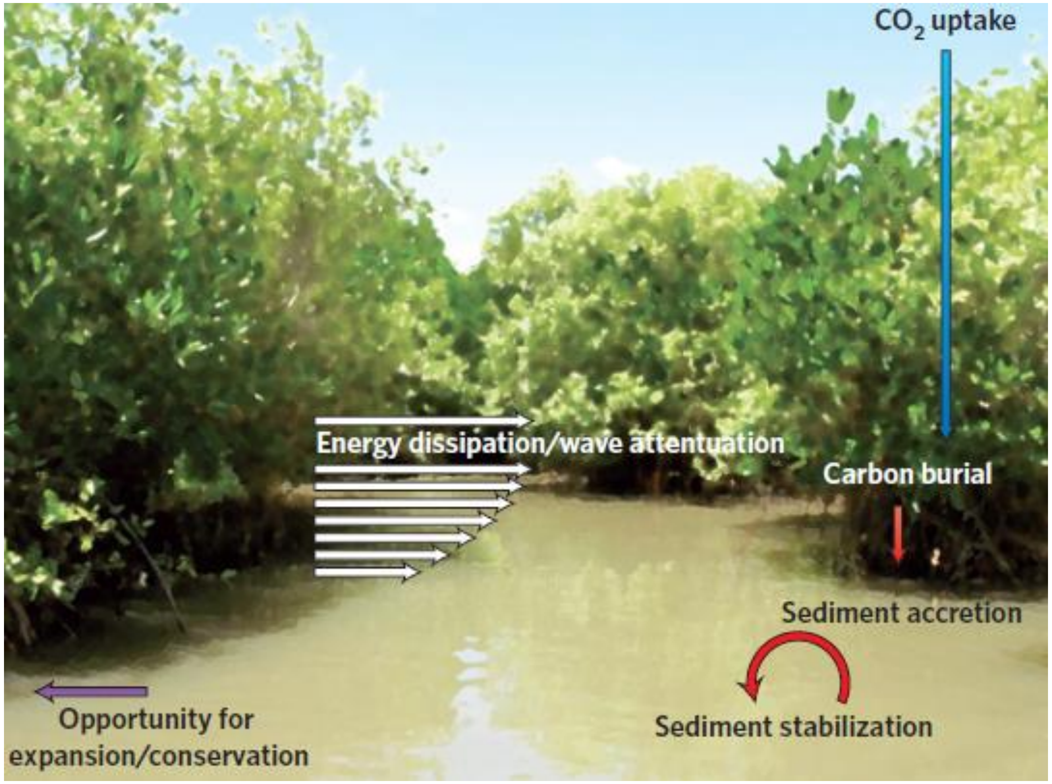
Ecosystem-based DRR/CCA

The sustainable management, conservation, and restoration of ecosystems to reduce disaster risk and adapt to the consequences of climate change, with the aim of achieving sustainable and resilient development

Chapter 1 of Renaud et al (2016): Ecosystem-Based Disaster Risk Reduction and Adaptation in Practice, Springer. DOI 10.1007/978-3-319-43633-3_1. Photos: F. Renaud/UNU-EHS

Eco-DRR/CCA, Ecosystem Services, and the components of risk

- Regulating services:
  - ✓Erosion regulation
  - ✓Environmental hazard regulation
  - ✓Carbon storage
  - ✓Exposure reduction



Source for the figure: Duarte et al (2013): The role of coastal plant communities for climate change mitigation and adaptation. Nature Climate Change DOI: 10.1038/NCLIMATE1970

Eco-DRR/CCA, Ecosystem Services, and the components of risk

- Regulating services
  - ✓Carbon storage
  - ✓Erosion regulation
  - ✓Environmental hazard regulation
  - ✓Exposure reduction
- **Provisioning services**
  - ✓**Fish and seafood**
  - ✓**Fire wood**

Photo: Fabrice Renaud/UNU-EHS

Eco-DRR/CCA, Ecosystem Services, and the components of risk

- Regulating services
  - ✓Carbon storage
  - ✓Erosion regulation
  - ✓Environmental hazard regulation
  - ✓Exposure reduction
- Provisioning services
  - ✓Fish and seafood
  - ✓Timber
- **Cultural services**
  - ✓**Recreation & tourism**
  - ✓**Cultural heritage**

Photos: Fabrice Renaud/UNU-EHS

Mountain forest

▶ ***Forests on steep slopes***

- Protection against avalanches, particularly during the snow melt
- Protection against landslides and rock fall, particularly following storms or sudden earth movements
- Slowing rate of flood waters
- Slope stabilization

Source: Dudley, N., Buyck, C., Furuta, N., Pedrot, C., Renaud, F., and K. Sudmeier-Rieux (2015). Protected Areas as Tools for Disaster Risk Reduction. A handbook for Practitioners . Tokyo and Gland, Switzerland: MOEJ and IUCN., photo: Sudmeier-Rieux

Forest (floodplains)

Element	What it provides
Forests ▶ ***Forests beside rivers & streams***	• Protection against extreme weather events and sudden water, earth and lava movements • Storage and sequestration of carbon to mitigate climate change • Emergency supplies of human food and livestock fodder in times of drought and famine • Medicine supplies during times of disaster and epidemic • Slowing and buffering discharge rates in floods • Bank stabilization against erosion

Source: Dudley, N., Buyck, C., Furuta, N., Pedrot, C., Renaud, F., and K. Sudmeier-Rieux (2015). Protected Areas as Tools for Disaster Risk Reduction. A handbook for Practitioners . Tokyo and Gland, Switzerland: MOEJ and IUCN., slide: Sudmeier-Rieux, picture: El Cangrecal river, Honduras© C Warmenbol 2007

Sand dunes

Barrier islands & sand dunes	• Buffering against ocean surge and other inundation as a result of typhoons, hurricanes and tsunamis

Source: Dudley, N., Buyck, C., Furuta, N., Pedrot, C., Renaud, F., and K. Sudmeier-Rieux (2015). Protected Areas as Tools for Disaster Risk Reduction. A handbook for Practitioners . Tokyo and Gland, Switzerland: MOEJ and IUCN., slide: Sudmeier-Rieux, picture: Sri Lanka ©McAdoo

Part 2
The Global Delta Risk Index

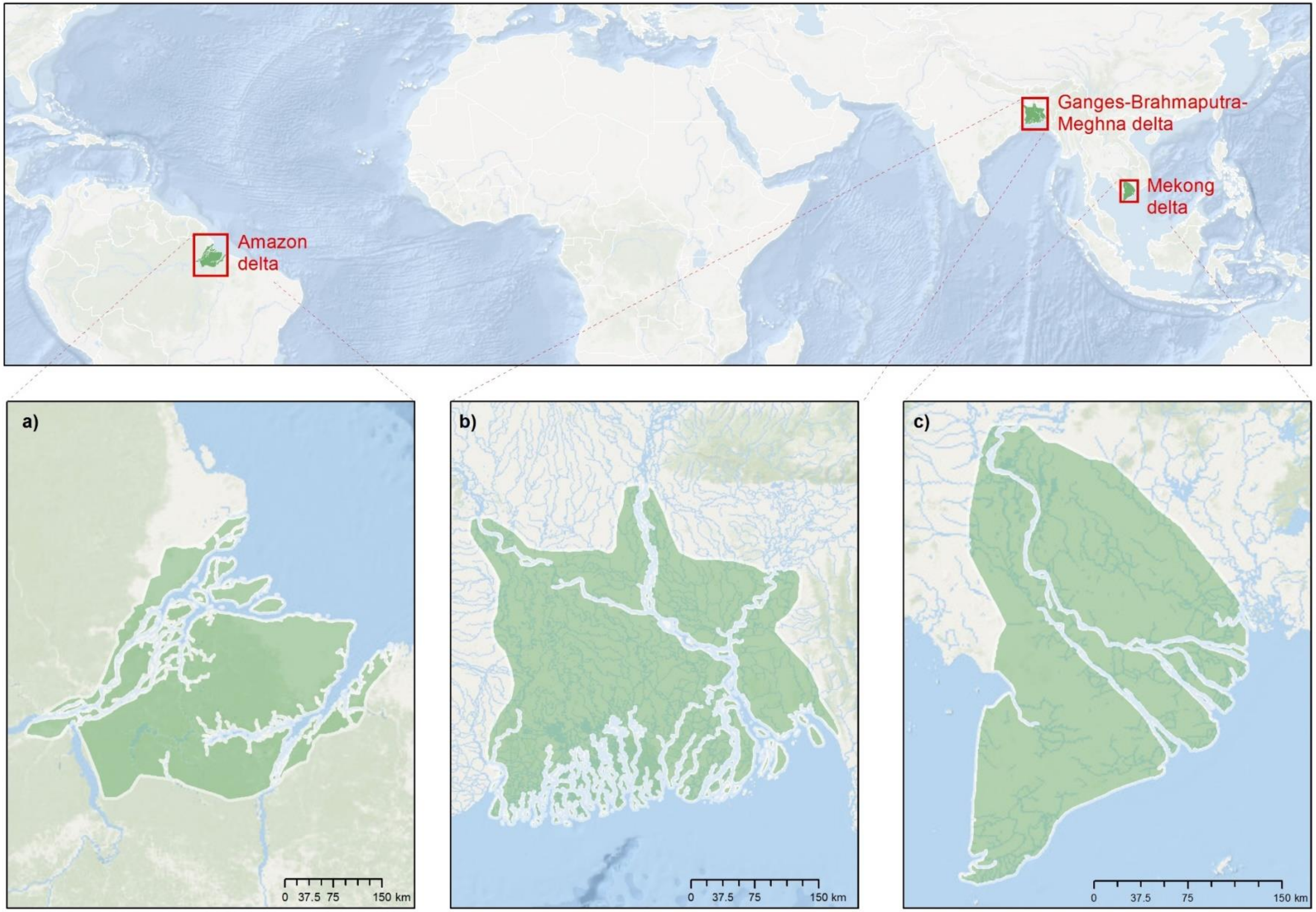
Global Delta Risk Index (GDRI)

“DELTAS: Catalyzing action towards sustainability of deltaic systems with an integrated modelling framework for risk assessment”

Slides adapted from a presentation by Fabrice Renaud an Mihael Hagenlocher/UNU-EHS

Global Delta Risk Index (GDRI)

Study sites



Global Delta Risk Index (GDRI) – Objectives

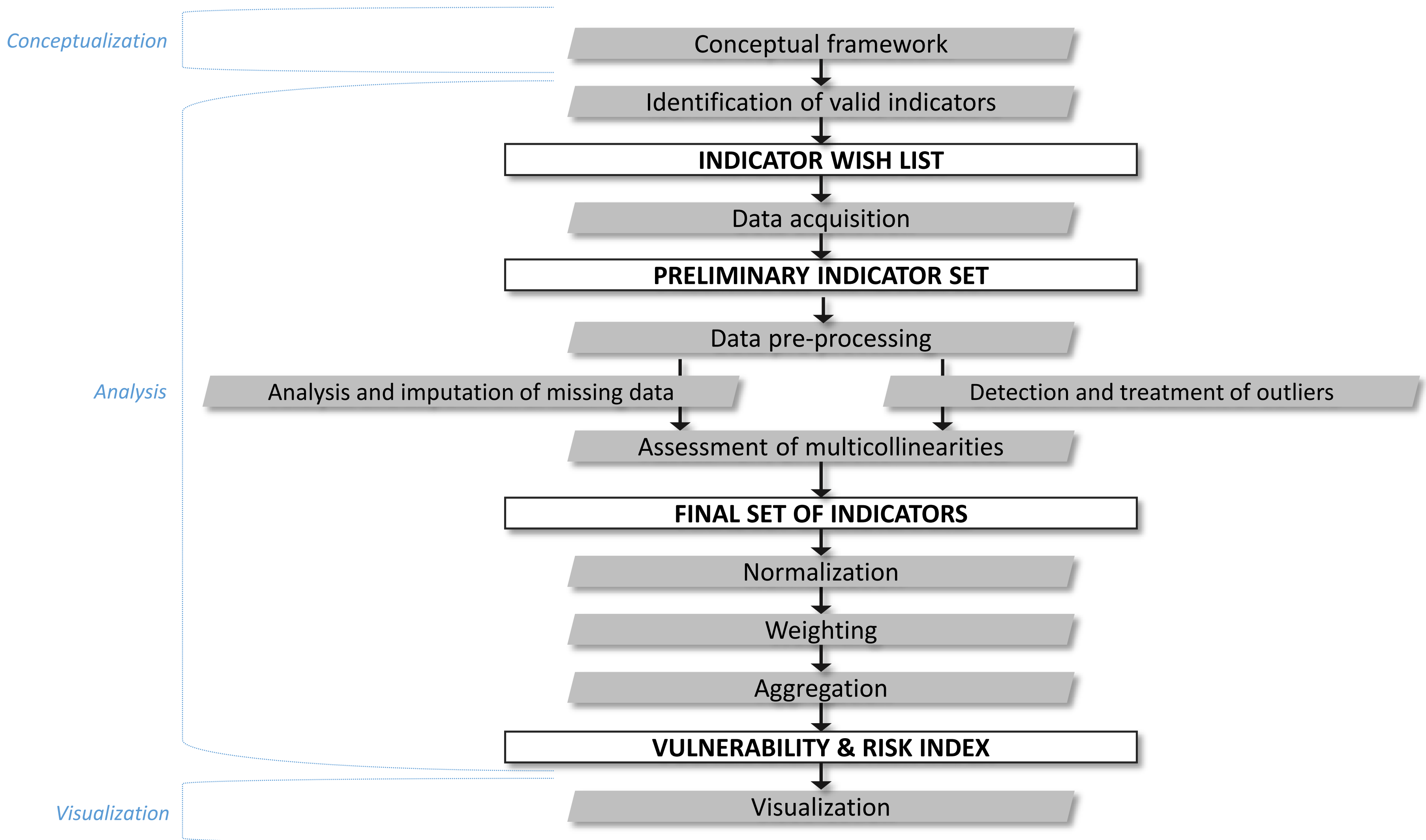
To support the planning and implementation of DRR and adaptation measures in deltas facing multiple hazards by:

- Developing a conceptual **framework** for assessing multi-hazard vulnerability (and risk) of SES at the sub-delta level

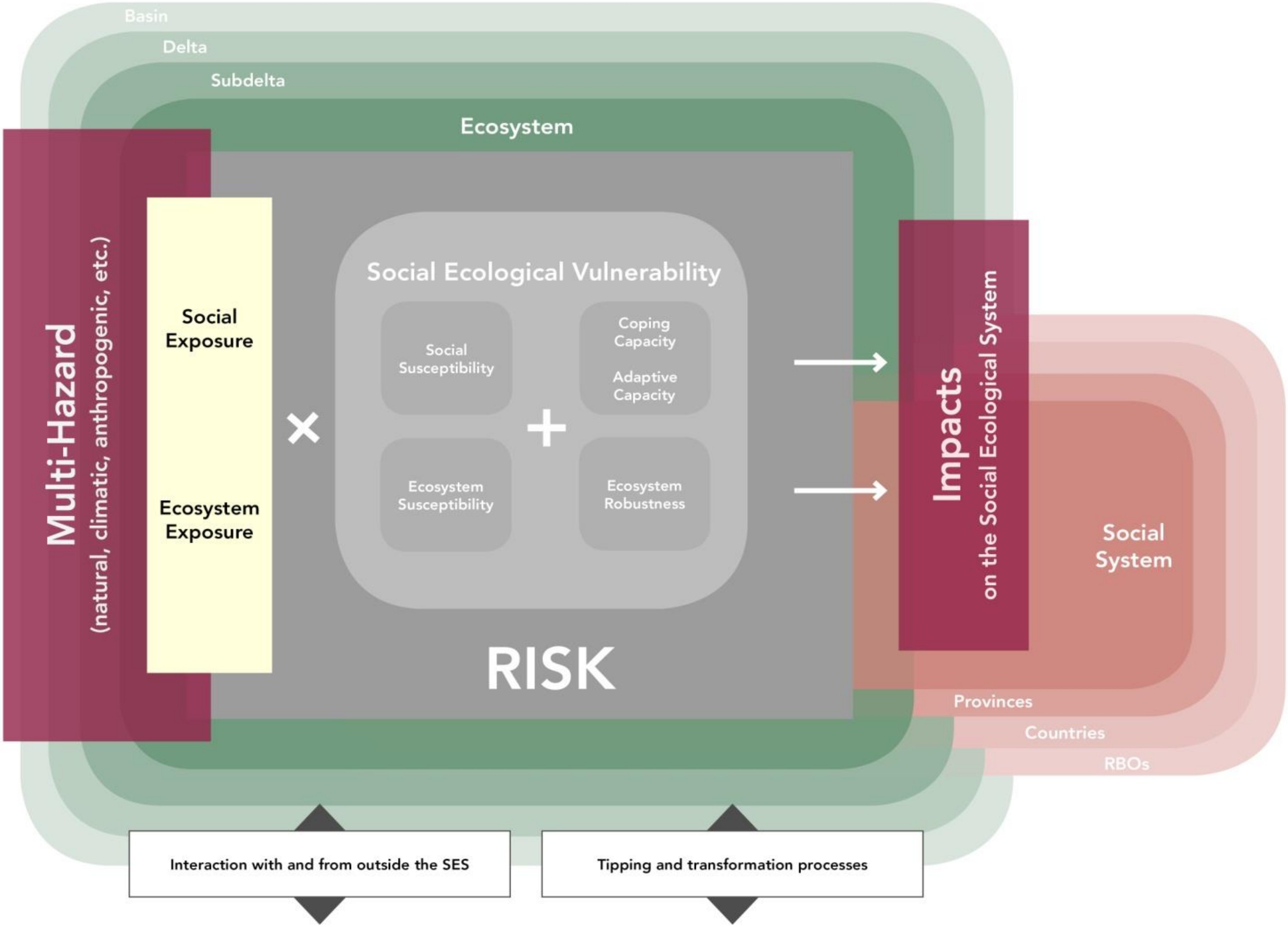
- Defining **indicators** that:
  - Represent vulnerability of the SES
  - Respond to multiple hazards in a hazard specific way
  - Are quantifiable at the sub-delta scale
  - Are transferable to different delta contexts

- Conduct an **assessment of multi-hazard risk** in the three model deltas at the sub-delta scale

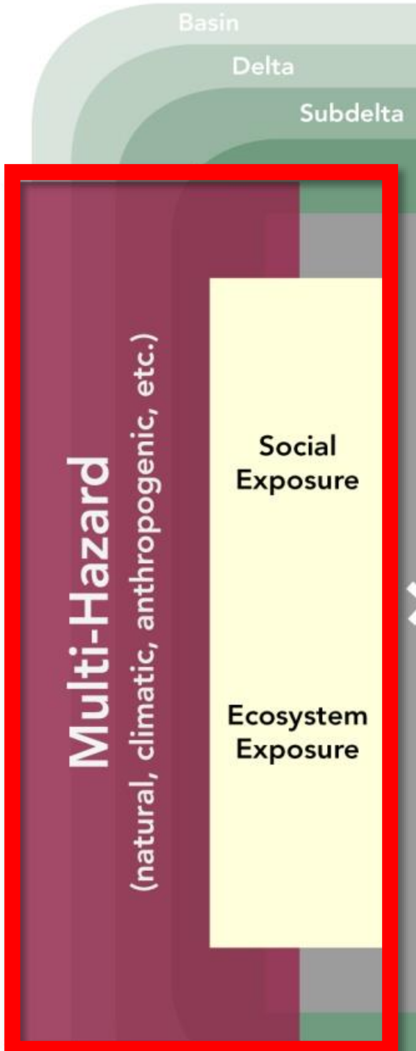
Global Delta Risk Index (GDRI) – Workflow



Source: Hagenlocher et al. (forthcoming), based on Nardo et al. (2005), OECD (2008), Hagenlocher & Castro (2015)



Source: Sebesvari et al. (2016), based on Turner et al. (2009), Garschagen (2014), Kloos et al. (2015)

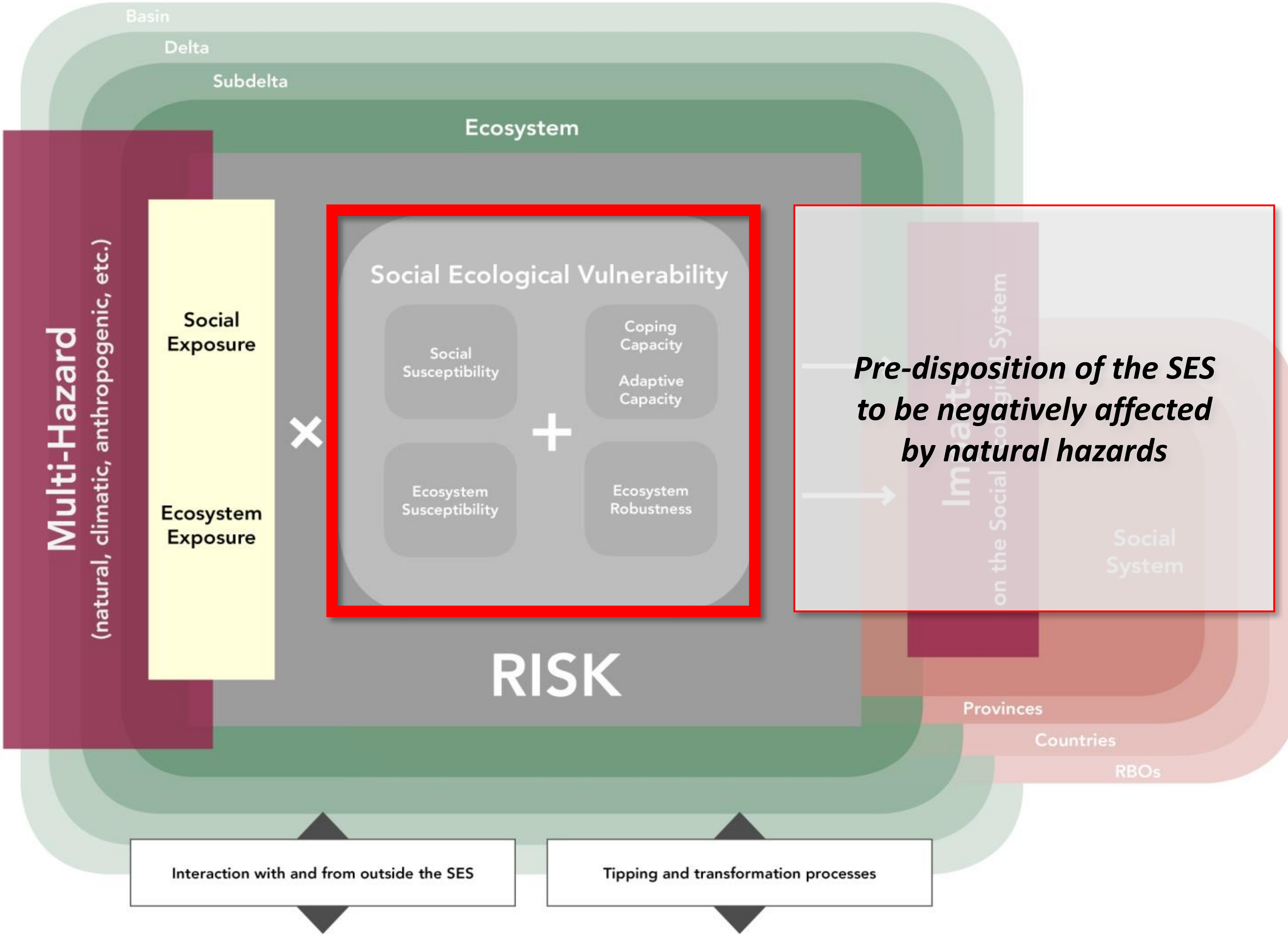


The extent to which elements and processes of the SES are in the reach or subjected to hazards

- **People** living in areas affected by natural hazards (e.g. flooding, drought, etc.)

- **Ecosystems** in areas affected by natural hazards (e.g. flooding, drought, etc.)

Source: Sebesvari et al. (2016), based on Turner et al. (2009), Garschagen (2014), Kloos et al. (2015)



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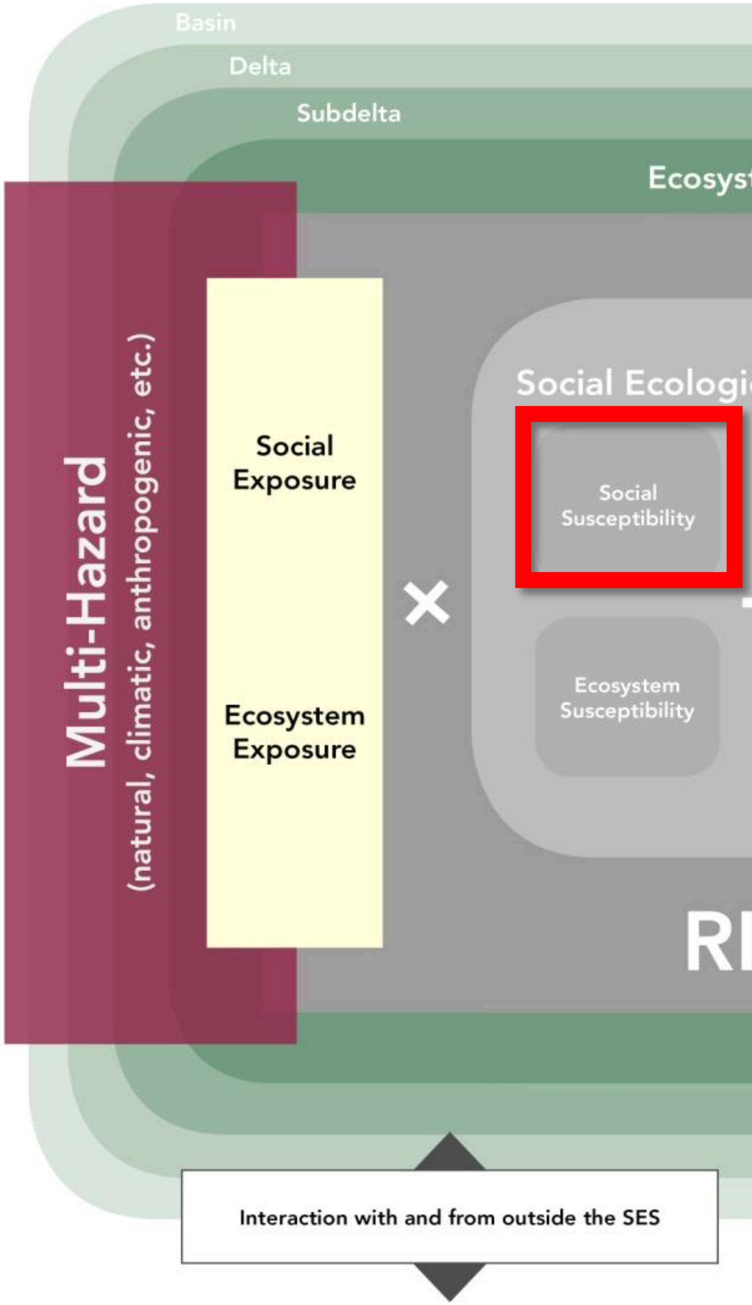
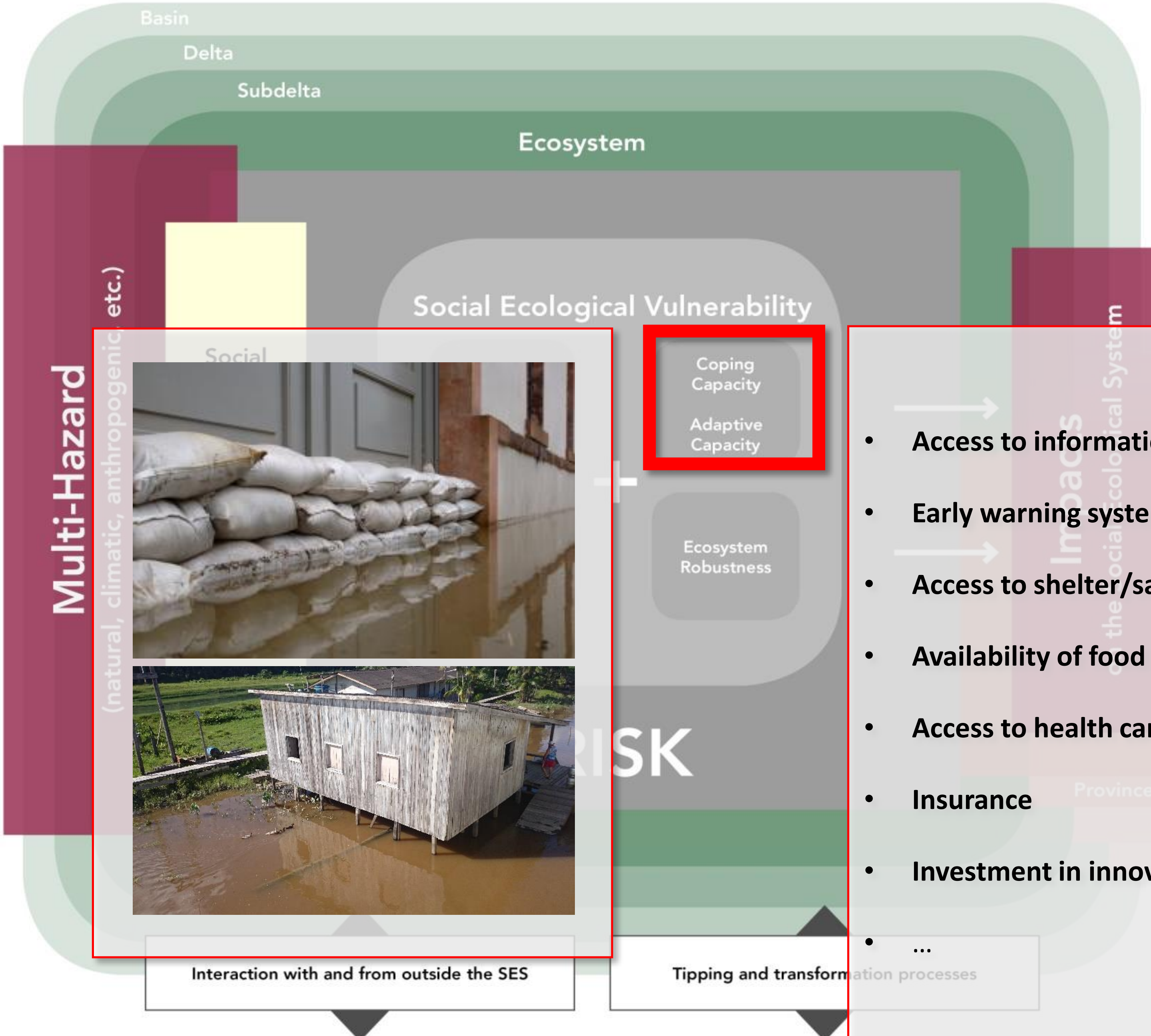


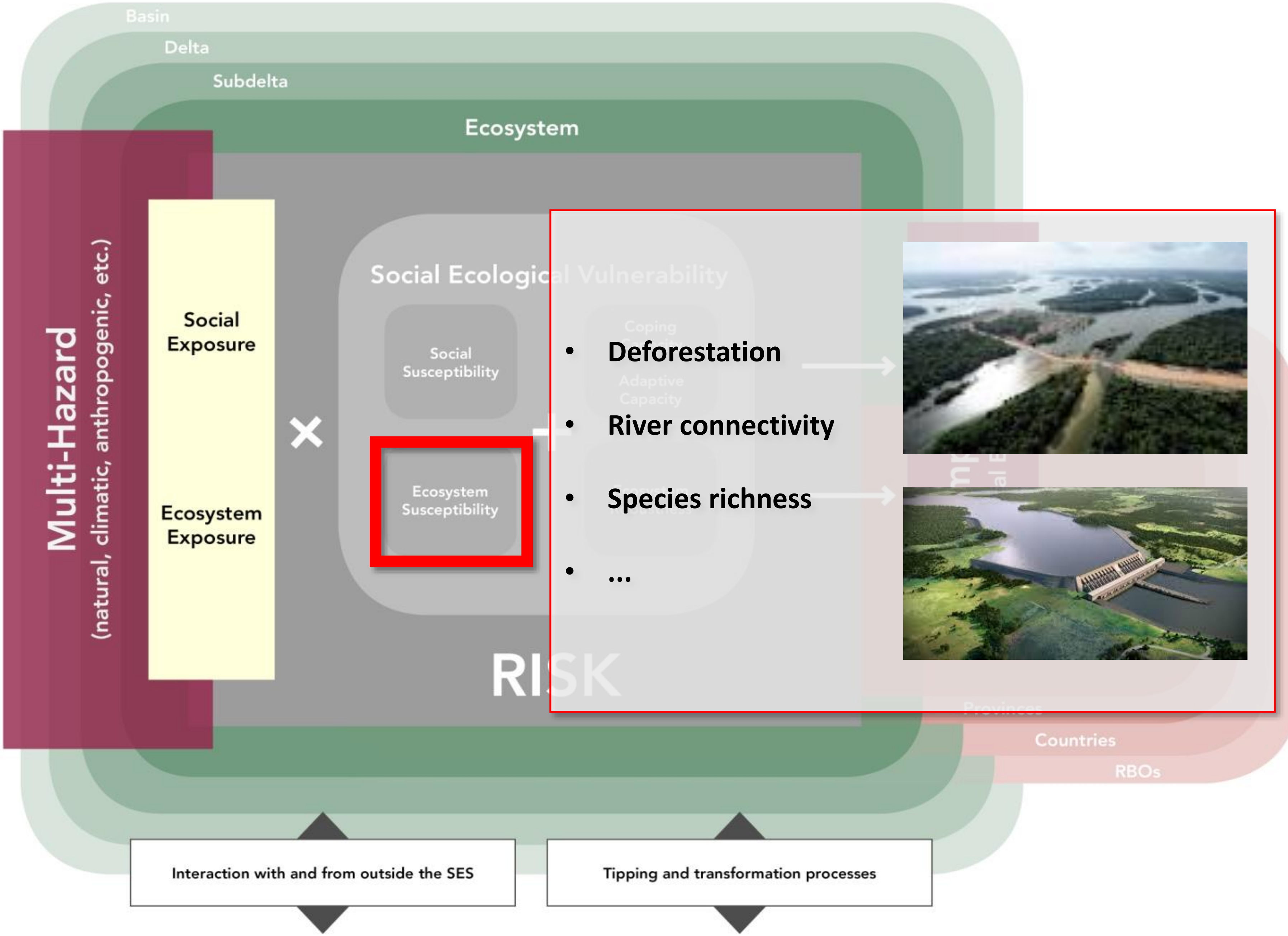
- **Demographic factors** (e.g. age, gender, etc.)
- **Social factors** (e.g. illiteracy, etc.)
- **Economic factors** (e.g. poverty, inequality, dependency, etc.)
- **Infrastructure** (e.g. water, sanitation, electricity))
- …

Source: Sebesvari et al. (2016), based on Turner et al. (2009), Garschagen (2014), Kloos et al. (2015)

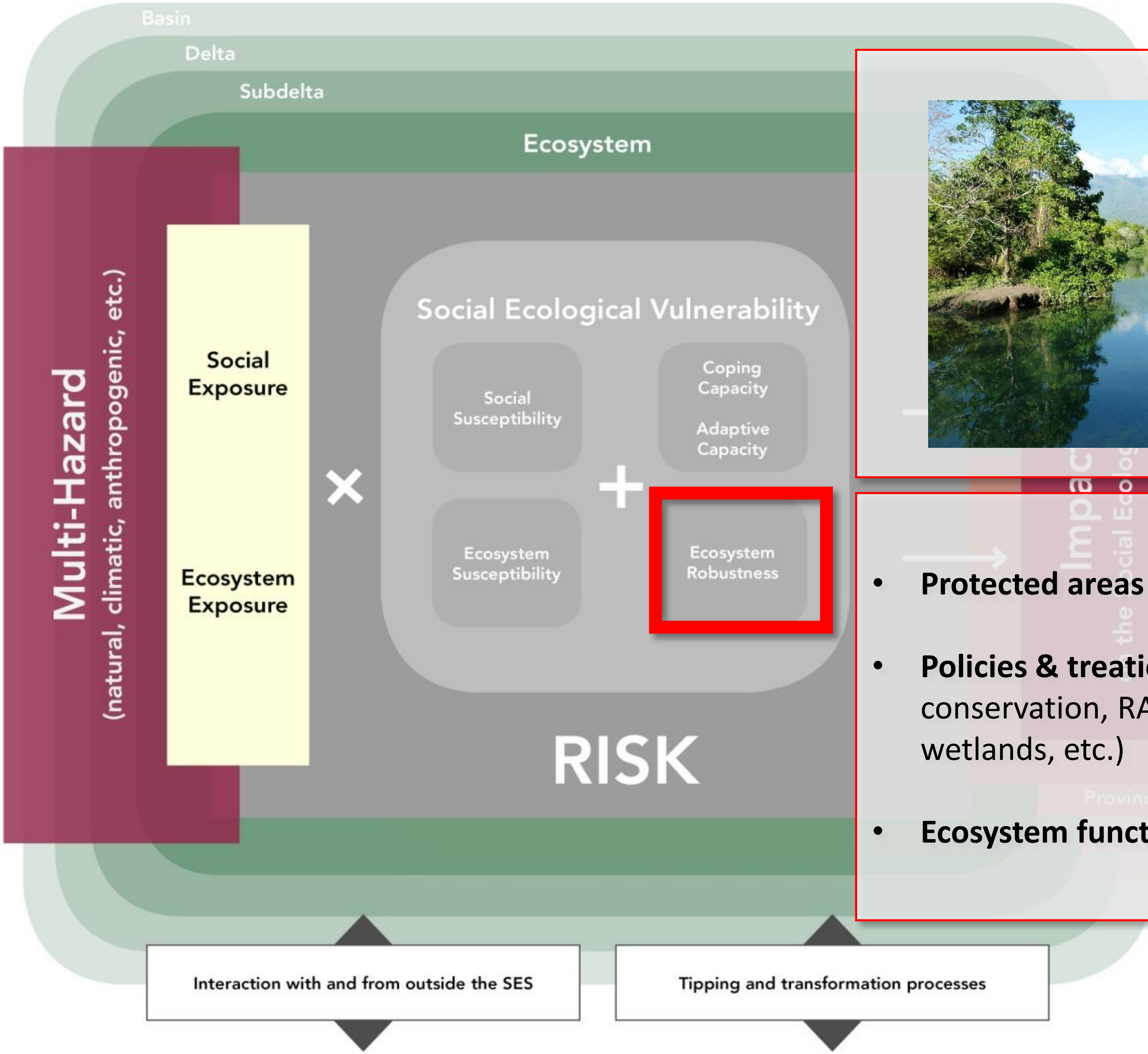


- **Access to information** (e.g. radio/TV, etc.)
- **Early warning systems**
- **Access to shelter/safe places**
- **Availability of food reserves**
- **Access to health care** (e.g. hospitals, etc.)
- **Insurance**
- **Investment in innovation & research**
- …

Source: Sebesvari et al. (2016), based on Turner et al. (2009), Garschagen (2014), Kloos et al. (2015)

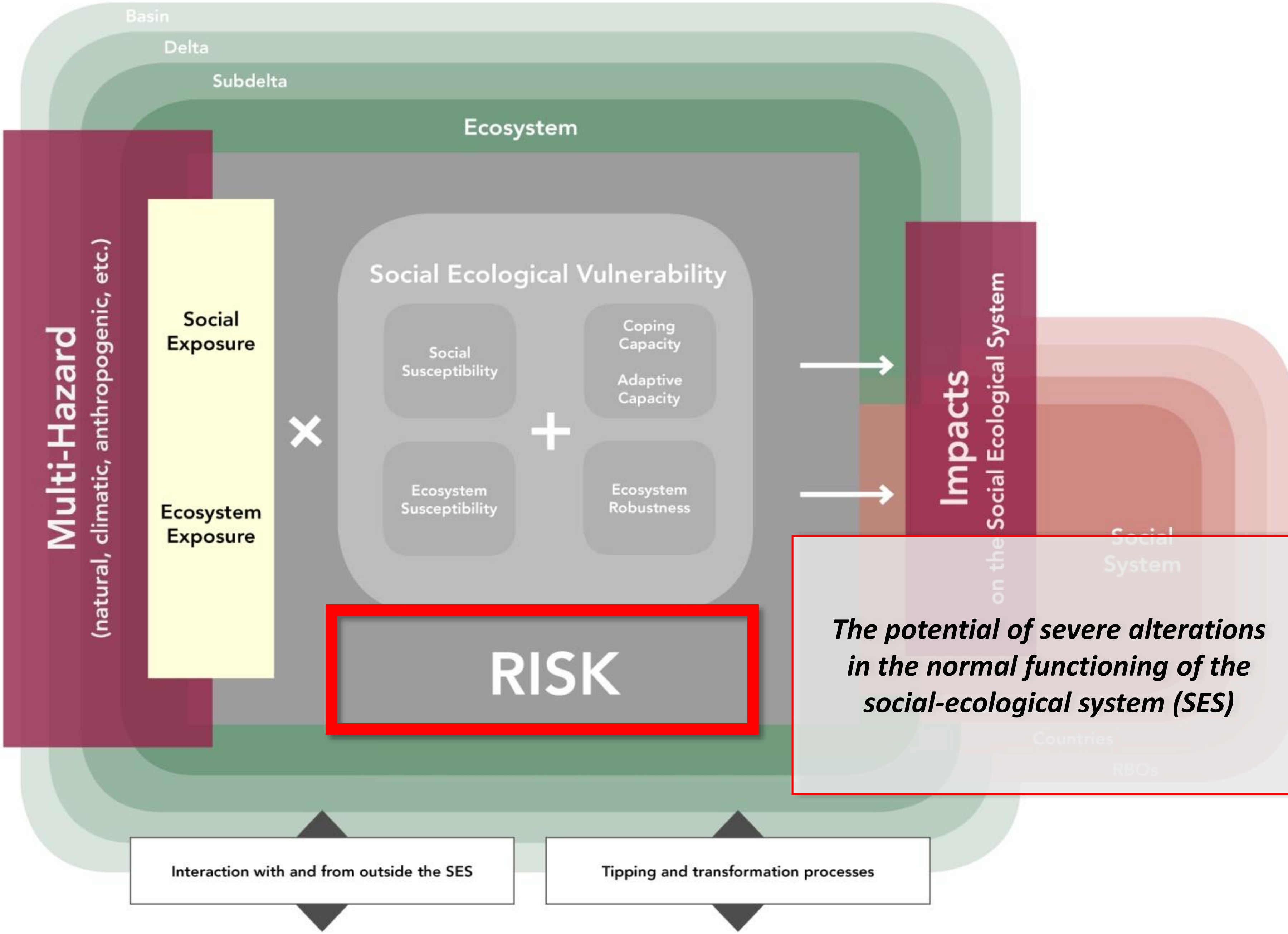


Source: Sebesvari et al. (2016), based on Turner et al. (2009), Garschagen (2014), Kloos et al. (2015)



- **Protected areas**
- **Policies & treaties** (e.g. biodiversity conservation, RAMSAR convention on wetlands, etc.)
- **Ecosystem functionality**…

Source: Sebesvari et al. (2016), based on Turner et al. (2009), Garschagen (2014), Kloos et al. (2015)



The potential of severe alterations in the normal functioning of the social-ecological system (SES)

Source: Sebesvari et al. (2016), based on Turner et al. (2009), Garschagen (2014), Kloos et al. (2015)

Global Delta Risk Index (GDRI) –
Identification of indicators

Local stakeholder consultations in the three demonstration deltas:

- Mekong: 2-3 April 2014
- Ganges -Brahmaputra-Meghna: 3-4 September 2014
- Amazon: 12-13 May 2015

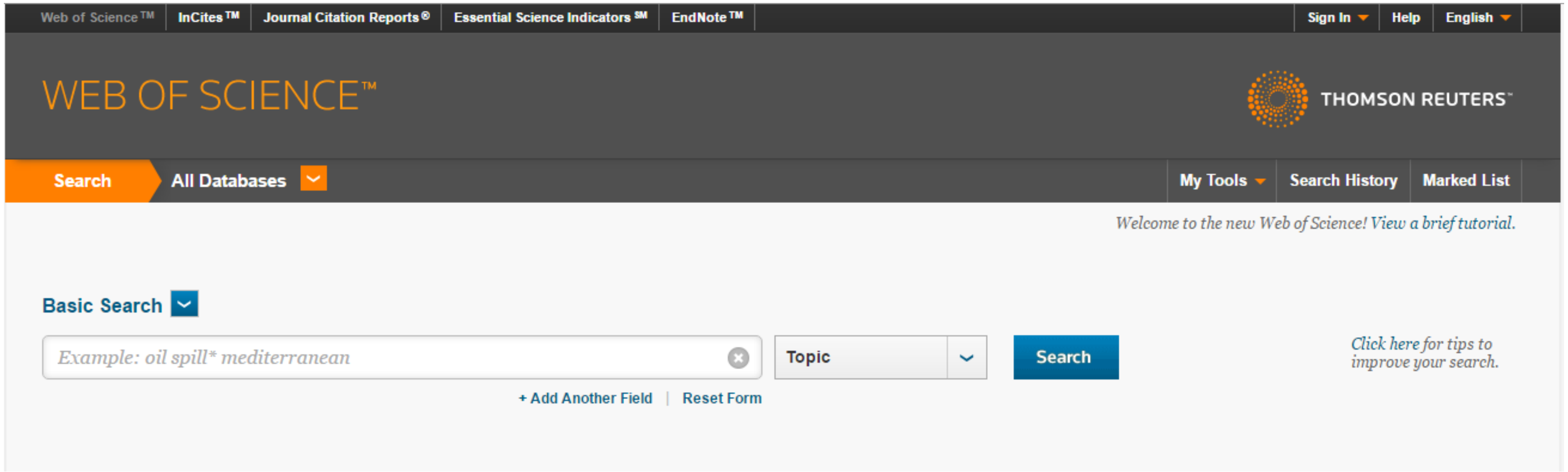
Selection of participants (inclusive approach):

- Government,
- Academia
- Civil society
- Independent consultants,
- Project partners
- …

Global Delta Risk Index (GDRI) –
Identification of indicators

Global Delta Risk Index (GDRI) –
Identification of indicators

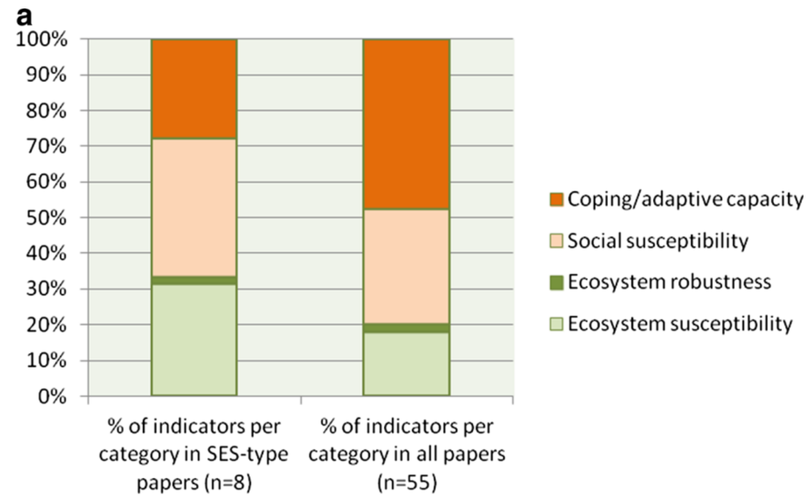
- Comprehensive review of vulnerability assessments and indicators in the three model deltas
  - **geomorphic terms related to coastal river deltas:** (''delta* OR estuary* OR coast* OR shore*''),
  - **assessment terms:** (''risk OR vulner* OR resil*'', and ''eval* OR assess* OR profile OR index OR indic*'')
  - **geographic terms:** (''Bangladesh OR Ganges OR Brahmaputra OR Amazon OR Mekong'')



Source: Sebesvari et al. (2016)

Global Delta Risk Index (GDRI) – Identification of indicators

- 55 papers reviewed systematically:
  - 236 indicators identified and classified according to the SES vulnerability framework
  - Indicators of ecosystem susceptibility and robustness are underrepresented even in SES-type studies
  - truly integrate social and ecological indicators
    > **SES-TYPE ASSESSMENTS**
  - account for vulnerability and risk in multi-hazard settings
    > **MULTI HAZARD ASSESSMENTS**



Source: Sebesvari et al. (2016)

Global Delta Risk Index (GDRI) – Indicator library

SOCIAL SUSCEPTIBILITY INDICATORS

Category	Indicator	Code	Data (yes/no)	Hazard setting **						Indicator library (potential proxies)
				storms	drought	floods (pluvial/fluvial)	salinity intrusion	coastal flooding	pollution	
Gender	Percentage female-headed households (%)	S_SOC3	x	+		+		+		Percentage female population (%)
Remoteness	Travel time to closest city (mins)	S_SOC4	x	+		+		+		Percentage rural population (%)
Disability & health status	Percentage of the population with disabilities (%)	S_SOC5	x	+	+	+		+		
	Percentage malnurished population (%)	S_SOC6		+	+	+	+	+	+	Stunting children (%); infant mortality rate (%)
	Percentage of population with chronic illnesses (%)	S_SOC7			+				+	Percentage of the population with HIV, tuberculosis, malaria, cardiovascular, respiratory disease, cancer (%)
	Percentage of illiterate population (%)	S_SOC8	x	+	+	+	+	+	+	Number of teachers per 10,000; gross school enrolment rate (%); distance to schools (km); density of schools (km^2)
Poverty & inequality	Percentage of population below national poverty line (%)	S_ECO1	x	+	+	+	+	+	+	Percentage of the population below 1 US$ per day (%); asset-based poverty index
	Dependency ratio (%)	S_ECO2	x	+	+	+	+	+	+	Percentage of children < 5 years (%); percentage of population in retirement (%)
	GINI index (0-100)	S_ECO4	x	+	+	+	+	+	+	GDP per capita PPP; income per capita PPP
Agriculture	Dependency on agriculture/forestry/fisheries for livelihood (%)	S_OCU1	x	+	+	+	+	+	+	Percentage of contribution of agriculture/forestry/fisheries to GPD (%) per province
	Percentage of households without access to irrigation (%)	S_OCU2	x		+					
Public infrastructure	Percentage of population without access to (improved) sanitation (%)	S_INF1	x	+	+	+		+		
	Percentage of population without access to clean water (%)	S_INF2	x	+	+	+	+	+	+	
	Percentage of population without access to electricity (%)	S_INF3	x	+	+	+	+	+	+	
Settlement & housing	Percentage of population living in informal settlements (%)	S_HOU1		+	+	+	+	+	+	
	Percentage of population living in poorly-constructed houses (%)	S_HOU2		+		+		+		
	Percentage of reinforced/elevated houses (%)	S_HOU3		-	+	-		-		
	Percentage of floating houses (%)	S_HOU4		+		-		-		
	Percentage of houses with more than one floor (%)	S_HOU5				-		-		
	Percentage of households without official land title (%)	S_HOU6		+	+	+	+	+	+	
Stability	Prevalence of population who experience violence (%)	S_STA1	x	+	+	+	+	+	+	Homicide rate per 100,000 inhabitants; % of population who experienced sexual violence
	Prevalence of population affected by armed conflict (%)	S_STA2		+	+	+	+	+	+	Density of armed conflict events (km2)
	Number of fatalities caused by terrorists per 10,000 per year	S_STA3	x	+	+	+	+	+	+	Global Terrorism Index (GTI)

Source: Hagenlocher et al. (forthcoming)

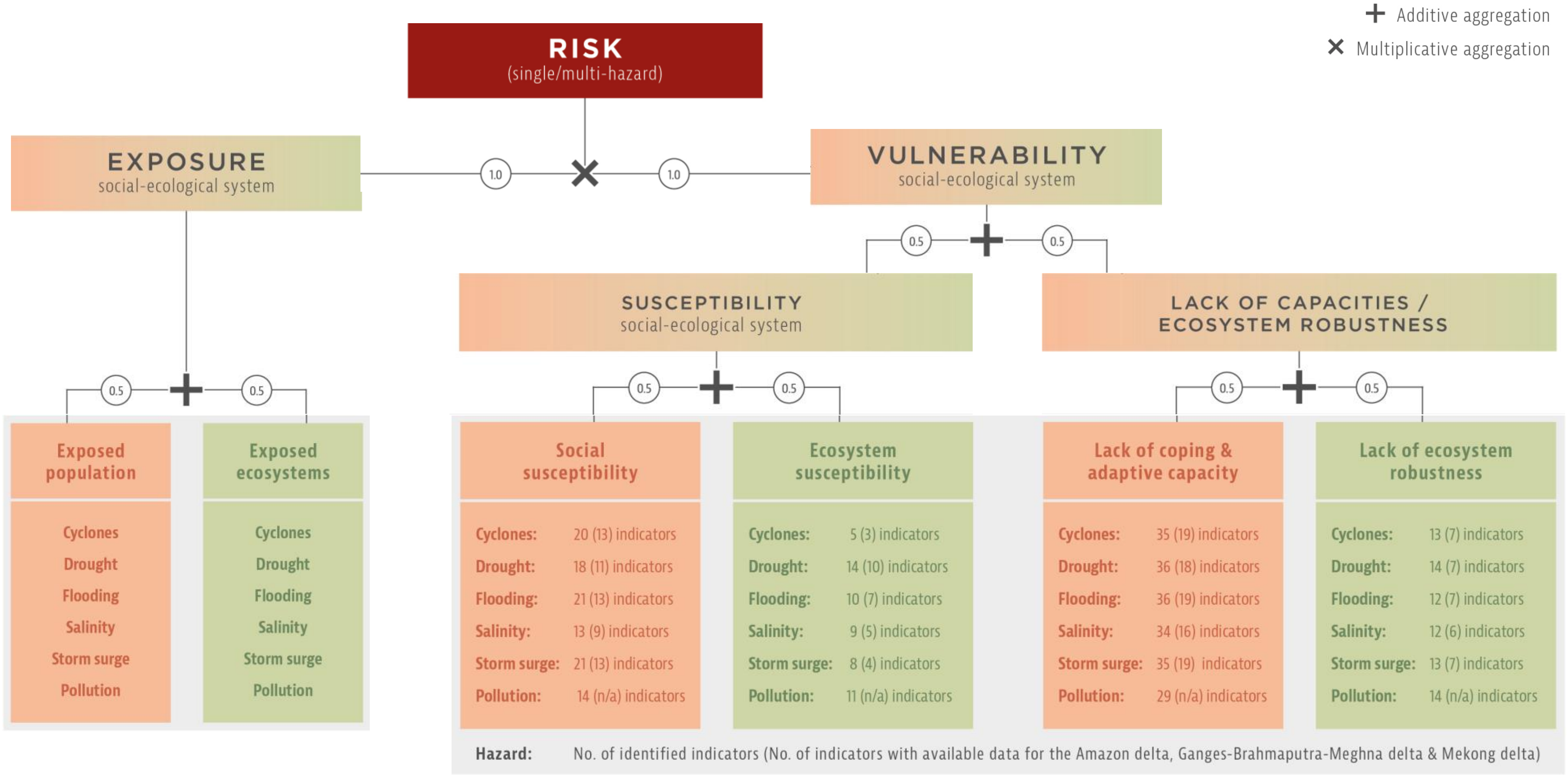
Global Delta Risk Index (GDRI) – Indicator library

ECOSYSTEM SUSCEPTIBILITY INDICATORS

Category	Indicator	Code	Data (yes/no) *	Hazard setting **: storms	drought	floods (pluvial/fluvial)	salinity intrusion	coastal flooding	pollution	Indicator library (potential proxies)
Habitat										
Habitat destruction	Percentage of wetlands drained (wetland loss)	ES_DES1			+	+	+	+	+	
	Freshwater scarcity	ES_DES2	x		+		+		+	Global fresh water resources; baseline water stress
	Percentage of deforested area (%)	ES_DES3	x	+	+	+		+	+	
	Percentage of shoreline eroded (%)	ES_DES4		+			+	+		
Habitat fragmentation	Wetland connectivity	ES_FRA1			-	-	-	-	-	
	River connectivity	ES_FRA2	x		-	-	-	-	-	Number of dams and sluice gates per river (# per km)
	Forest connectivity (RS)	ES_FRA3	x		-	-			-	
Habitat degradation	Water quality of freshwater bodies	ES_DEG1	x		-	-			-	Water Quality Index; Water quality for major watersheds; upstream protected land; Biochemical Oxygen Demand (BOD) in rivers, lakes and groundwater
	Groundwater quality	ES_DEG2	x	+	+	+	+	+	+	Arsenic in groundwater (probability of occurrence)
	Return Flow Ratio	ES_DEG4	x		+	+			+	
	Soil organic matter	ES_DEG6	x		-	-				Average carbon content in the topsoil as a % in weight (%)
	Thickness of the soil organic layer	ES_DEG7			-					
	Cation exchange capacity	ES_DEG9					-			
Ecosystem										
Fragile ecosystems	Percentage of area covered by "problem soils" (%)	ES_FRG1			+					
	Percentage of area covered by critical sites for conservation (danger of extinction)	ES_FRG3		+	+	+	+	+	+	
Biodiversity	Species richness adjusted by intactness	ES_BIO1a		-	-	-	-	-	-	

Source: Hagenlocher et al. (forthcoming)

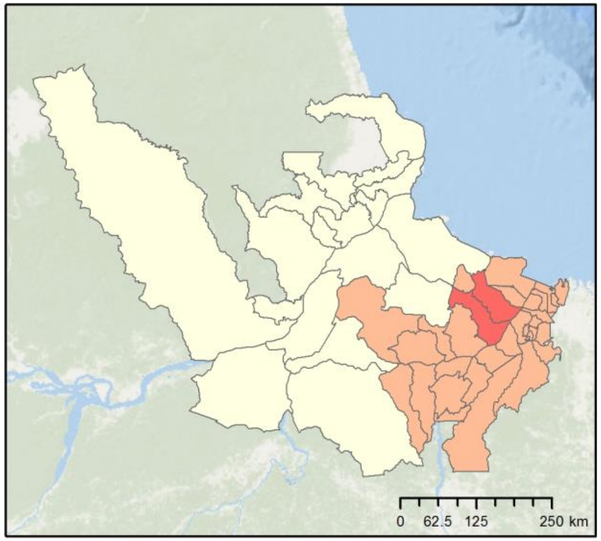
Global Delta Risk Index (GDRI) – Structure



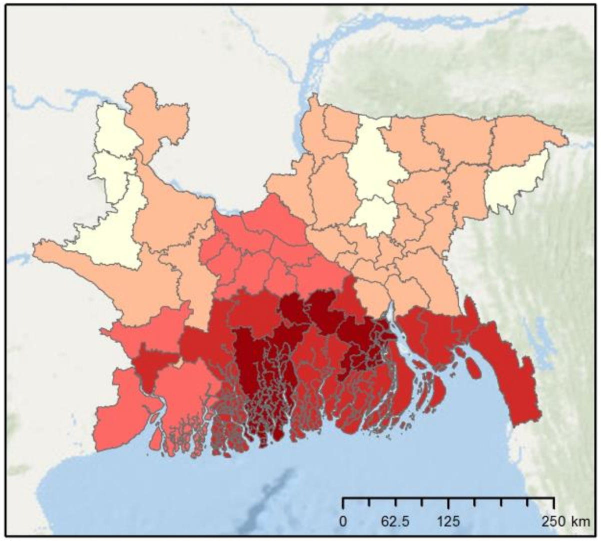
Source: Hagenlocher et al. (forthcoming)

Global Delta Risk Index (GDRI) – Results: multi-hazard exposure of the SES

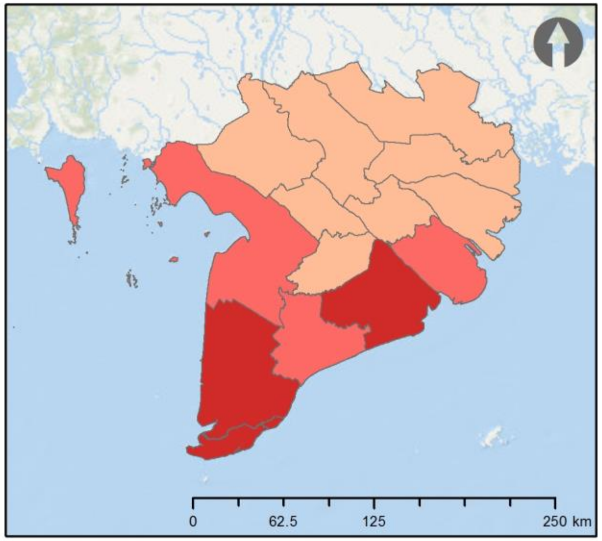
Amazon



Ganges-Brahmaputra-Meghna



Mekong



Multi-hazard exposure of the SES: 0.0 | > 0.0 - 0.15 | > 0.15 - 0.30 | > 0.30 - 0.45 | > 0.45 - 0.60 | > 0.60 - 0.75 | max value = 1.0

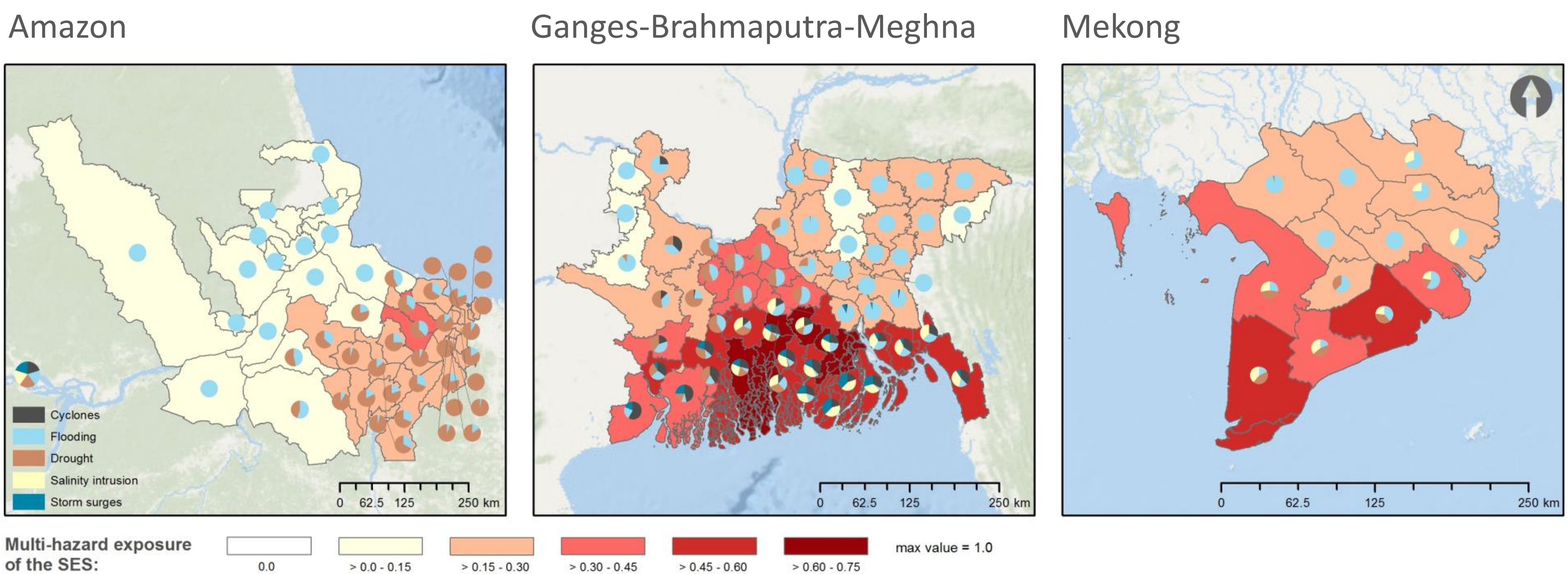
- flooding

- storm surges
- cyclones
- salinity intrusion
- flooding

- salinity intrusion
- flooding

Source: Hagenlocher et al. (forthcoming)

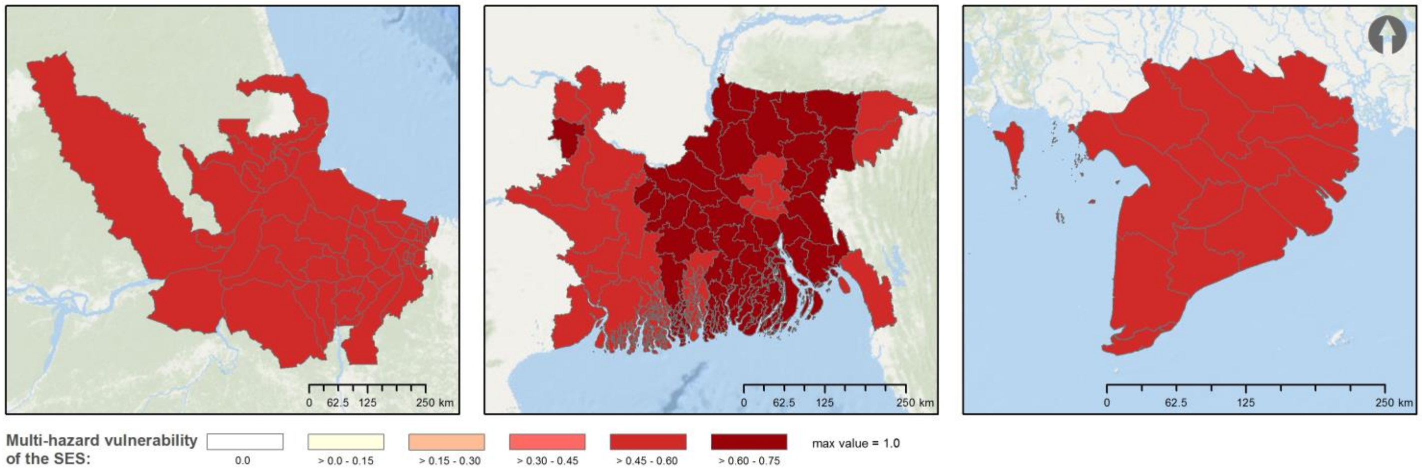
Global Delta Risk Index (GDRI) – Results: multi-hazard exposure of the SES



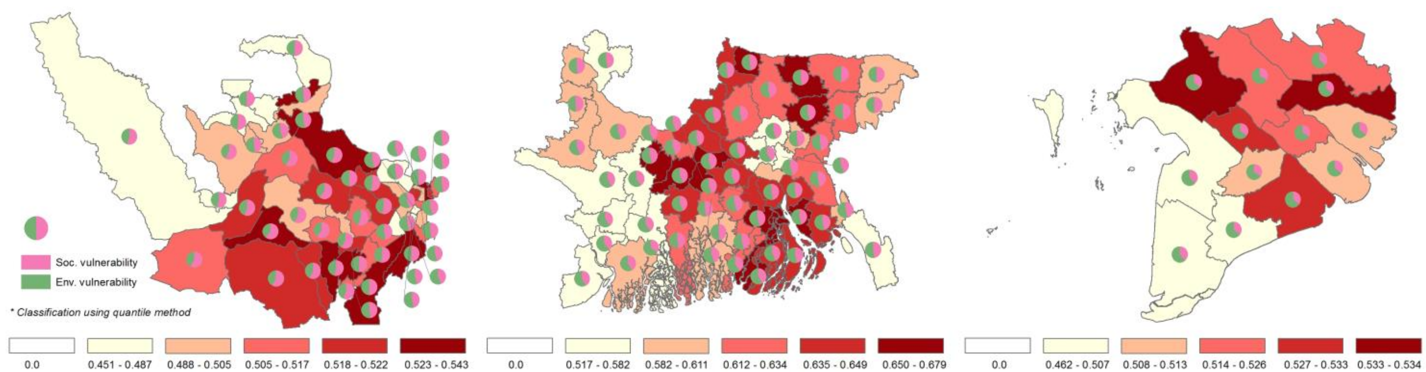
Source: Hagenlocher et al. (forthcoming)

Global Delta Risk Index (GDRI) – Results: multi-hazard vulnerability of the SES

Across delta comparison



Variability within delta

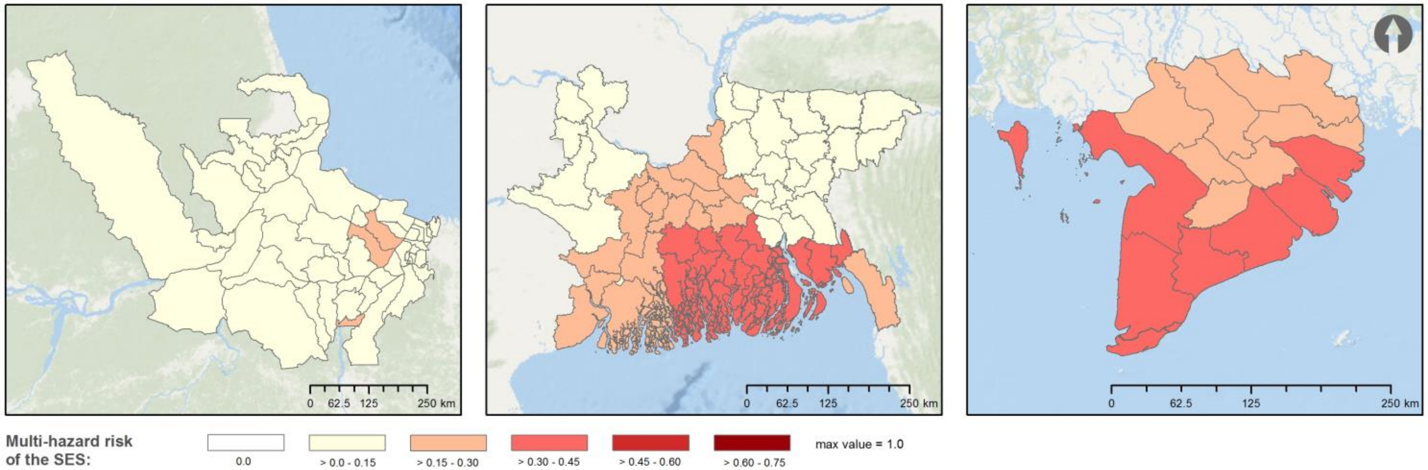


EQUAL WEIGHTS!

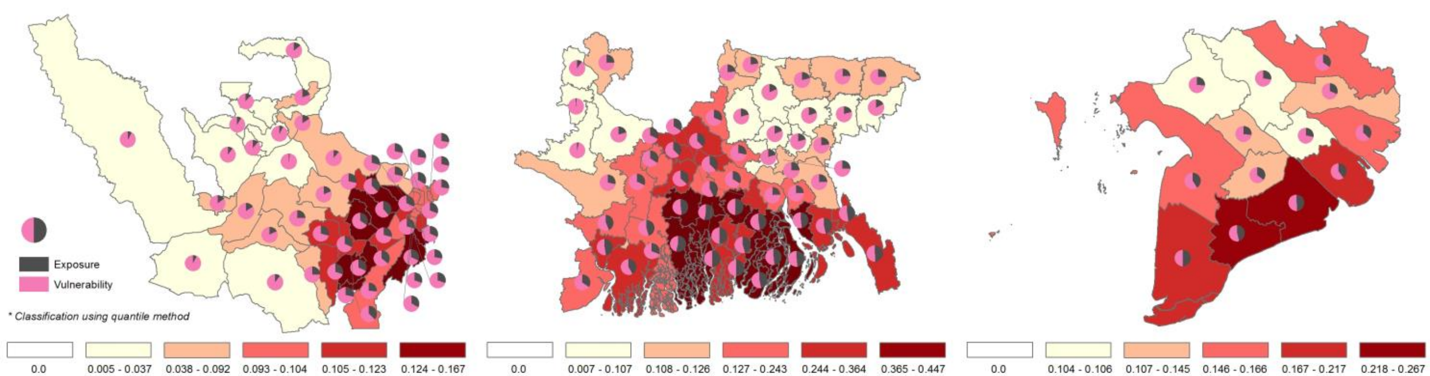
Source: Hagenlocher et al. (forthcoming)

Global Delta Risk Index (GDRI) – Results: multi-hazard risk of the SES

Across delta comparison



Variability within delta



Source: Hagenlocher et al. (forthcoming)

Global Delta Risk Index (GDRI) – Policy messages

Exposure (multi-hazard, SES)				
	Min	Max	Mean	Std
Amazon delta	0.01	0.32	**0.17**	0.08
GBM delta	0.01	0.72	**0.34**	0.19
Mekong delta	0.19	0.50	**0.31**	0.11

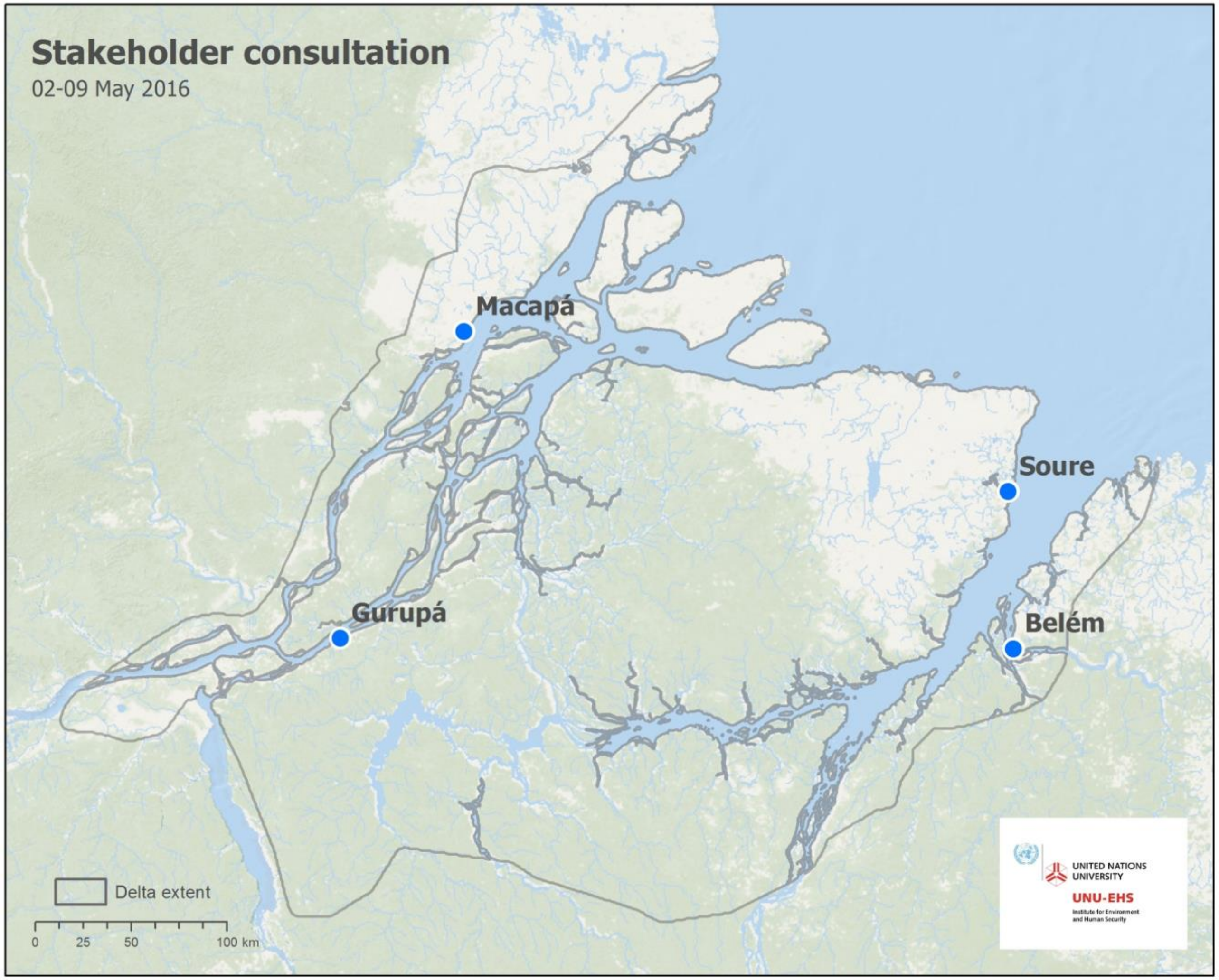
Vulnerability (multi-hazard, SES)				
	Min	Max	Mean	Std
Amazon delta	0.45	0.54	**0.51**	0.02
GBM delta	0.52	0.68	**0.62**	0.04
Mekong delta	0.46	0.53	**0.51**	0.02

Risk (multi-hazard, SES)				
	Min	Max	Mean	Std
Amazon delta	0.01	0.17	**0.09**	0.04
GBM delta	0.01	0.45	**0.21**	0.12
Mekong delta	0.09	0.24	**0.14**	0.05

- **Exposure, vulnerability** and **risk** and are **highest in the GBM Delta** but also the spatial variability
- In case exposure would increase with e.g. climate change, the **risk could dramatically increase** in the **Amazon**

Source: Hagenlocher et al. (forthcoming)

Global Delta Risk Index (GDRI) – Feedback on indicators / results








Source: Hagenlocher et al. (forthcoming)

Thank You!

Fabrice.Renaud@glasgow.ac.uk