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"Advancing human security through knowledge-based approaches to reducing vulnerability and environmental risks"

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Vulnerability of Coupled Socio-Ecological Systems Exposed to Hydro-Climatic Hazards

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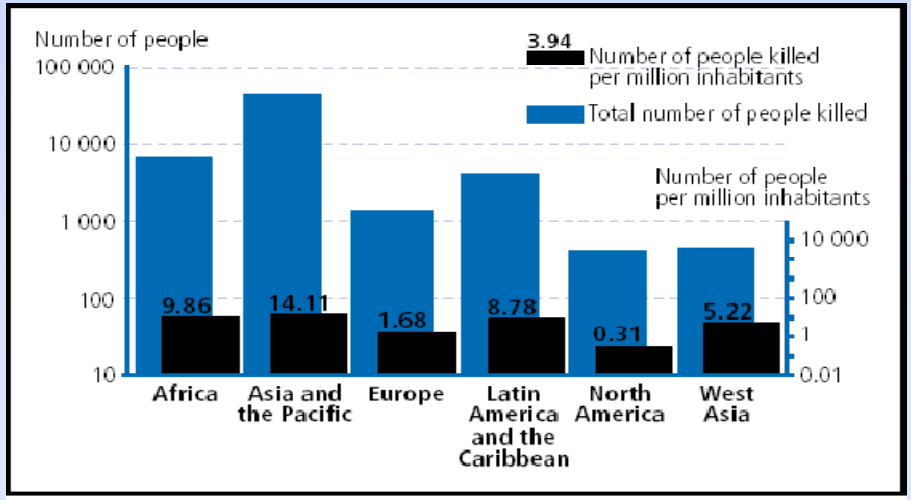
Outline

1. Introduction: Example – Climate Change, Droughts and Vulnerability
2. Links between ecosystems and DRR
3. Vulnerability of Coupled Systems: Example of floods in Germany
4. Vulnerability of Coupled Systems: Example of droughts and groundwater in I.R. Iran
5. Conclusions

Droughts Impacts in Africa

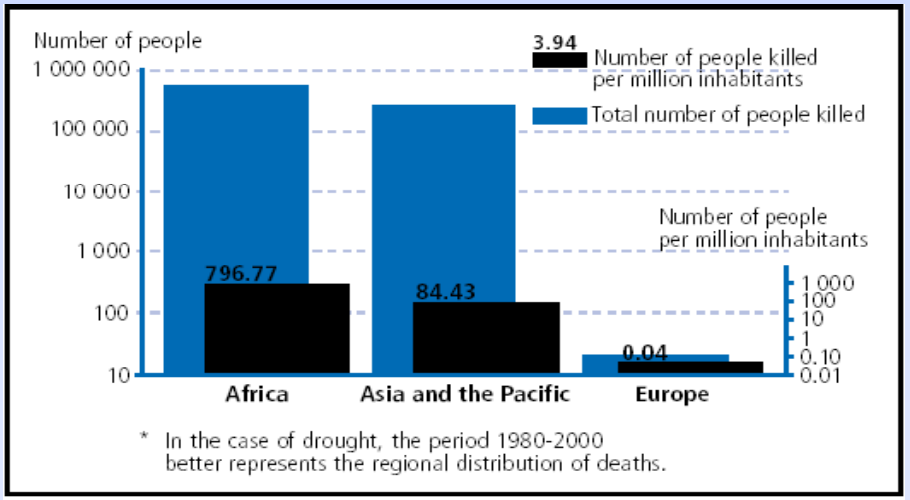
Source: UNDP, 2004, Reducing Disaster Risk

Floods (1990-99)



Source: EM-DAT: The OFDA/CRED International Disaster Database

Droughts (1980-2000)



Source: EM-DAT: The OFDA/CRED International Disaster Database

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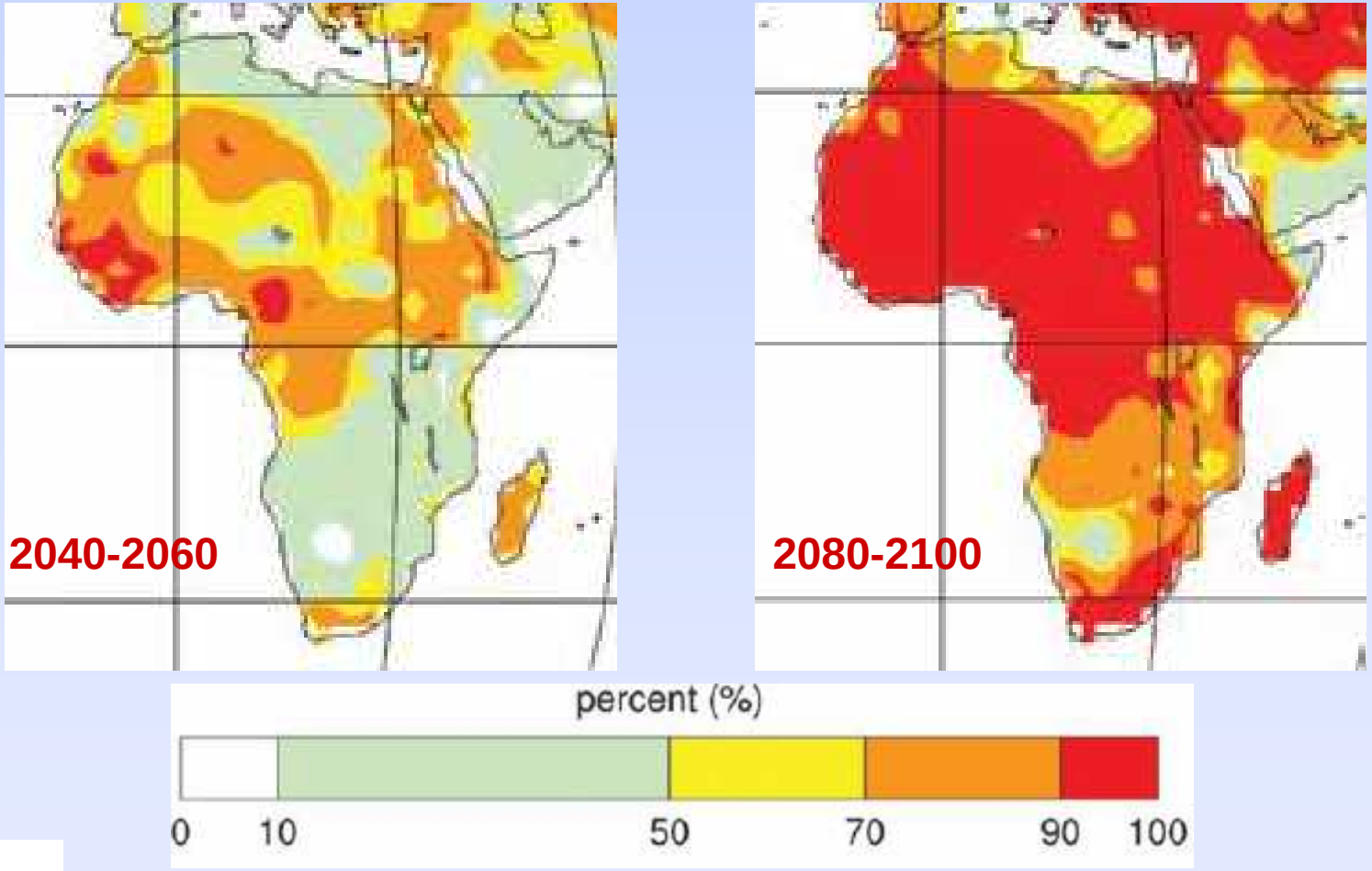
Potential Effects of Climate Change in Africa

Boko et al. (2007): IPCC Report

- Africa is the most vulnerable continent to climate change with low adaptation capacities
- In rural areas, existing adaptation strategies may not be sufficient or adapted to deal with the future effects of climate change
- Agricultural productivity could be negatively affected with consequences in terms of food security
- Increased risk of flooding, including in coastal areas
- Important negative effects are expected on water resources
- Impacts on ecosystems
- Impacts on human health

Climate Change - Likelihood that future summer average temperatures exceed highest summer temperatures observed on record

Battisti et Naylor (2009): Historical warnings of future food insecurtiy with unprecedented historical heat. Science 323: 240-244



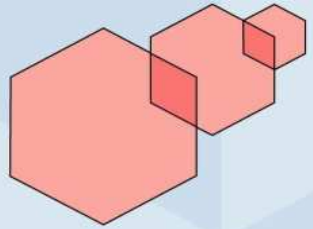
Vulnerability and Climate Change

[1]Barnett & Adger (2007): Climate change, human security and violent conflicts. Political Geography 36:639-655

- Vulnerability of people and communities with respect to climate change depends on[1]:
  - Their dependence with respect to ecosystem services
  - The impact of climate change on these ecosystems
  - Adaptation capacities of the communities

- Capacity to adapt reduces vulnerability:
  - Societies adapt constantly
  - However, what are their limits when considering climate change?
  - Migration is a type of adaptation

Environment and Disaster Risk Reduction

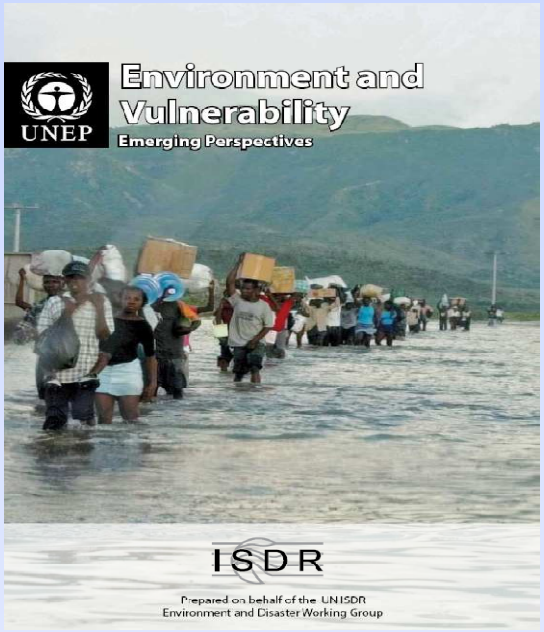


UNEP. 2007. *Environment and vulnerability. Emerging perspectives*. Results from the UN ISDR Working Group on Environment and Disasters. UNEP, 32p.

- Hyogo framework for action 2005-2015 – "Building the resilience of nations & communities to disasters":
  - Hyogo framework for action → Reducing the underlying risk factors
    - Encourage sustainable use and management of ecosystems
    - Integrated environmental management
    - Identification of climate-related risks; specific risk reduction measures
  - Connections between environment and disasters:
    - Degraded ecosystems reduce community resilience
    - Healthy ecosystems often provide natural defences
    - Environmental degradation is a hazard in itself
  - UN/ISDR Partnership on Environment and Disaster Risk Reduction (PEDRR)

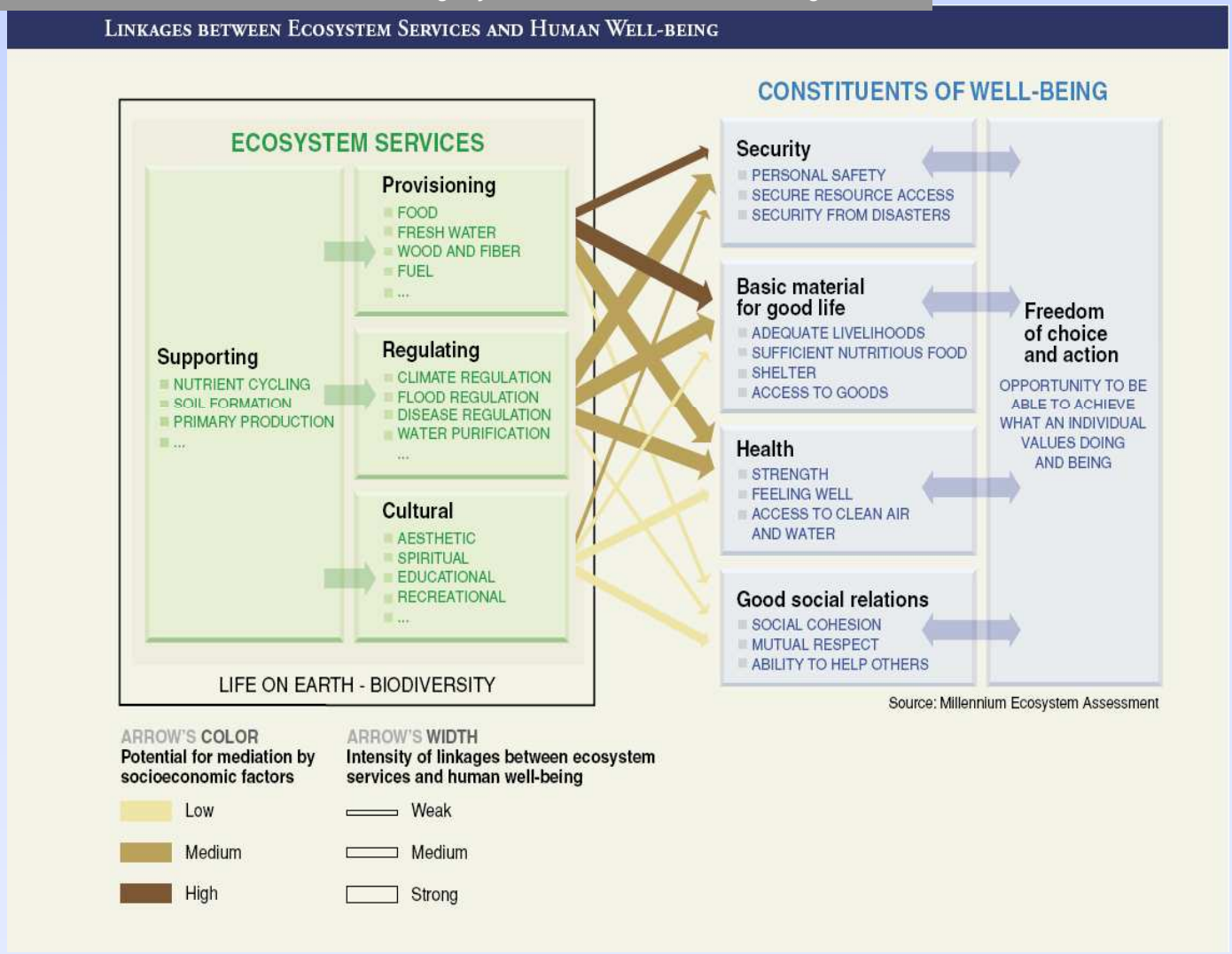
Examples of links between ecosystems and disasters

- Better use of environmental management to reduce disaster risk:
  - Engage environmental managers fully in national disaster risk management mechanisms
  - Assess environmental change as a parameter of risk
  - Engage the scientific community to promote environmental research and innovation
  - Protect and value ecosystem services
  - Consider environmental technologies and designs for structural defences
  - Integrate environmental and disaster risk considerations in spatial planning
  - Prepare for environmental emergencies
  - Strengthen capacities for environmental recovery



The Notion of Ecosystem Services

Source: Millennium Ecosystem Assessment. 2005. *Human Well-being: Synthesis*. Island Press, Washington, DC



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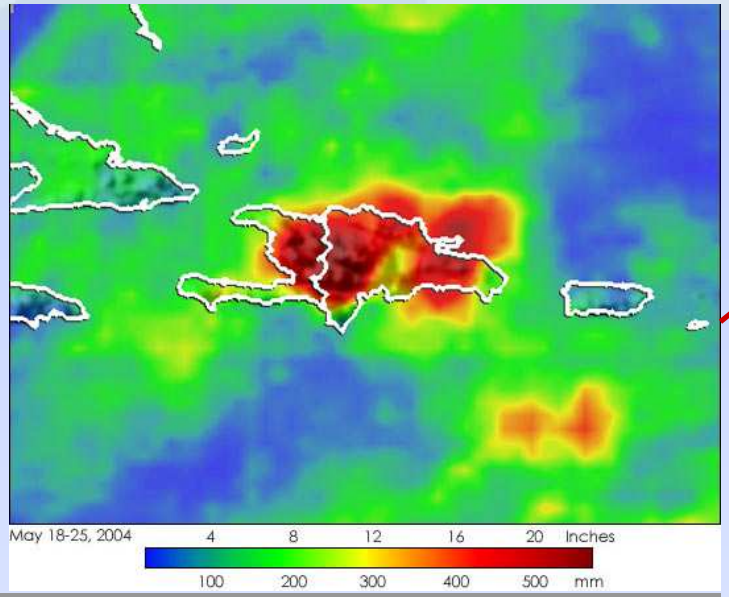
State of our Ecosystems

Source: MA, 2005

- We are living beyond our means
- Approx. 60% of the ecosystem services examined are being degraded or used unsustainably, including fresh water, capture fisheries, air and water purification, and the regulation of regional and local climate, natural hazards, and pests.
- Intense vulnerability of the 2 billion people living in dry regions to the loss of ecosystem services, including water supply
- Growing threat to ecosystems from climate change and nutrient pollution
- Impact on the achievement of the Millennium Development Goals

Deforestation – Floods: Haiti in 2004



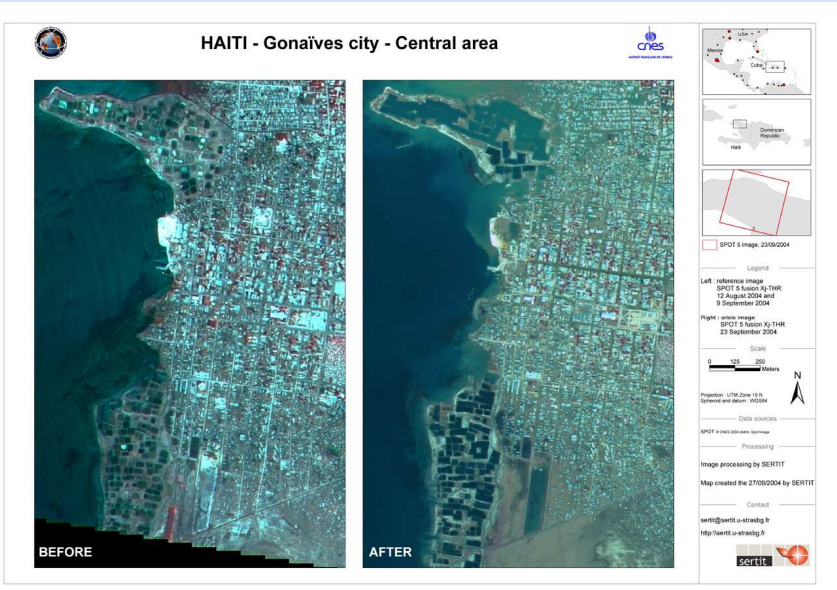
NASA: http://earthobservatory.nasa.gov/NaturalHazards/natural_hazards_v2.php3?img_id=12156

May 2004 floods:

Rank 3rd in Dominican Republic with 688 casualties

Rank 3rd in Haiti with 2665 casualties

(source: EM-DAT)



Tropical Storm Jeanne (September 2004): big differential of impacts between two countries

http://unosat.web.cern.ch/unosat/freeproducts/haiti/P24_Haiti_gonaives_bitemp_couleur321_5k_lowres.jpg

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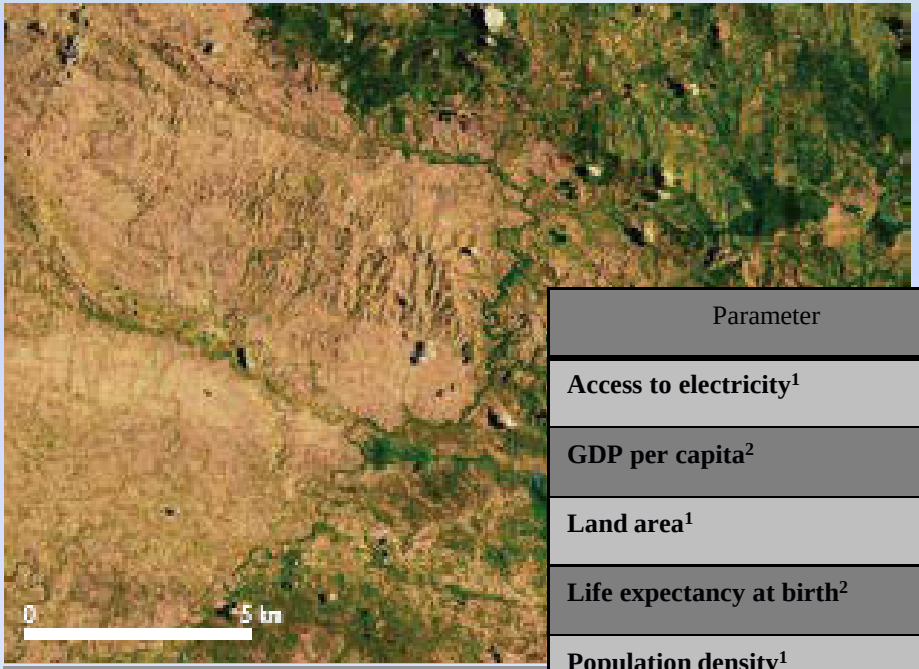
Deforestation – Floods: Haiti



NASA: http://visibleearth.nasa.gov/vie

Deforestation alone? Deforestation and other factors? Need to be careful to ascribe "straightforward" causal relations for extreme events as could limit depth of analysis

Parameter	Year	Unit	Haiti	Domin. Rep.
Access to electricity[1]	1994-96	%	31,0	66,8
GDP per capita[2]	2004	US $	1.610	6.640
Land area[1]	-	km^2	27.560	48.380
Life expectancy at birth[2]	2004	years	52	67
Population density[1]	2000	inh km^{-2}	295	173
Population growth rate[2]	2004	%	1,9	1,5
Proportion of irrigated land[1]	1998	%	17,0	8,0
Proportion of undernourished[1]	1997-99	%	56,0	25,0
Water quality indicator[1]	-	Rank	101 of 122	76 of 122

UNESCO. 2003. Water for people, water for life. UNESCO-WAPP, Paris.
UNESCO. 2004. Country profile: Haiti

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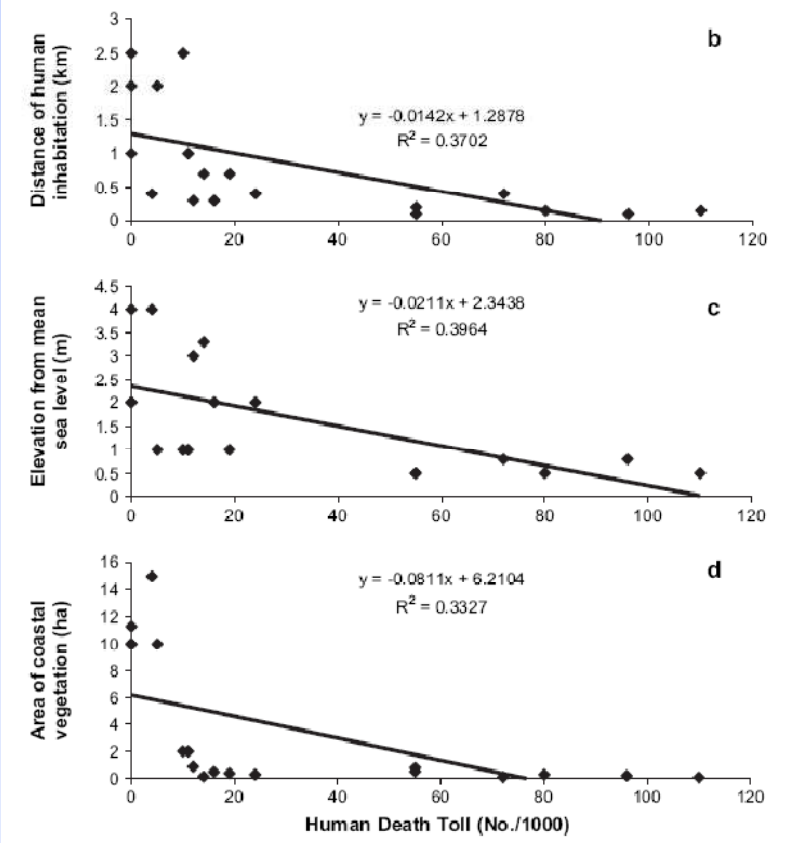
Did Natural Features Limit the Impact of the 2004 Tsunami?

Kathiresan & Rajendra. Estuarine, Coastal & Shelf Sci 65:601-606



Kerr et al. Estuarine, Coastal & Shelf Sci 67:539-541

- Performed stepwise regression analysis on data from Kathiresan
- Conclusion: vegetation area contributes little to explanation of variation in mortality

Kathiresan & Rajendra. Estuarine, Coastal & Shelf Sci 67:542

- Did not really address the statistical questions put forward by Kerr et al. but stood by their conclusions

Vermaat & Thampanya. Estuarine, Coastal & Shelf Sci 69:1-3

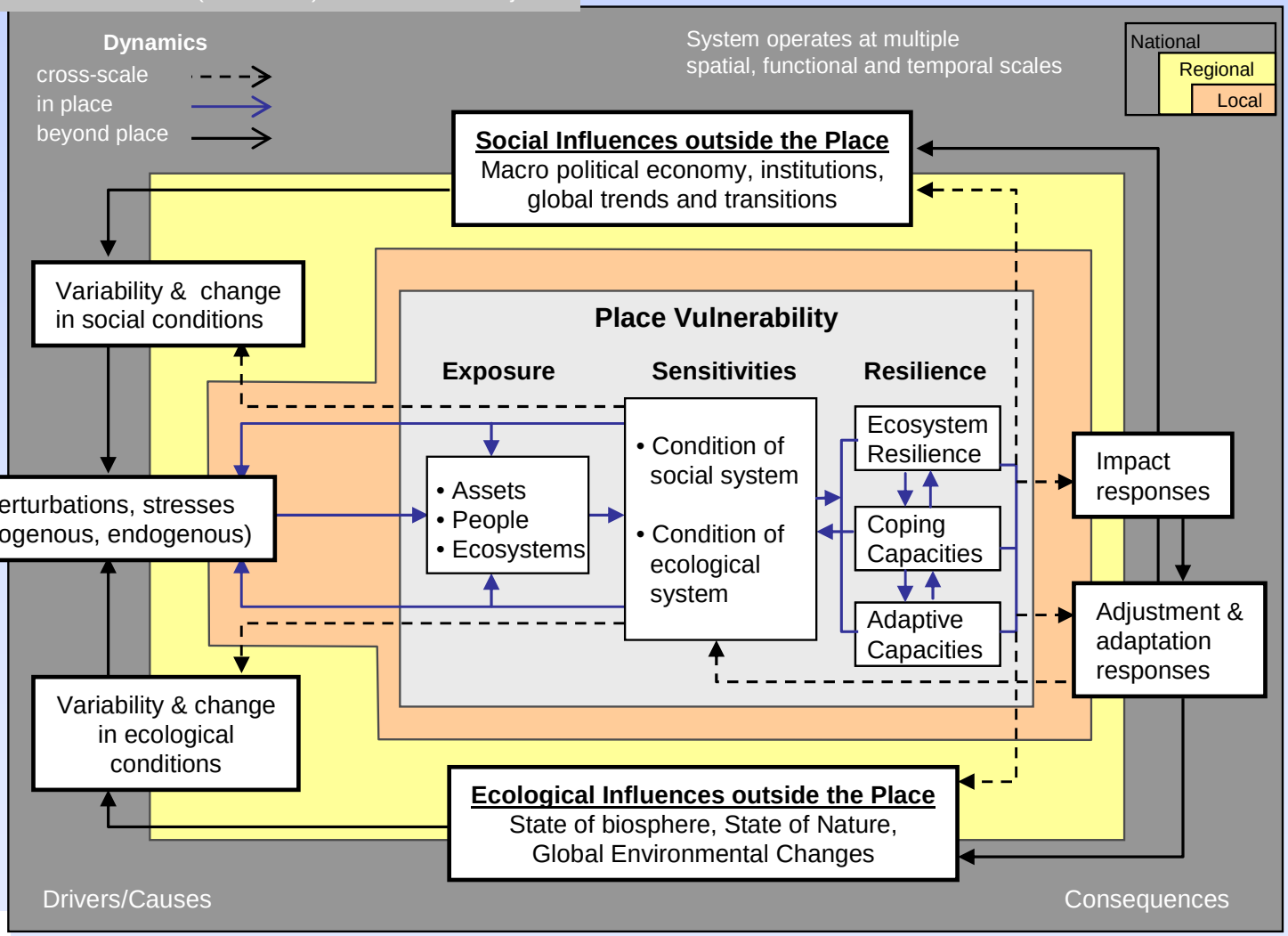
- Performed an ANOVA with distance and elevation as covariates
- Conclusion: interpretation by Kathiresan and Rajendra holds

Vermaat & Thampanya. Estuarine, Coastal & Shelf Sci (in press)

- Erratum→ Mistake in stats: mortality and property loss were not less behind mangroves

Example of Floods in Germany Conceptual Framework

Source: PhD research of Marion Damm (UNU-EHS) – DISFLOOD Project



Modified version from Turner et al. (2003)

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Indicators

Source: PhD research of Marion Damm (UNU-EHS) – DISFLOOD Project

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)

Resilience (R)

- 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)

Resilience (R)

- 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)

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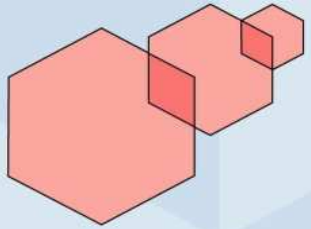
Weights and Aggregation

Source: PhD research of Marion Damm (UNU-EHS) – DISFLOOD Project



Agricultural Sector

$$CI_d = \sum_{q=1}^{Q} w_q I$$

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)

Resilience (R)

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- GDP per capita FS (c_2)
- side business income (c_3)
- % organic farms (a_1)
- % protected areas (a_2)

CI Vulnerability

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)

Resilience (R)

- 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)

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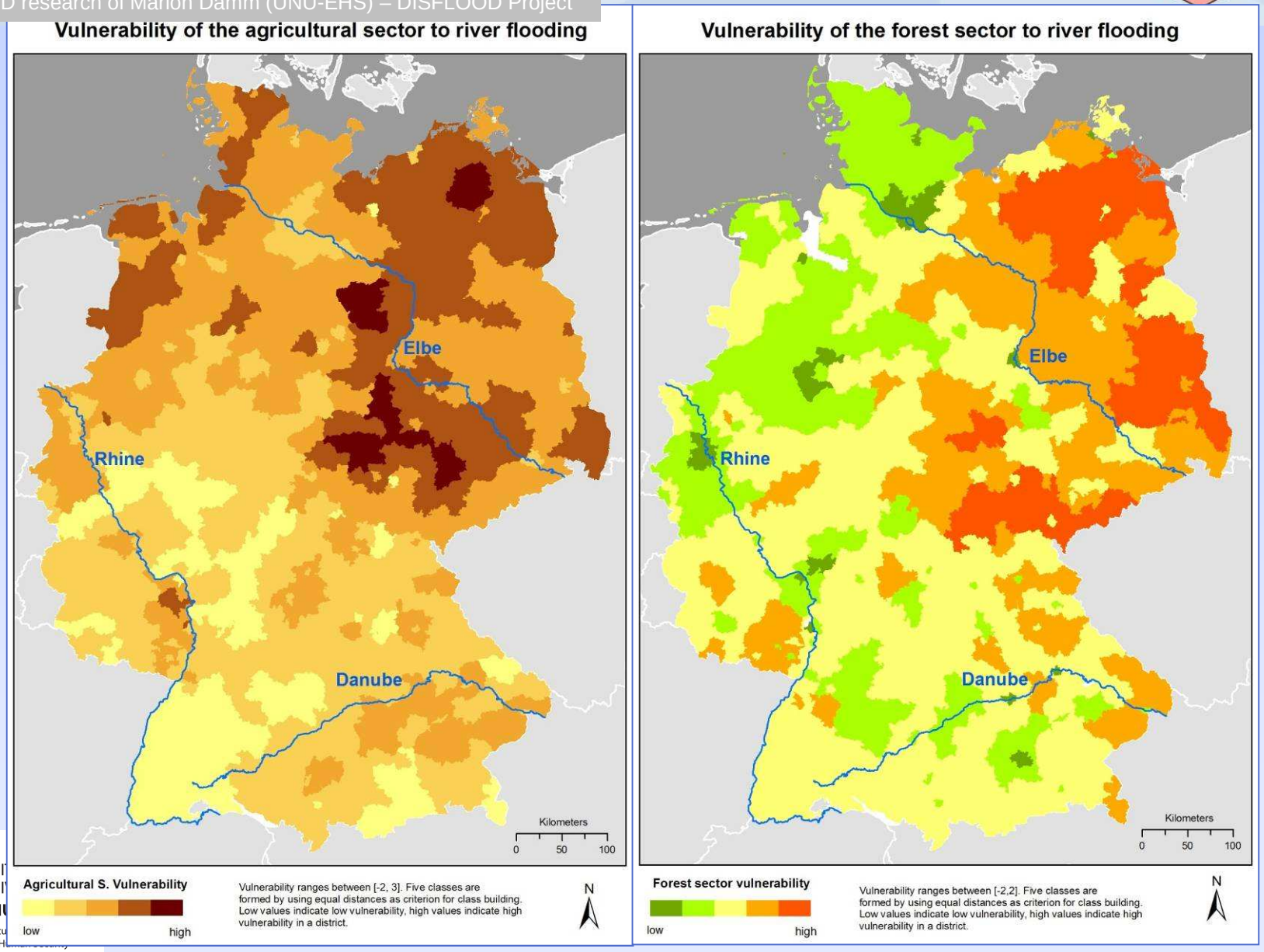
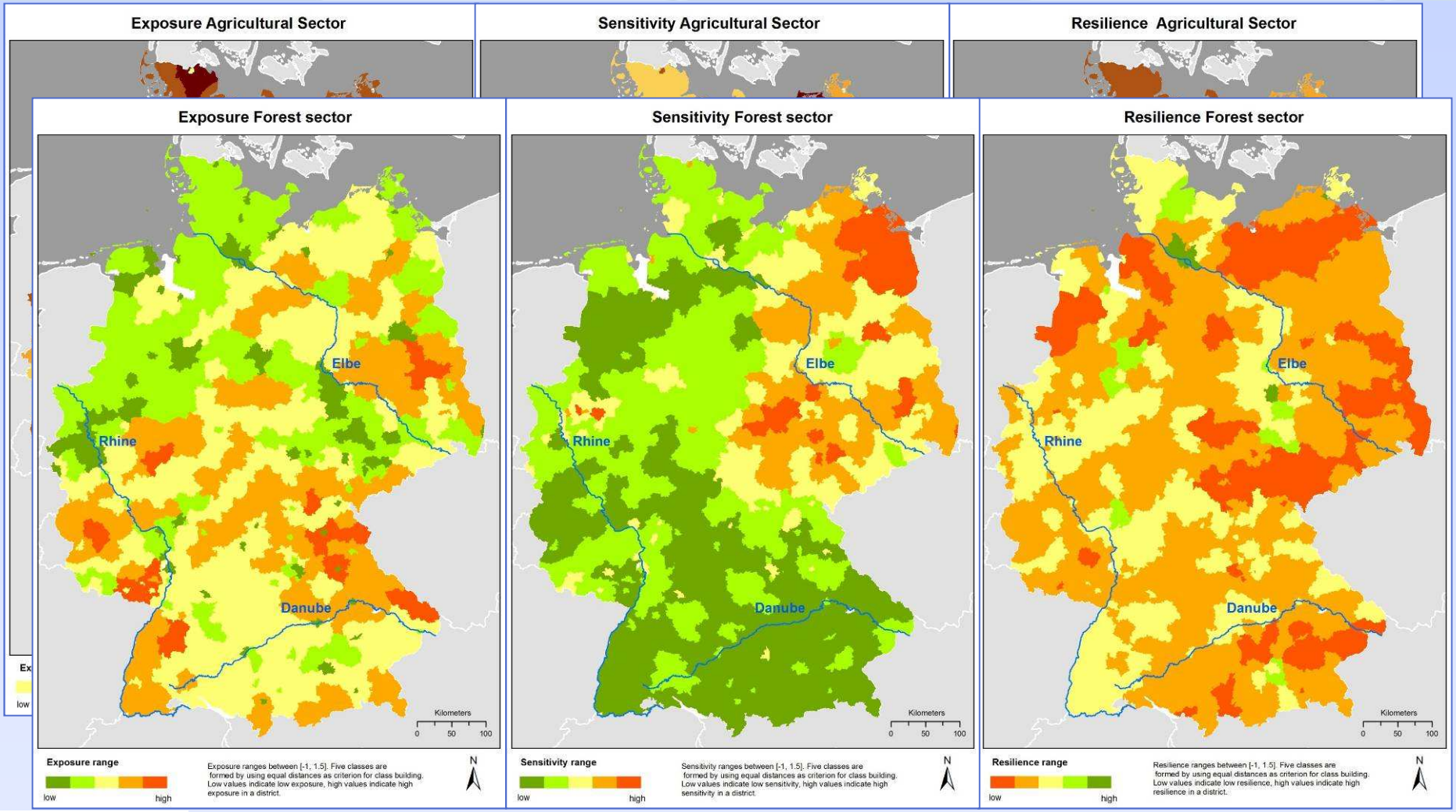
Vulnerability Maps

Source: PhD research of Marion Damm (UNU-EHS) – DISFLOOD Project

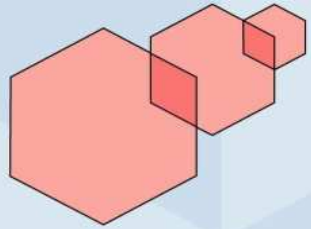


Vulnerability Maps

Source: PhD research of Marion Damm (UNU-EHS) – DISFLOOD Project



Example of Droughts and Groundwater GWAHS-CS - Objectives



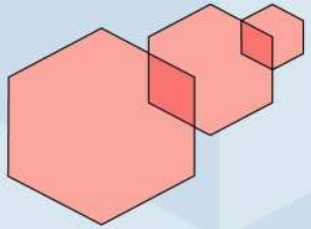
To address (1) the threats to human security and well-being currently posed by water scarcity and water quality degradation and (2) the role of groundwater management and protection in alleviating such threats.

- Adaptation of existing vulnerability and resilience assessment frameworks
- Development of socio-environmental indicators of vulnerability and resilience
- Vulnerability and resilience assessment in the four case study areas

- Groundwater degradation as:
  - A hazard to the communities
  - An element of vulnerability when communities face other hazards

- Coupled socio-ecological system is the element of analysis

GWAHS-CS – Steps



- Understanding of hydrogeology settings at various scales
- Status of groundwater quality
- Groundwater as an ecosystem service
  - Ecosystem maintenance
  - Community reliance
- Social and economic assessments
  - Household surveys – participatory investigations with communities
  - Vulnerability of various economic sectors
  - Statistical data at various scales
  - Policies related to groundwater
  - Discussions with stakeholders

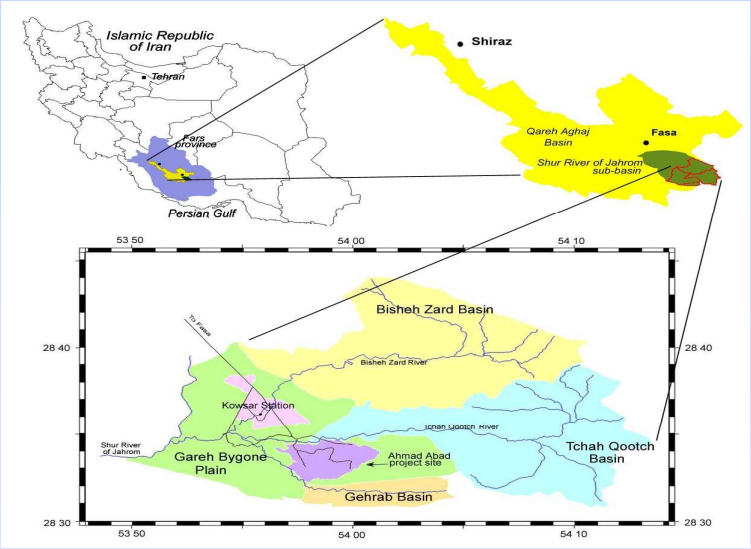
Selected Indicators

Hazard	Exposure	Sensitivity	Resilience
GW quantity	Dependence of pop on GW	Groundwater (DRASTIC)	Access to alternative sources of water
GW quality	Dependence of eco sectors on GW	Pop density	Access to knowledge of GW deg processes
	GW supporting ecosystems	Household structure	Access to info on GW management
	Well density	Education level	Institutions related to GW management
		Occupation	Legislation
		Ethnicity	GW infrastructure
		Household income	Out-migration
		Access to savings / credit	Participation in social networks
		Years settled in the area	
		Type of house	
		Type of provider system	

I.R. Iran - Gareh-Bygone Plain

Credit: Dr. Mehrdad Mohammadnia

- 200 km south-east of Shiraz, within 192 km^2 Bisheh Zard Basin
- Low and highly variable rainfall
- Aquifers tapped for irrigation and drinking water in rural and urban areas
- High concentration of nitrates
- Artifical recharge



Groundwater Balance

Credit: Dr. Mehrdad Mohammadnia

Total alluvial aquifer input	**5 Mm^3 from upstream watershed (Nowbadegan and Fasa) + Agricultural recycling water = 33.96 Mm^3**
Total alluvial aquifer output: production wells discharge	**90.42 Mm^3**
Alluvial aquifer balance	**-56.46 Mm^3**
Total Karstic aquifers' input	**39.4 Mm^3**
Total Karstic aquifers' output	**29.15 Mm^3**
Karstic aquifers' balance	**+10.25 Mm^3**

Main Threats to the Aquifers

Credit: Dr. Mehrdad Mohammadnia

Main threats	**Intrusion of saline water following groundwater overexploitation (non-point source)**
	Pollution due to farm mismanagement and overusing chemical fertilizers (non-point source)
	Geologic nitrate through surface and groundwater flows (non-point source)
	Latrines (point source)
	Animal husbandry (point source)
	Outward migration
	Urbanization
	Pesticides (non-point source)

Dependency on Groundwater – Hazard & Sensitivity

Credit: Dr Gholamreza Chabokrow

- Dependence on GW for domestic use: 100%
- Dependence of major economic sector on groundwater: Agriculture as the main economic sector (Farming, animal husbandry and horticulture): 96%

Name of villages	Occupation of men
Sennan	Agriculture- Animal husbandry
Miandeh	Agriculture-driver-unskilled worker
Nasir-Abad	Agriculture- Animal husbandry
Bisheh-Zard	Agriculture- Animal husbandry
Chah-Dowlat	Agriculture- Animal husbandry
Fedeshkouyeh	Agriculture- Animal husbandry
Zahed-Shahr	Agriculture- Animal husbandry
Rahim-Abad	Agriculture- Animal husbandry

Name of villages	Occupation of women
Sennan	Carpet weaving
Miandeh	Carpet weaving
Nasir-Abad	Unskilled worker in farm
Bisheh-Zard	Carpet weaving- farm worker
Chah-Dowlat	Carpet weaving- farm worker
Fedeshkouyeh	Carpet weaving- farm worker
Zahed-Shahr	Carpet weaving
Rahim-Abad	Carpet weaving- farm worker

Understanding Elements of Resilience

Credit: Dr Gholamreza Chabokrow

Name of villages	Access to information about groundwater degradation process					
	Yes		No		Total	
	Number	Percent	Number	Percent	Number	Percent
Sennan	22	64.7	12	35.3	34	100
Miandeh	39	59	27	41	66	100
Nasir-Abad	4	22.2	14	77.8	18	100
Bisheh-Zard	1	33.3	2	66.7	3	100
Chah-Dowlat	-	-	3	100	3	100
Fedeshkouyeh	56	80	14	20	70	100
Zahed-Shahr	100	66.7	50	33.3	150	100
Rahim-Abad	2	50	2	50	4	100

Name of villages	Ways of access to information									
	T.V		Radio		neighbor		No access		Total	
	No	%	No	%	No	%	No	%	No	%
Sennan	14	41.2	2	5.9	6	17.6	12	35.3	34	100
Miandeh	30	45.4	5	7.6	4	6	27	40.9	66	100
Nasir-Abad	3	16.7	1	5.5	-	-	14	77.8	18	100
Bisheh-Zard	1	33.3	-	-	-	-	2	66.7	3	100
Chah-Dowlat	-	-	-	-	-	-	3	100	3	100
Fedeshkouyeh	54	77.1	-	-	2	2.9	14	20	70	100
Zahed-Shahr	51	34	29	19.3	20	13.3	50	33.4	150	100
Rahim-Abad	2	50	-	-	-		2	50	4	100
Total	155	44.5	37	10.6	32	9.2	124	35.6	348	100

Name of villages	Type of decision making about groundwater degradation process									
	Change of type of product		Reduce of cultivated land		Other jobs		migration		Total	
	No	%	No	%	No	%	No	%	No	%
Sennan	15	44.1	9	26.5	6	17.6	4	11.8	34	100
Miandeh	13	19.7	30	45.4	15	22.7	8	12.1	66	100
Nasir-Abad	5	27.7	7	38.9	3	16.7	3	16.7	18	100
Bisheh-Zard	2	66.7	1	33.3	-	-	-	-	3	100
Chah-Dowlat	-	-	3	100	-	-	-	-	3	100
Fedeshkouyeh	16	22.8	19	27.1	17	24.3	18	25.7	70	100
Zahed-Shahr	41	27.3	102	68	4	2.7	3	2	150	100
Rahim-Abad	2	50	2	50	-	-	-	-	4	100
Total	94	27	173	49.8	45	12.9	36	10.3	348	100

Name of villages	Member of a society or group					
	Yes		No		Total	
	Number	Percent	Number	Percent	Number	Percent
Sennan	-	-	34	100	34	100
Miandeh	7	10.6	59	89.4	66	100
Nasir-Abad	14	77.8	4	22.2	18	100
Bisheh-Zard	-	-	3	100	3	100
Chah-Dowlat	1	33.3	2	66.7	3	100
Fedeshkouyeh	14	20	56	80	70	100
Zahed-Shahr	15	10	135	90	150	100
Rahim-Abad	1	25	3	75	4	100
Total	52	15	296	85	348	100

Dealing with the Problems



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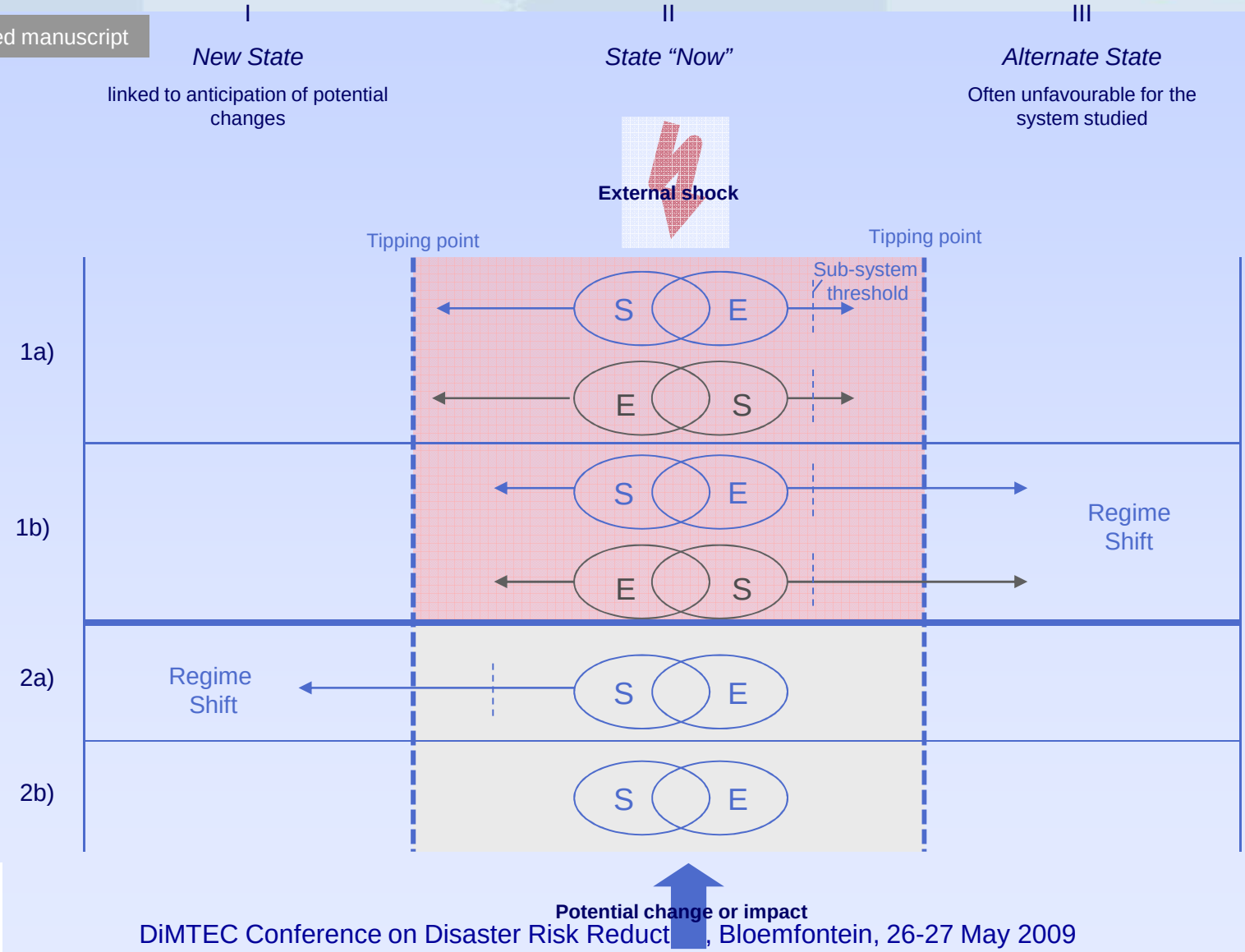
Change of States in Coupled Socio-Ecological Systems

Renaud et al. submitted manuscript



Conclusions

- Coupled systems at the centre of the analysis:
  - High complexity in terms of agents, scales and interactions
  - Indicators is only one way to assess vulnerability. Visualisation of certain key factors via GIS is another possibility
- Identifying thresholds is difficult but
  - Understanding components of the coupled systems might be sufficient to determine their resilience
  - Potential pre-emptive adaptation strategies can be identified
- The outcome of the analyses has to provide useful information to decision-makers
  - The methodology has to be designed to serve this purpose

Thank You
Merci

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