Geospatial Indicators of Global Change

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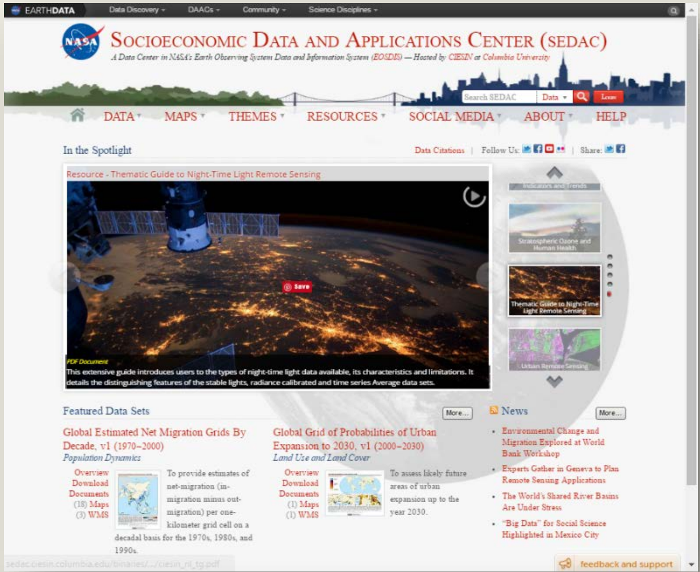
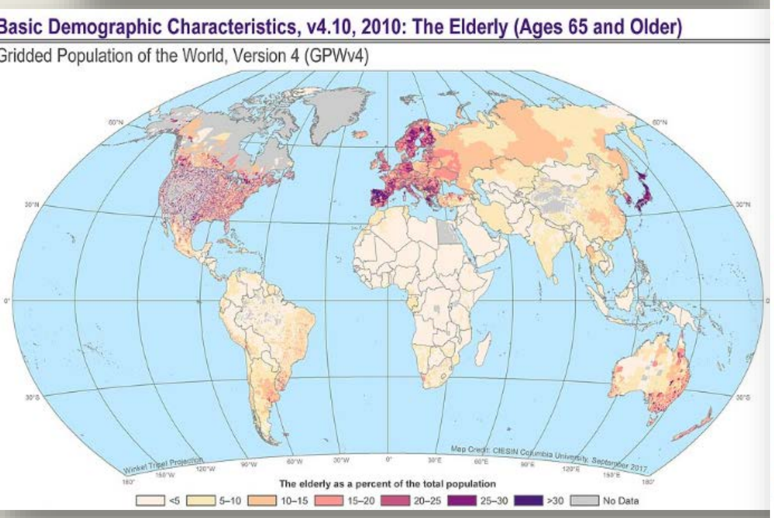
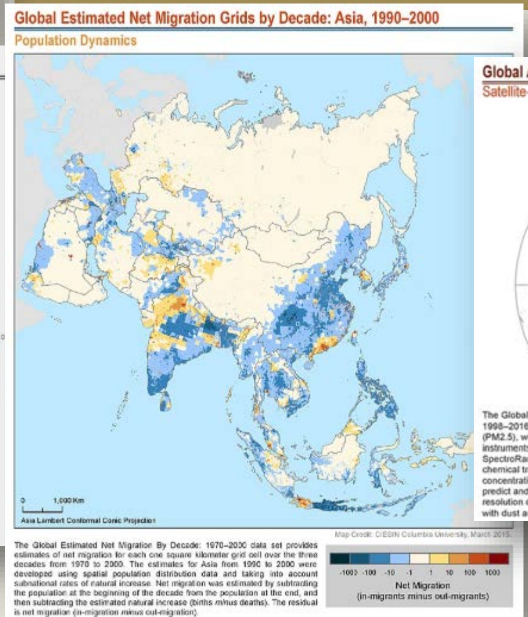
PERN

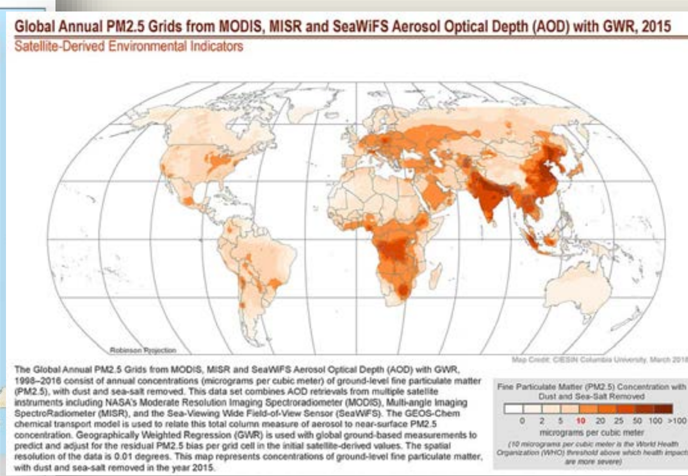
NASA Socioeconomic Data and Applications Center (SEDAC)



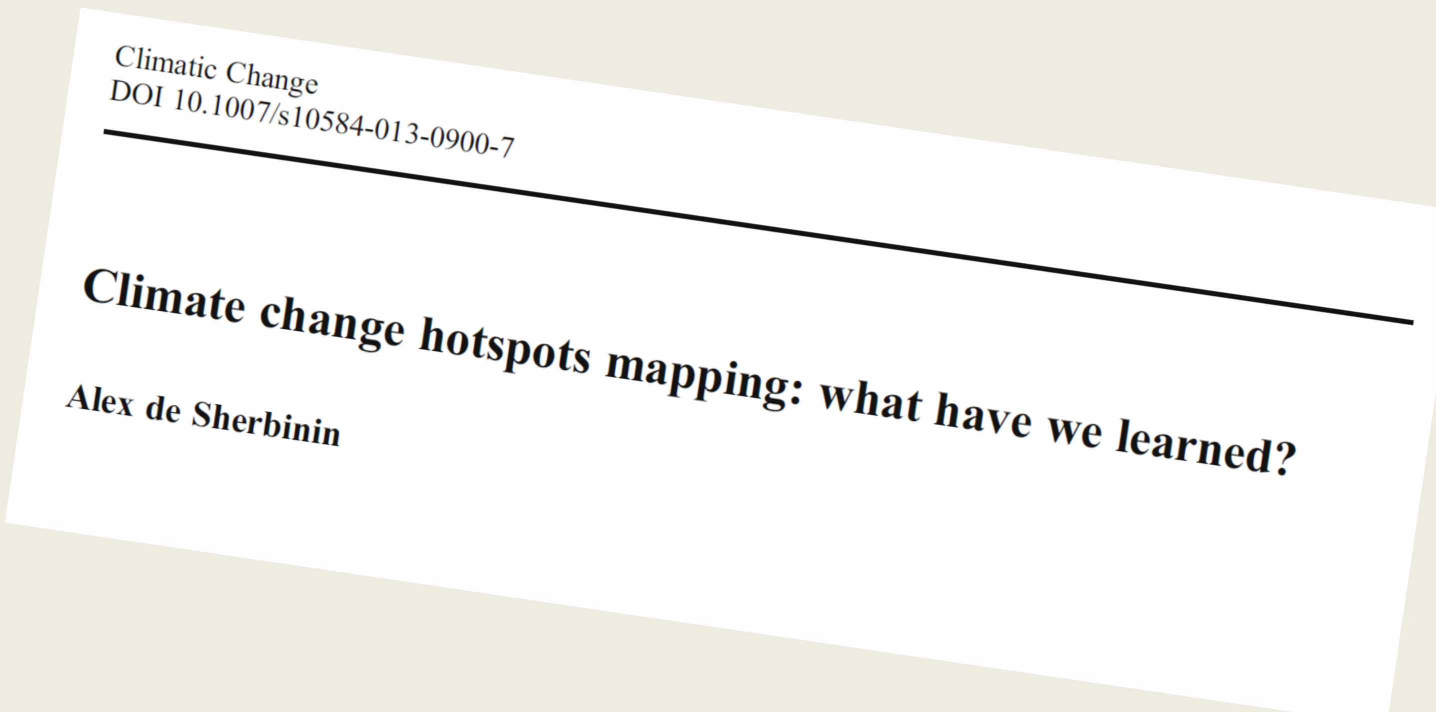
- SEDAC data provide the ground level context for NASA's remote sensing data
- Focus on human dimensions of environmental change
- Big emphasis on data integration
- Direct support to scientists, applied and operational users, decision makers, and policy communities
- Strong links to geospatial data community







Climate Change Hotspots



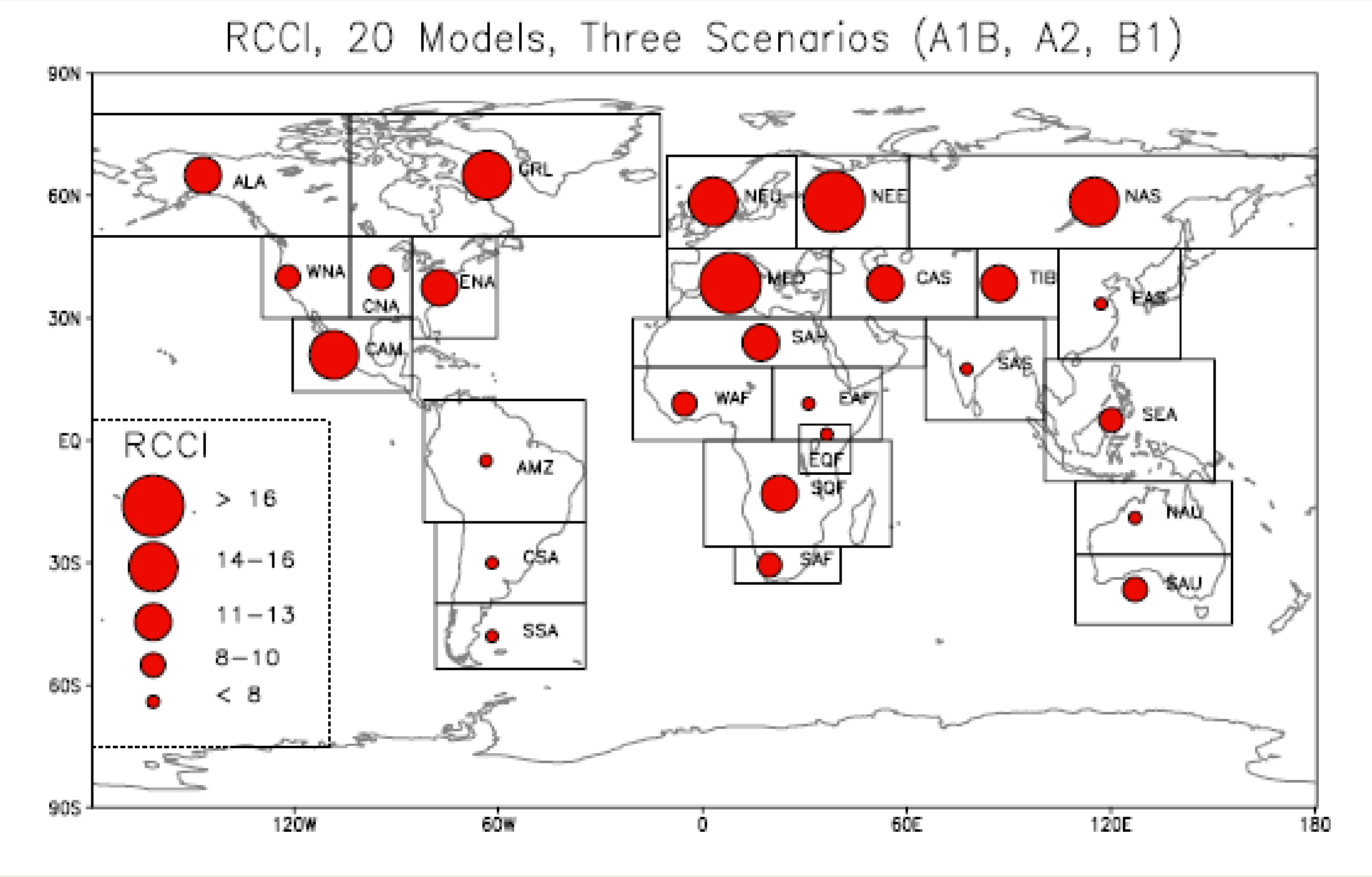
Climatic Change
DOI 10.1007/s10584-013-0900-7

Climate change hotspots mapping: what have we learned?

Alex de Sherbinin

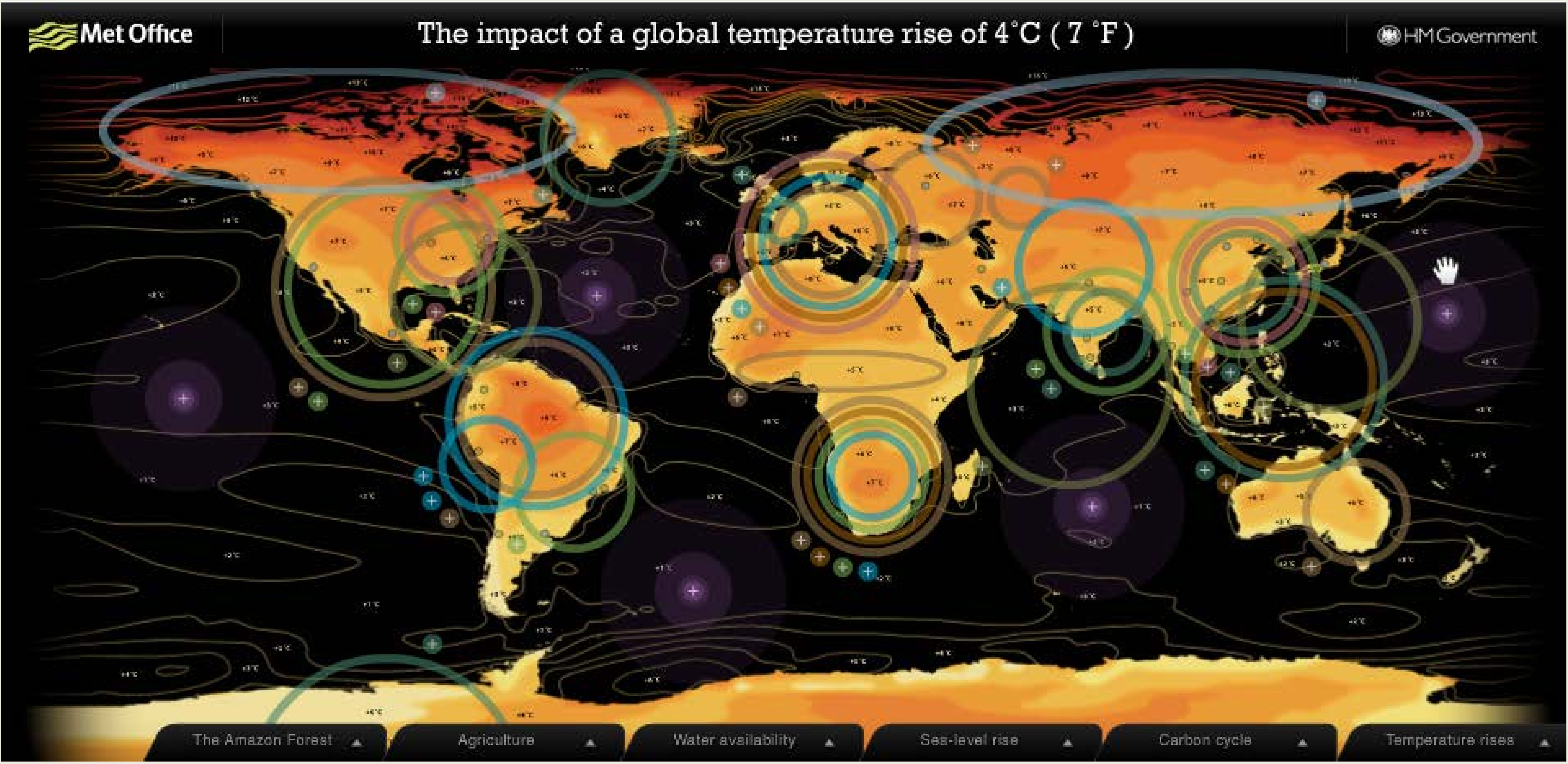
Regional Climate Change Index

- A relative indicator of change in precip and temp from 1960-79 to 2080-99
- Based on multi-model ensembles for A1B, B1, and A2 scenarios



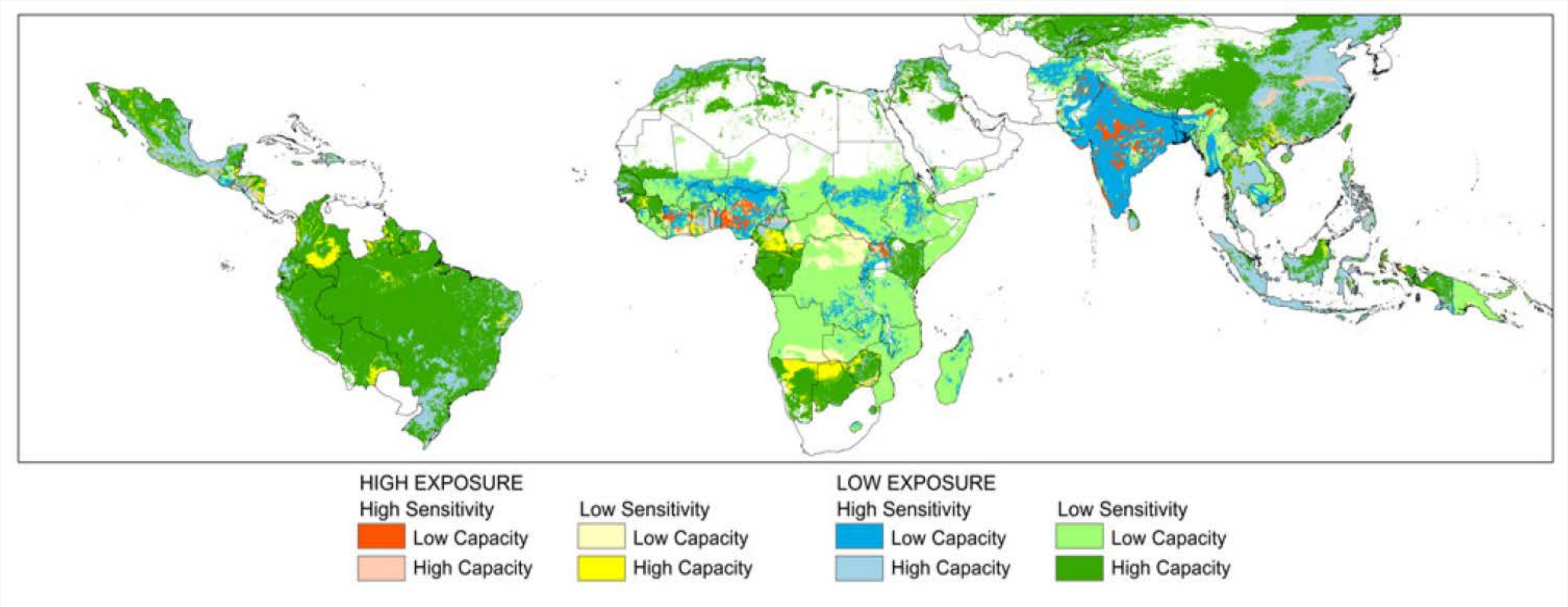
Source: Giorgi, F. 2006. Climate change hot-spots, *Geophysical Research Letters*, 33, L08707

UK Met Office: Temperature Focus



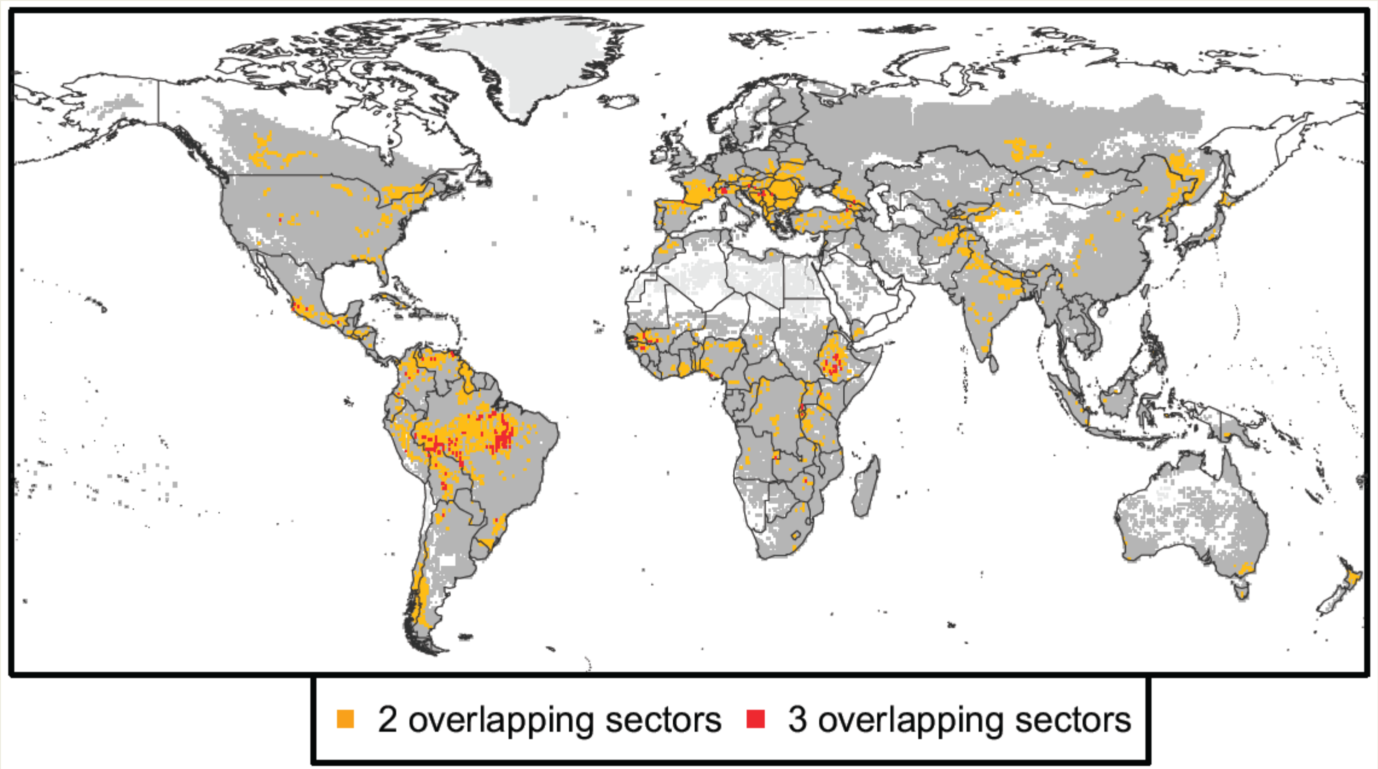
Source: UK Met Office, http://www.metoffice.gov.uk/climate-change/guide/impacts/high-end/map

Vulnerability to maximum daily growing season temperature exceeding 30ºC



Source: Ericksen, P., P. Thornton, A. Notenbaert, L. Cramer, P. Jones, M. Herrero. 2011. *Mapping hotspots of climate change and food insecurity in the global tropics*. CCAFS Report no. 5. CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS). Copenhagen, Denmark

Multisectoral Hotspots of Impacts

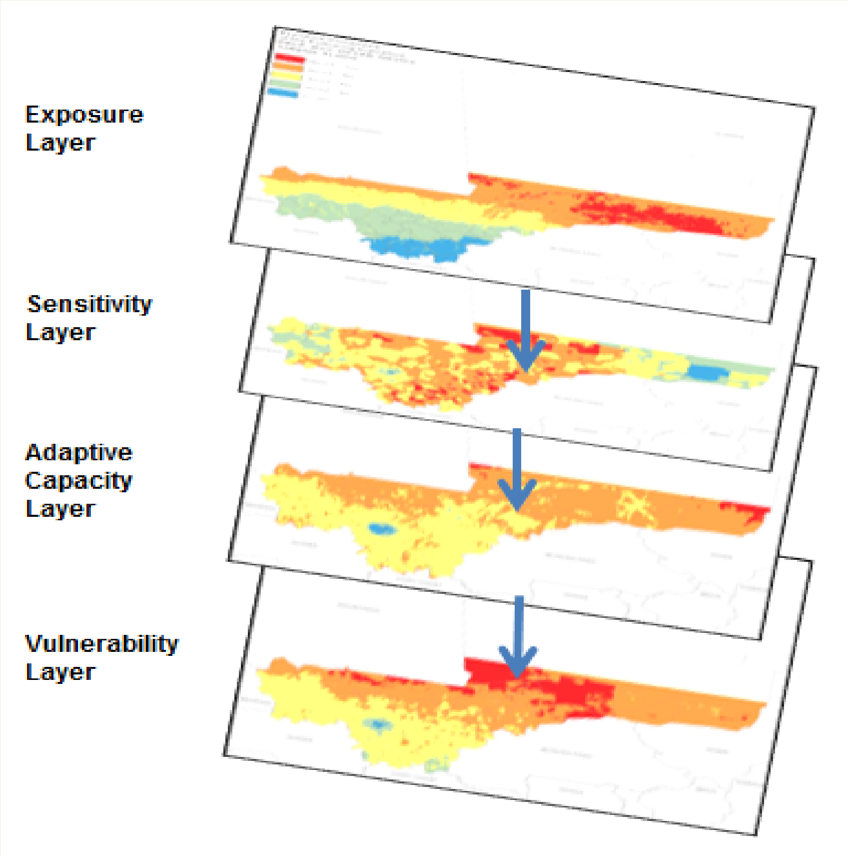


Based on sector specific thresholds for climate change impacts in water, agriculture, ecosystems and health. The above map shows where 50% of GIM-GCM combinations agree on the threshold crossing in each sector, for a GMT change of up to 4.5 ° C. Regions in light gray are regions where no multisectoral overlap is possible.

Source: Piontek F, Müller C, Pugh TAM et al (2013) Multisectoral climate impacts in a warming world. *Proceedings of the National Academy of Sciences*. doi:10.1073/pnas.1222471110.

Mapping climate vulnerability "hotspots"

- Integrates *spatial variability* in:
  - Climate / biophysical changes
  - Human / system vulnerabilities

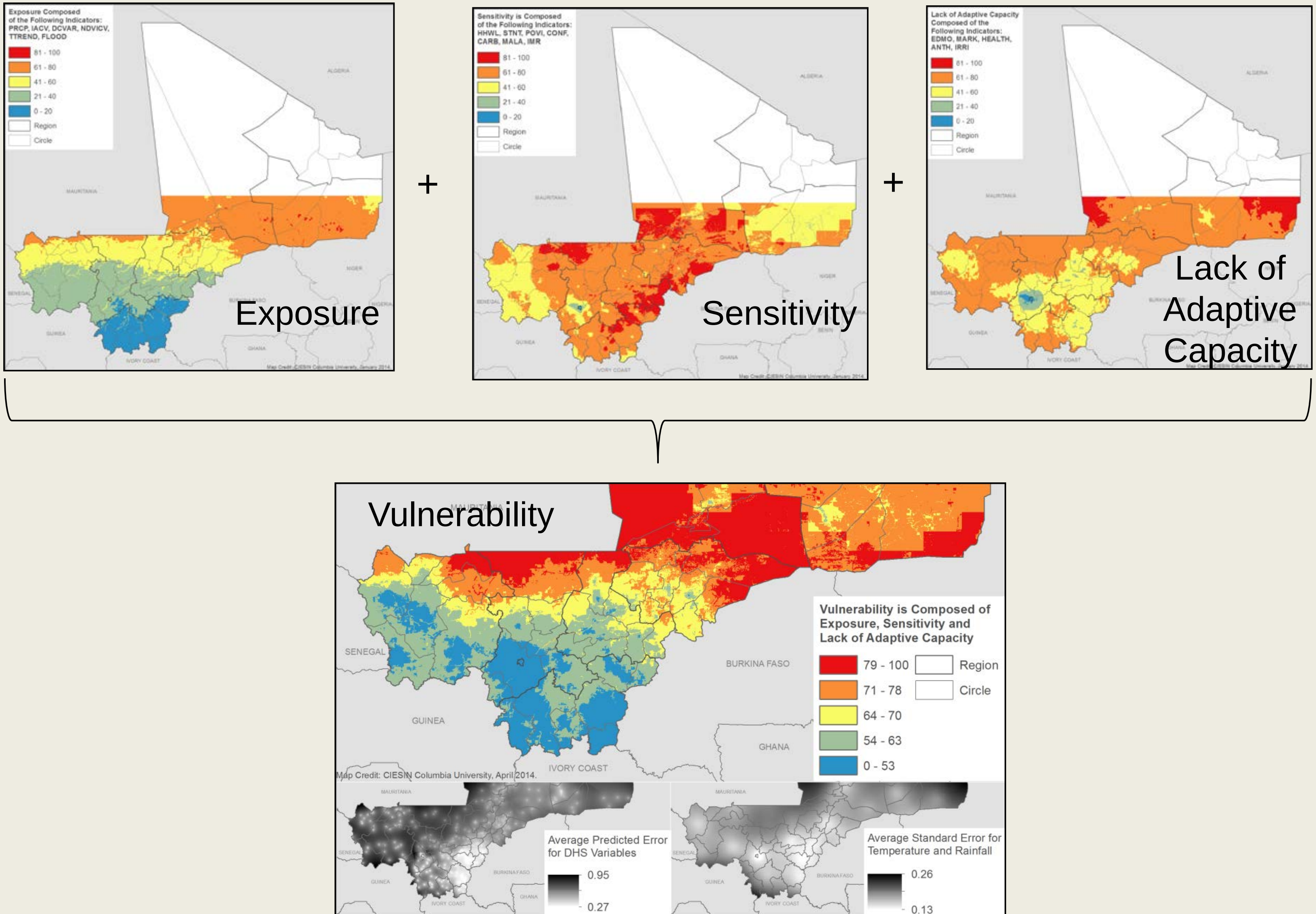


- Exposure, sensitivity, and adaptive capacity are all **spatially** differentiated

Mapping can illuminate key vulnerabilities in the coupled human-environment system and, in turn, inform where adaptation may be required.

Mapping will *not* necessarily tell you what needs to be done or how to build resilience.

Mali Vulnerability Mapping

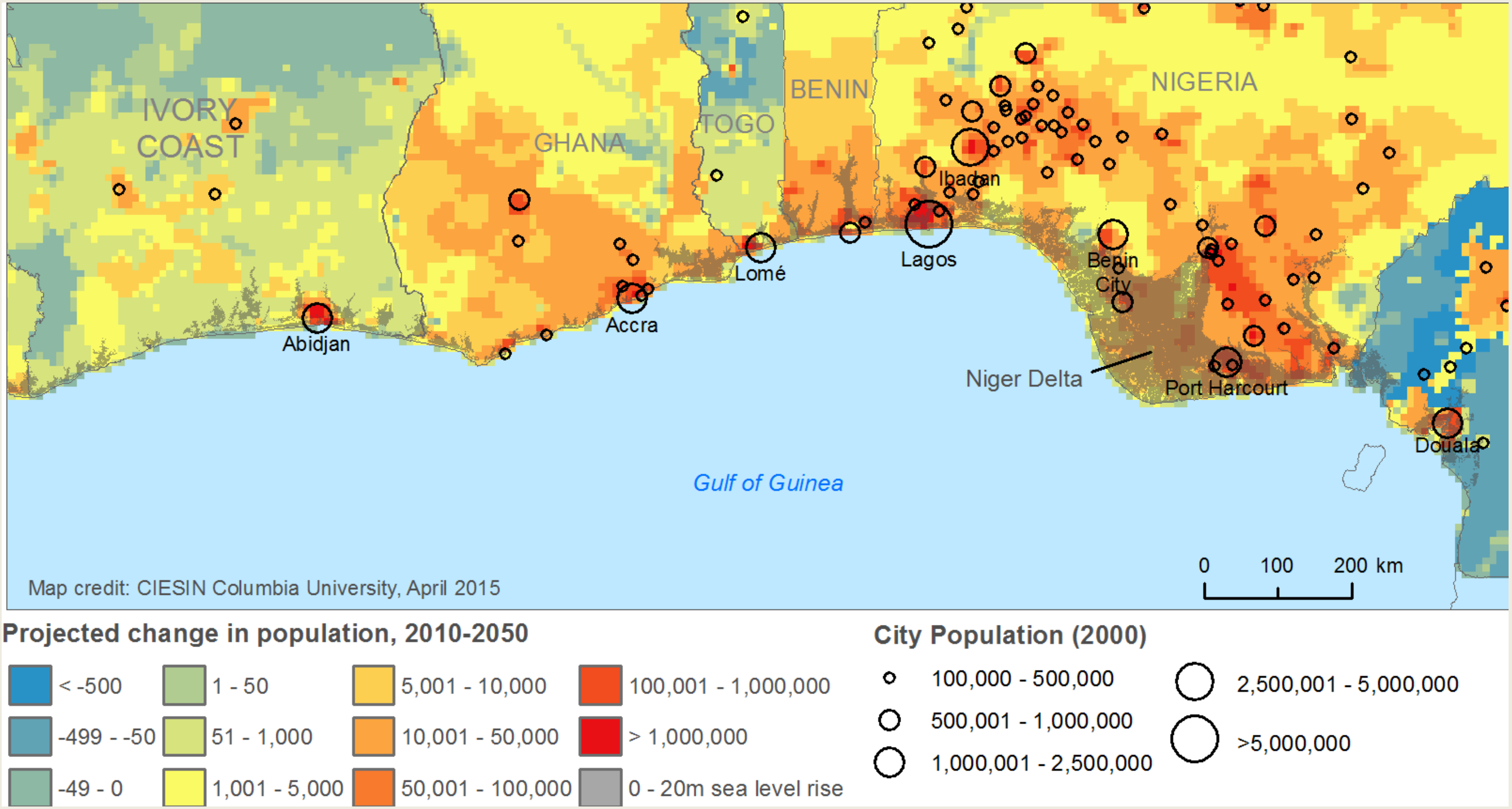


Source: de Sherbinin, et al.. 2015. Data Integration for Climate Vulnerability Mapping in West Africa. ISPRS International Journal of Geo-Information. 4, 2561-2582;.

Mali Vulnerability Mapping: Indicators

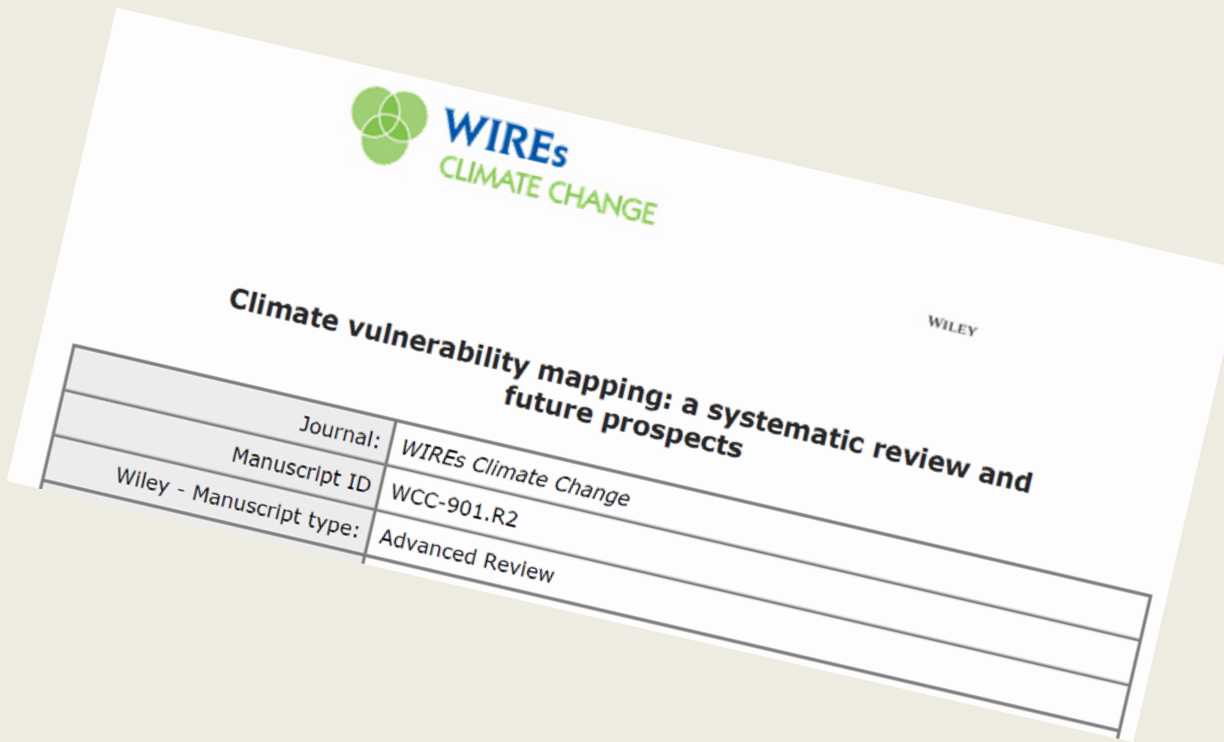
Component	Indicator Code	Data Layer
Exposure	PRCP	Average annual precipitation (1950-2009)
	IACV	Inter-annual coefficient of variation in precipitation (1950-2009)
	DCVAR	% of precipitation variance explained by decadal component (1950-2009)
	NDVICV	Coefficient of variation of NDVI (1981-2006)
	TTREND	Long-term trend in temperature in July-August-Sept. (1950-2009)
	FLOOD	Flood frequency (1999-2007)
Sensitivity	HHWL	Household wealth (2006)
	STNT	Child stunting (2006)
	IMR	Infant mortality rate (IMR) (2006)
	POVI	Poverty index by commune (2008)
	CONF	Conflict events/political violence (1997-2012)
	CARB	Soil organic carbon/soil quality (1950-2005)
	MALA	Malaria stability index
Adaptive Capacity	EDMO	Education level of mother (2006)
	MARK	Market accessibility (travel time to major cities)
	HEALTH	Health infrastructure index (2012)
	ANTH	Anthropogenic biomes (2000)
	IRRI	Irrigated areas (area equipped for irrigation) (1990-2000)

Coastal West Africa Exposure Mapping



Source: de Sherbinin, et al. 2014. Mapping the Exposure of Socioeconomic and Natural Systems of West Africa to Coastal Climate Stressors. Technical Paper for the USAID African and Latin American Resilience to Climate Change (ARCC) project. Washington, DC: USAID.

Best Practices: Vulnerability Mapping



WIREs CLIMATE CHANGE

WILEY

Climate vulnerability mapping: a systematic review and future prospects

Journal:	*WIREs Climate Change*
Manuscript ID	WCC-901.R2
Wiley - Manuscript type:	Advanced Review

SESYNC Pursuit: Meta-Analysis of Climate Change Vulnerability Mapping Studies

- Award Year: 2015
- Principal Investigators:
  - Alex de Sherbinin, Columbia University
  - Brian Tomaszewski, Rochester Institute of Technology
- Goal: Identify the strengths and weaknesses of the various vulnerability mapping approaches and benchmark the state-of-the-art with respect to vulnerability mapping practice.
- See: https://www.sesync.org/project/pursuit/climate-change-vulnerability-mapping-studies

- Journal article in press at *WIRES Climate Change*

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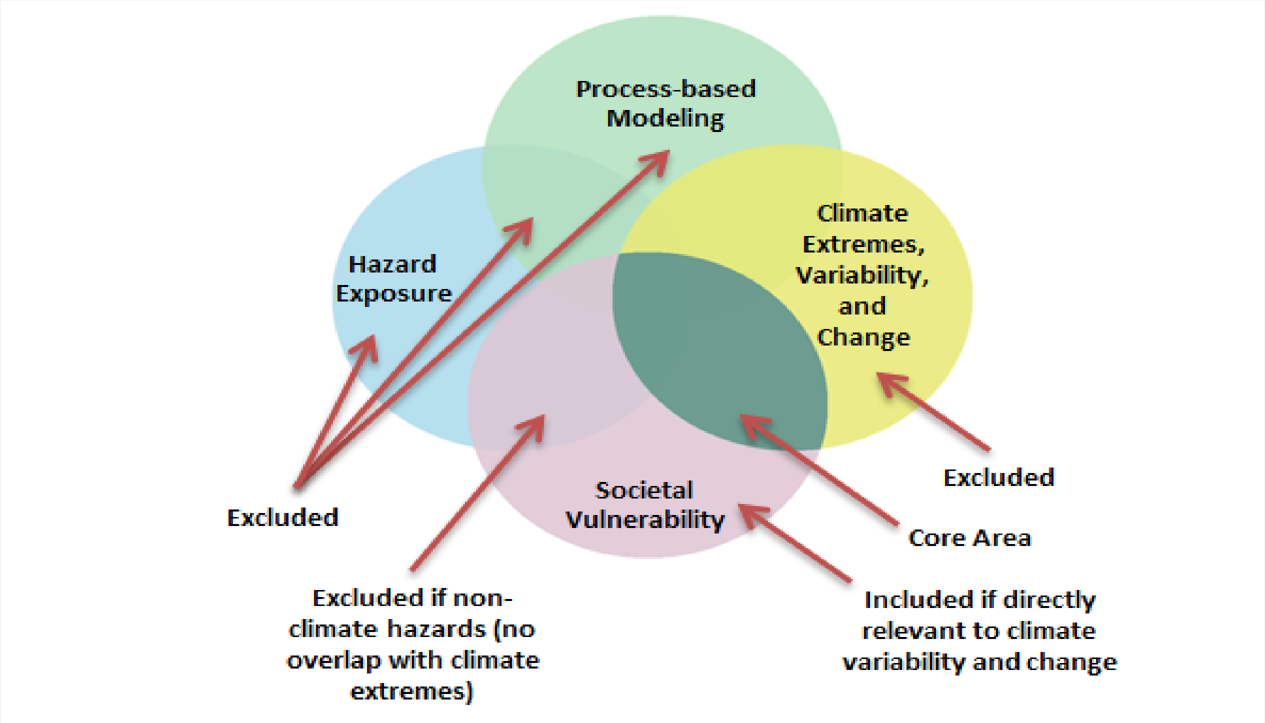
Sainan Zhang	UN Population Fund (UNFPA)

Target Studies



- Studies had to include both *climate hazard* (or exposure) and *differential social vulnerability*.
- Climate hazard could be represented by past, present, or future climate variability, extremes, and change (trends or delta),
- Social vulnerability had to account for socioeconomic characteristics or institutional dimensions affecting the susceptibility of certain populations to climate change impacts and related risks (i.e., differential vulnerability), and not simply population exposure.

Additional Criteria

- Vulnerability assessment portrayed in **cartographic form**
- Mapping units based on **subnational ecological / administrative units or grid cells**
- Publication after the Intergovernmental Panel on Climate Change (IPCC) fourth assessment report (AR4) public release (2007 and onwards)

van Wesenbeeck et al 2016 (10088)

“Localization and characterization of pops vulnerable to CC” *Applied Geography*

- Combines georeferenced data related to households, biophysical, and agronomic conditions
- Uses the Food and Nutrition Security Conceptual Framework
- Uses DHS & MICS data on
  - BMI of women
  - Child malnutrition
  - Morbidity adults & children (malaria, cough, diarrhea)
- Combines dimensions into a single HH-level index for severely V, V, at risk, or not
- Then characterizes households using
  - V explanatory variables like age & gender of HH head, dependency ratio, assets, education
  - AC explanatory variables like remittance income, food aid, integration into the community
- Use joint empirical frequency distribution to identify “winners” – value of y conditional on x
- “Studying the variables jointly improves the specificity of target groups and identification of focal areas for interventions.”
- Summarized climate info as LGP

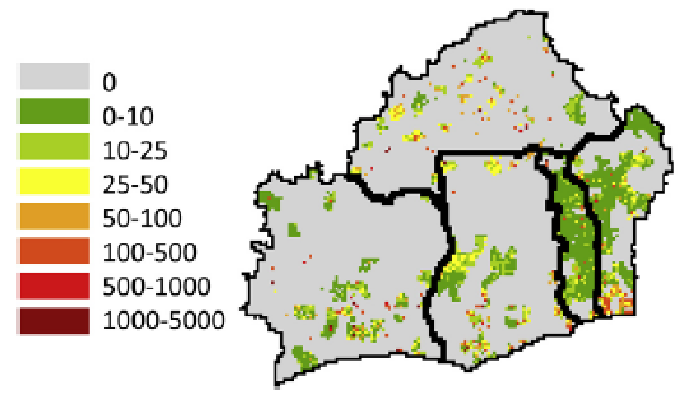


Fig. 4. Vulnerable rural populations in West African study area in persons per km^2.

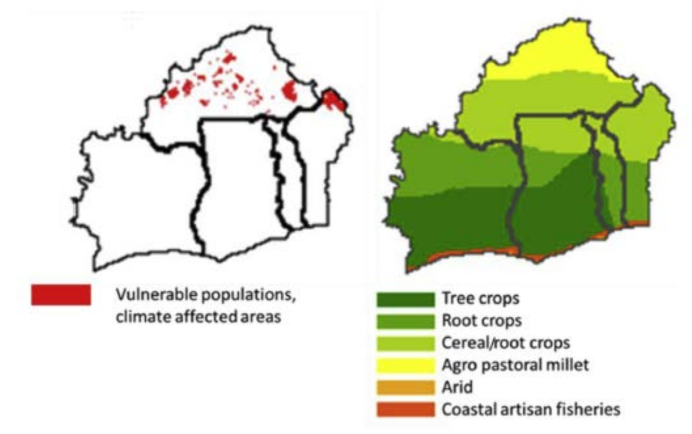


Fig. 6. Vulnerable populations in climate affected areas and farming systems: A comparison.

Holsten and Kropp (2012)

“An integrated and transferable climate change vulnerability assessment for regional application” *Natural Hazards*

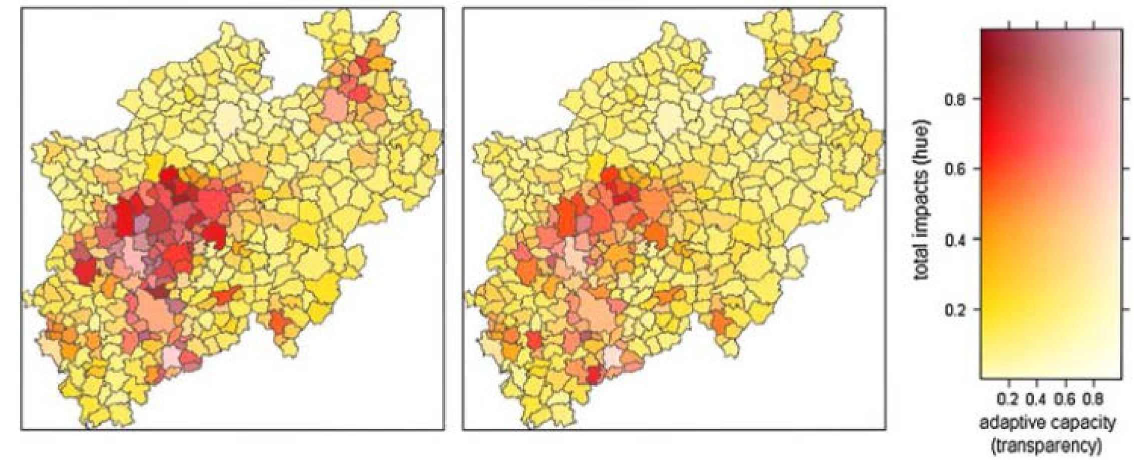


Fig. 9 Visualization of vulnerability based on aggregated impacts and the generic adaptive capacity for CCLM (*left*) and REMO (*right*). A high adaptive capacity reduces negative impacts (hue from *yellow* to *red*), which is visualized by changes in the level of transparency. For the aggregation of the dimensions, equal weighting factors have been applied. The underlying exposure is represented by changes in climatic variables between 1961–1990 and 2071–2100 under scenario A1B

- Textual discussion/mapping of uncertainty (different climate models)
- Methods: Linear aggregation, Geometric mean, Weighting - Other, Overlay
- Combined both metric aggregation as well as visual overlays without arriving at a final index.

- Study area: Local (North Rhine-Westphalia) with policy outputs
- What's vulnerable: health/heat stress, livelihood (agriculture) economic assets (homes, farms, infrastructure), ecosystem services, winter tourism
- Sensitivity and exposure indicators (for environmental, built environment, social and economic dimensions) produced the ***Impacts*** Dimension with was visually overlaid with **Adaptive Capacity** Dimension
- Indicators: Household income, municipality budgets, participation in climate change and sustainability initiatives, education
- Biophysical: LU/LC, lakes, conservation/protected areas, forests, ski runs

Wang & Yarnal 2012, *Natural Hazards*: The vulnerability of the elderly to hurricane hazards in Sarasota, Florida

- “Explores vulnerability to physical exposure to hurricane storm-surge inundation and precipitation induced flooding among older adults”
- Local, baseline assessment; components but no index
- Block groups, PCA

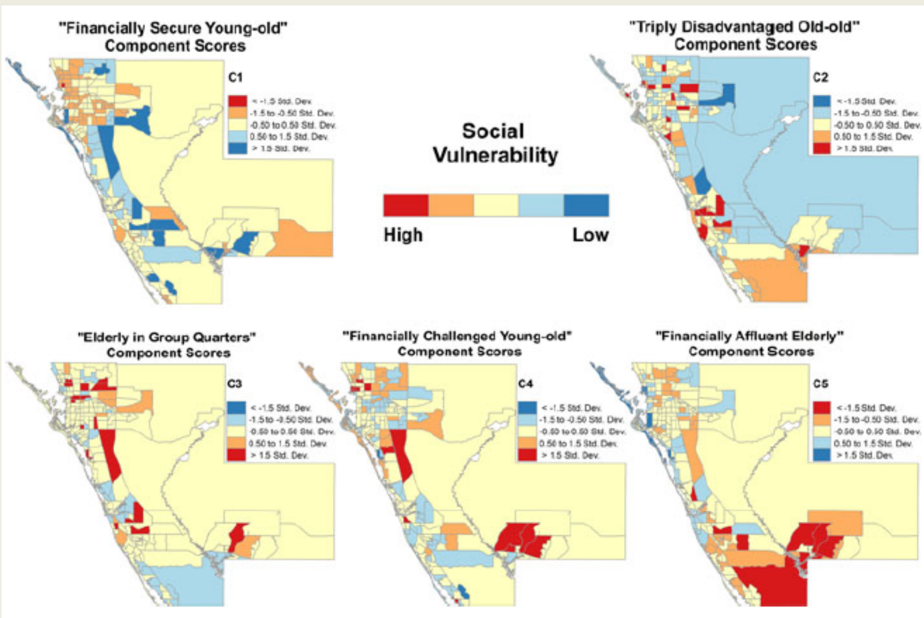
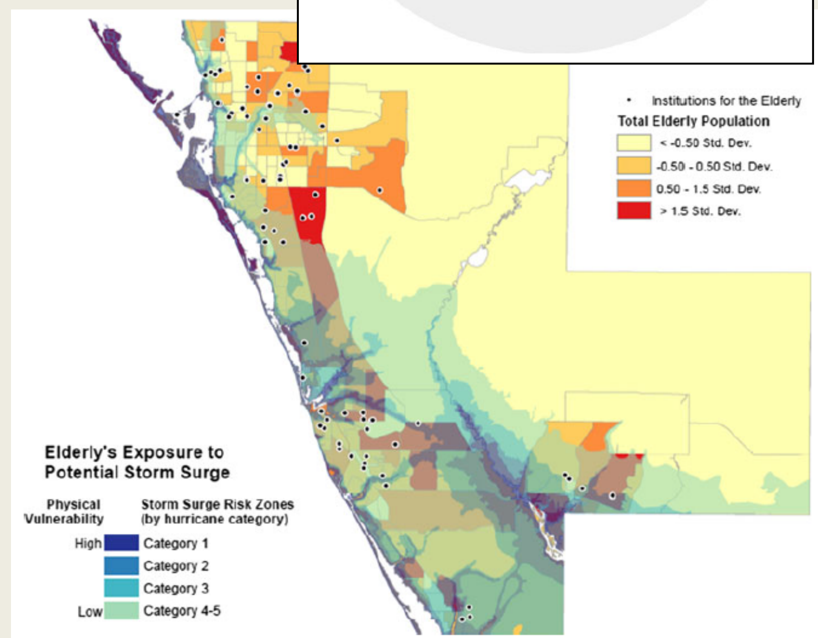
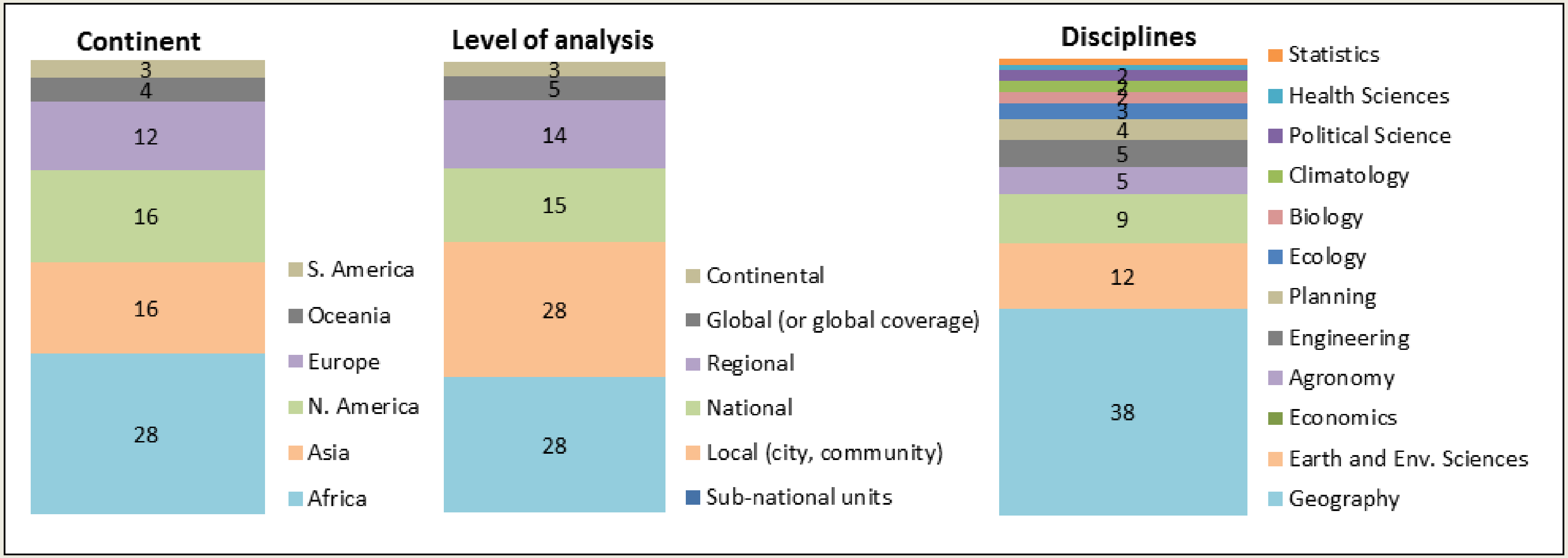


Fig. 9 Social vulnerability of the elderly by individual component in Sarasota County



Methods

- Each study was coded by two researchers across a total of 32 parameters, such as
  - Disciplines of principal and additional authors
  - Spatial extent of the mapping and location
  - Frameworks utilized
  - Stated purpose of the study
  - Valued attribute
  - Time frames addressed in the study
  - Statistical approaches to index construction (where appropriate)
  - Climate related parameters included, etc.
- Coding results were harmonized during a SESYNC workshop in May 2017


Continent
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28
S. America
Oceania
Europe
N. America
Asia
Africa
Level of analysis
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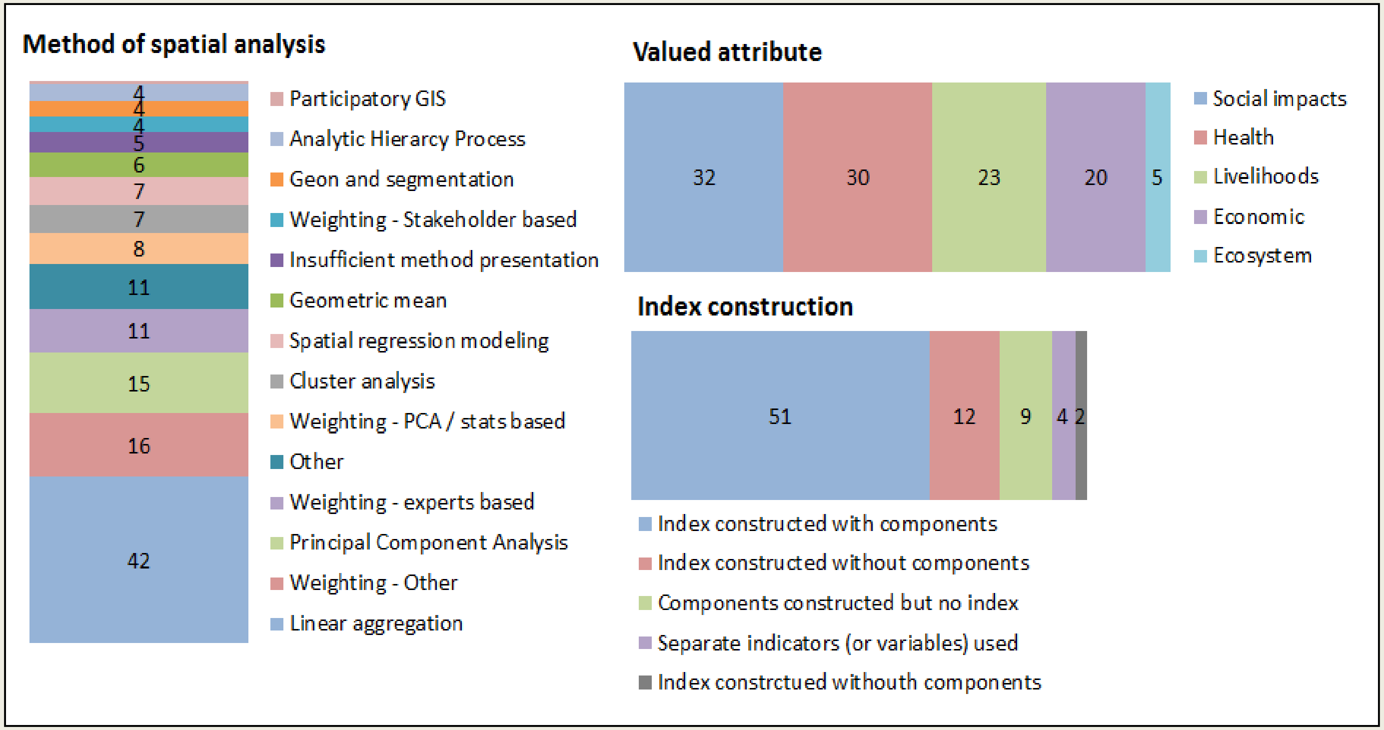
14
15
28
28
Continental
Global (or global coverage)
Regional
National
Local (city, community)
Sub-national units
Disciplines
3
4
5
5
9
12
38
Statistics
Health Sciences
Political Science
Climatology
Biology
Ecology
Planning
Engineering
Agronomy
Economics
Earth and Env. Sciences
Geography


Method of spatial analysis
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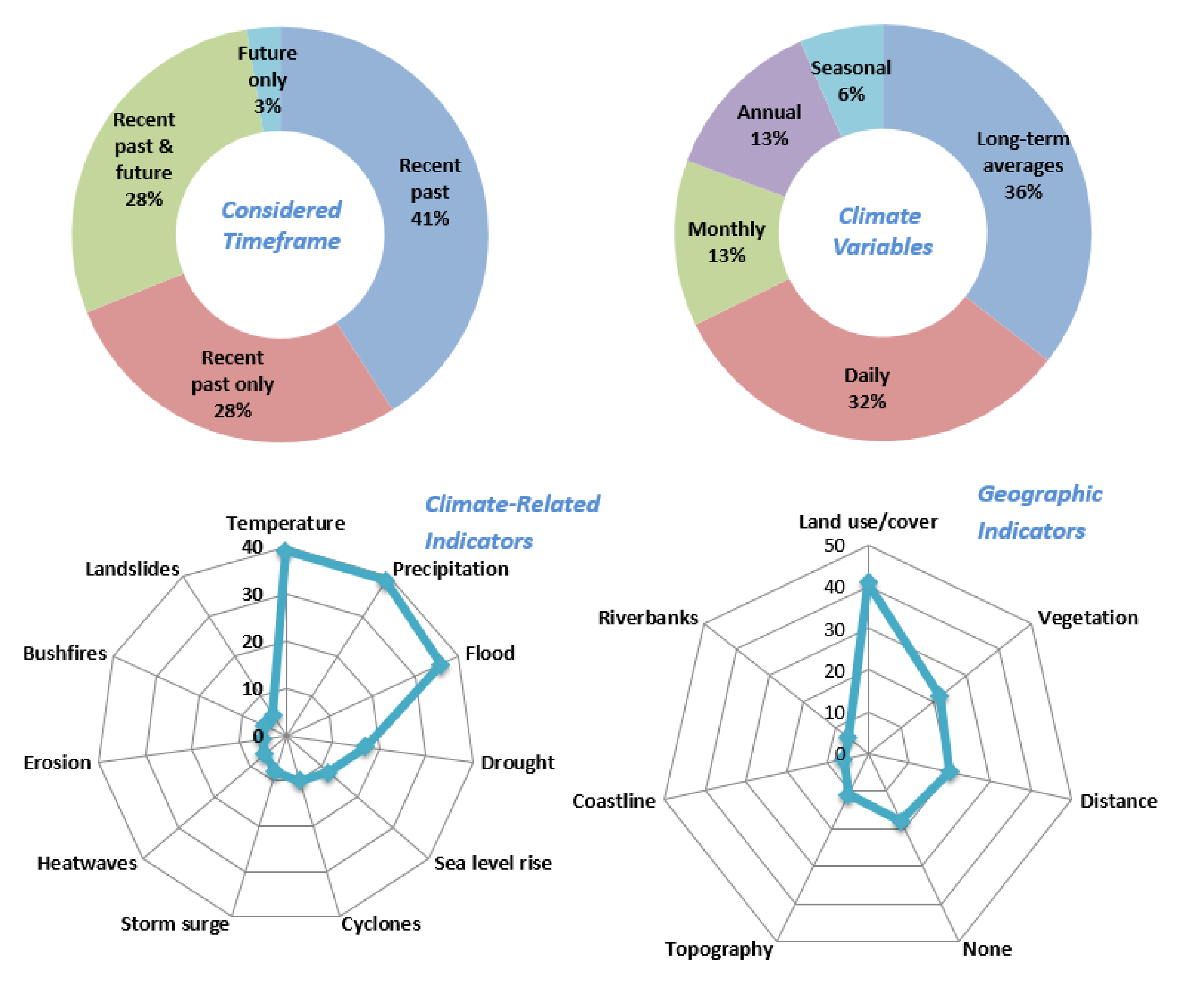
42
Participatory GIS
Analytic Hierarcy Process
Geon and segmentation
Weighting - Stakeholder based
Insufficient method presentation
Geometric mean
Spatial regression modeling
Cluster analysis
Weighting - PCA / stats based
Other
Weighting - experts based
Principal Component Analysis
Weighting - Other
Linear aggregation
Valued attribute
32
30
23
20
5
Social impacts
Health
Livelihoods
Economic
Ecosystem
Index construction
51
12
9
4
2
Index constructed with components
Index constructed without components
Components constructed but no index
Separate indicators (or variables) used
Index constrctued withouth components

Summary of the studies in terms of (a) timeframes of analysis (upper left), (b) temporal nature of the climate parameters considered (upper right), (c) climate-related phenomena or parameters considered (bottom left), and (d) spatial data layers or parameters considered (bottom right).



Uncertainty / Validation

- Uncertainty resulting from:
  - measurement error
  - introduced errors (e.g., errors in spatial processing)
  - choice of the conceptual framework
  - inclusion/exclusion of datasets
  - imputation of missing values
  - data normalization
  - weighting and aggregation schemes
- Only 40% of studies addressed uncertainty, with 20% providing textual discussion only, 18% providing additional quantitative assessment, and 2% presenting maps to support quantification
- Only 18% of studies provided any quantitative assessment of error, and only 2% mapped error

Policy Relevance

- Many claims to policy relevance
- Few studies provided specific policy recommendations or engaged with policy makers and other stakeholders to frame research questions or to assess outcomes
- Co-production is time consuming but important
  - Such engagement requires working relationships and demands additional forms of inquiry such as interviews with stakeholders or follow-up research investigating the utility of the maps
  - co-production of knowledge takes time and a commitment to process: listening to concerns, joint problem identification and design of the analytical framework, choice of weighting schemes, interpretation of the map products, communication of uncertainty, and design of adaptation interventions
  - Requires a different skill set than possessed by some academics

Main Recommendations (1)

- Maps and data visualization
  - Field needs to adhere to basic cartographic conventions (see http://colorbrewer2.org/)
  - Including uncertainty information on the map is more effective than including it in an adjacent map; this inclusion does not interfere with map reading if done correctly
  - Online decision support tools can help formulate or test hypotheses, identify unknowns, and support decisions under a variety of scenarios
- Beyond the map
  - Advanced data sources and statistical methods are moving beyond the mapping of hotspots to help elicit the drivers of vulnerability and, by extension, what interventions are possible
  - Use DHS, LSMS, or other survey data with advanced statistics and geospatial analysis to target development interventions

Main Recommendations (2)

- Mapping the future
  - Combining socioeconomic and climate scenarios is important for understanding the relative contributions of changes in human factors (demography, economic development, urbanization) *and* climatic factors in generating future risks
  - Builds on SSPs
- Validation
  - Vulnerability is an emergent phenomena that makes it difficult to measure and therefore to validate
  - External validation is where vulnerability metrics are validated against independent outcomes of interest such as past health outcomes or economic losses from extreme weather events
  - Internal validation -- statistical tests and sensitivity analysis -- to assess the effects of metric construction on results
  - Neither approach overcomes the challenge of validating estimates of *future* vulnerability

sustainability

IMPACT FACTOR 2.075

Special Issue "Climate Risk and Vulnerability Mapping"

- Special Issue Editors
- Special Issue Information
- Keywords
- Published Papers
- Planned Papers

A special issue of *Sustainability* (ISSN 2071-1050). This special issue belongs to the section "Sustainable Use of the Environment and Resources".

Deadline for manuscript submissions: **30 November 2019**

Please Submit!

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Special Issue Editors

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Spatial Data Visualization

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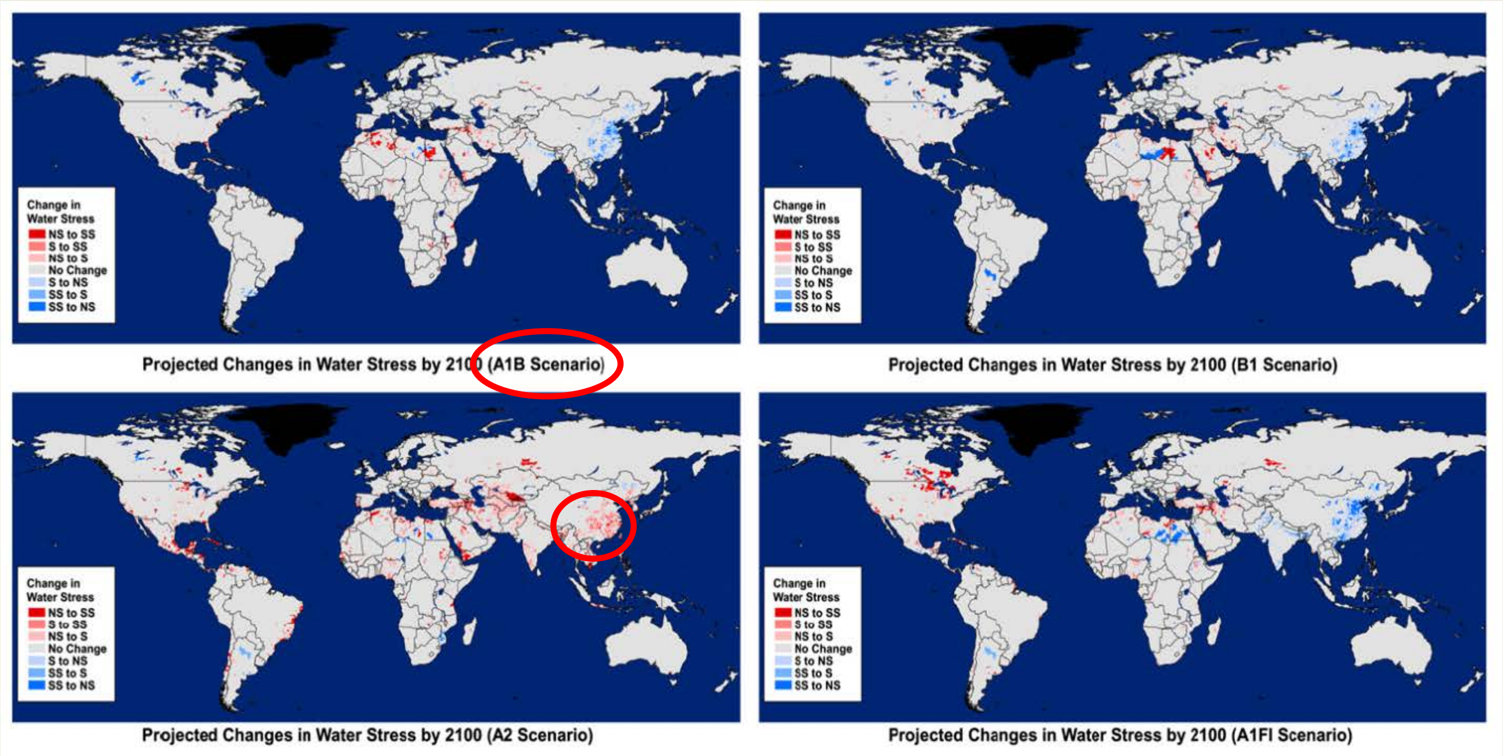
Users (decision makers) are likely to be confused by a large number of model runs

Cognitive science suggests that **we can only remember around seven numbers or items**. More information than that can overload our “working memory”, which is limited. This number is **likely smaller for visual information** but more work is needed to examine the limits.

There are are a number of issues here:

1. What **data reduction methods** can be used to simplify maps, while retaining as much information as possible
2. How to convey **lack of agreement / uncertainty**
3. How to **highlight the probability** of any given model run occuring

In the absence of information on probabilities, users perform mental averages, or conclude that majority rules



A1B is an outlier for China (it contradicts the other three maps), but is probably the most likely scenario!

Source: Parish, E.S., E. Kodra, K. Steinhauser, and A.R. Ganguly. 2012. Estimating future global per capita water availability based on changes in climate and population. *Computers & Geosciences*, 42: 79-86.

Where multiple scenarios are represented, higher agreement / certainty is generally represented by stippling

Good practice

Problem: the stippling could be interpreted visually as contributing to a darker shade of the color over which the stippling is applied

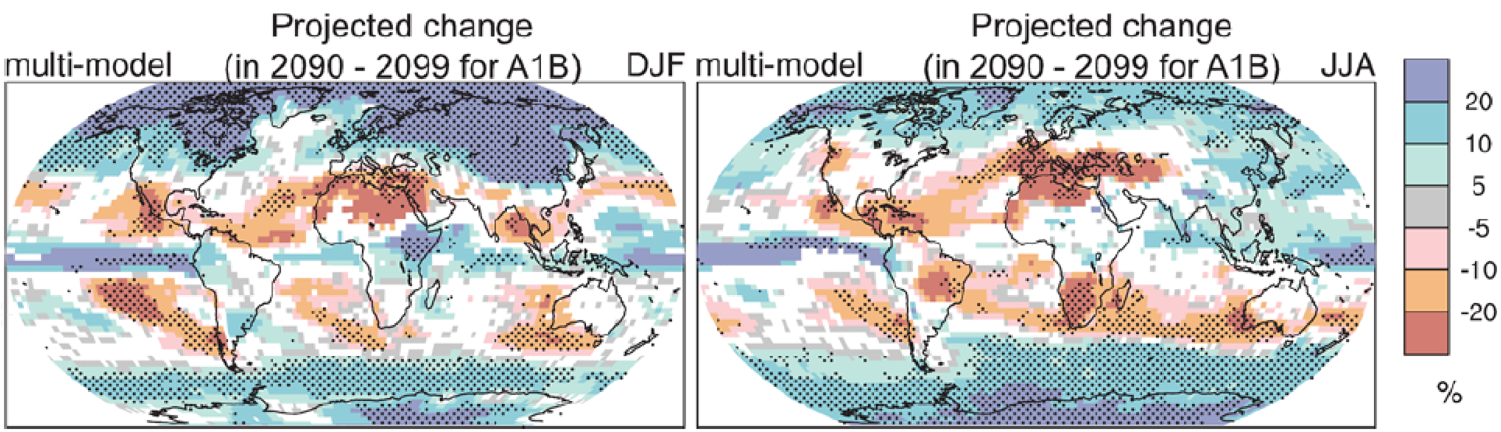
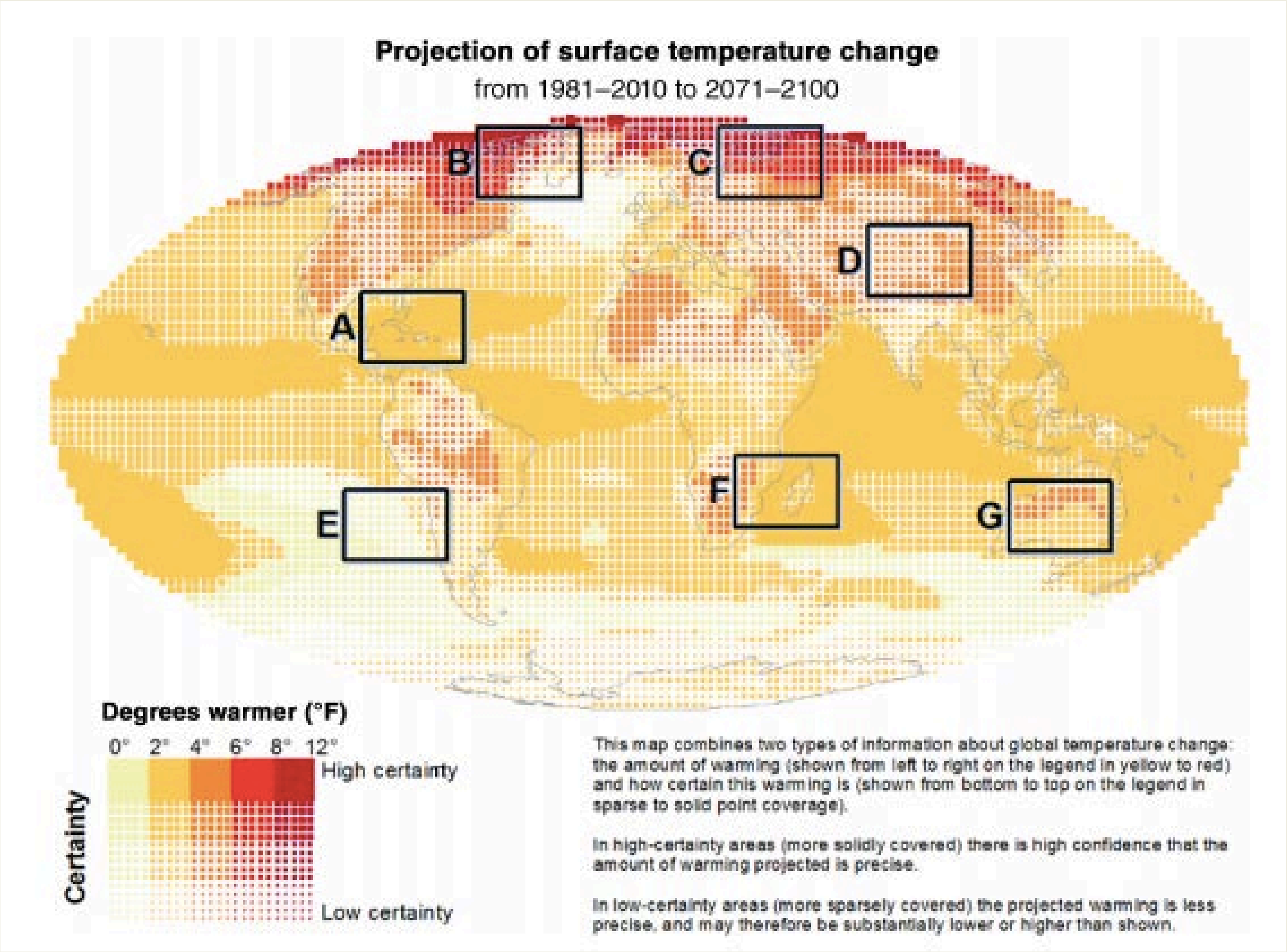


Fig. 1. Spatial patterns of changes (%) in precipitation by the period 2090 to 2099 relative to 1980 to 1999 based on the SRES A1B scenario. December to February means are in the left column, June to August means in the right column. Changes are plotted only where more than 66 % of the models agree on the sign of the change. The stippling indicates areas where more than 90 % of the models agree on the sign of the change. (Map and legend of Fig. TS.30., reprinted from IPCC Working Group I "Summary for Policymakers" (2007a, p. 76).

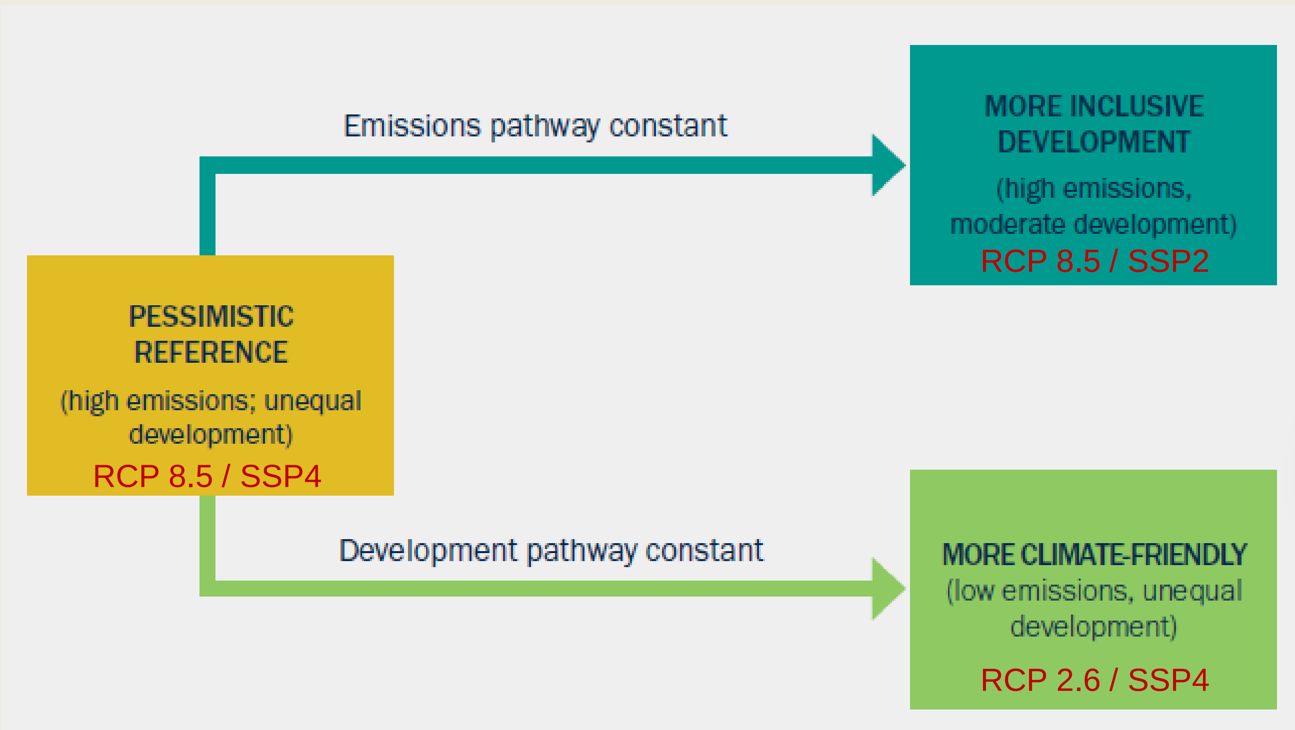
Source: Kaye et al. 2012. Mapping the climate: guidance on appropriate techniques. *Geoscience Model Development*, 5:245-256

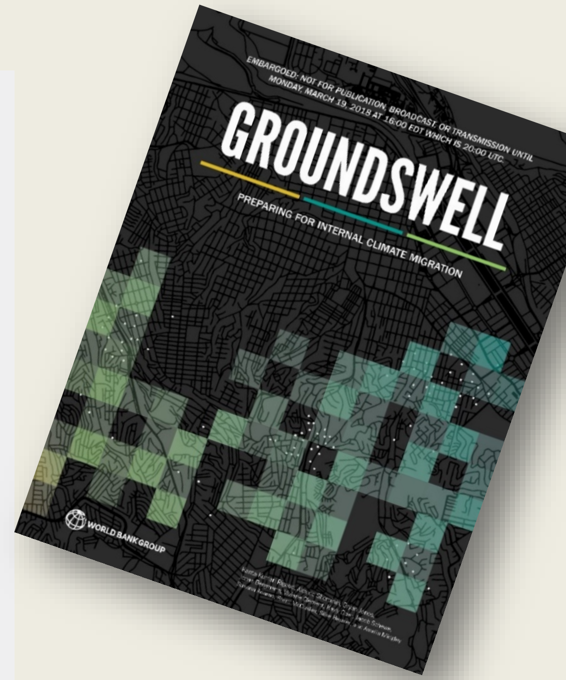
Best practice based on user testing



Source: Retchless, D.P., & Brewer, C. A. (2016). Guidance for representing uncertainty on global temperature change maps. *International Journal of Climatology*, 36(3), 1143-1159.

Three scenarios of climate change-induced migration

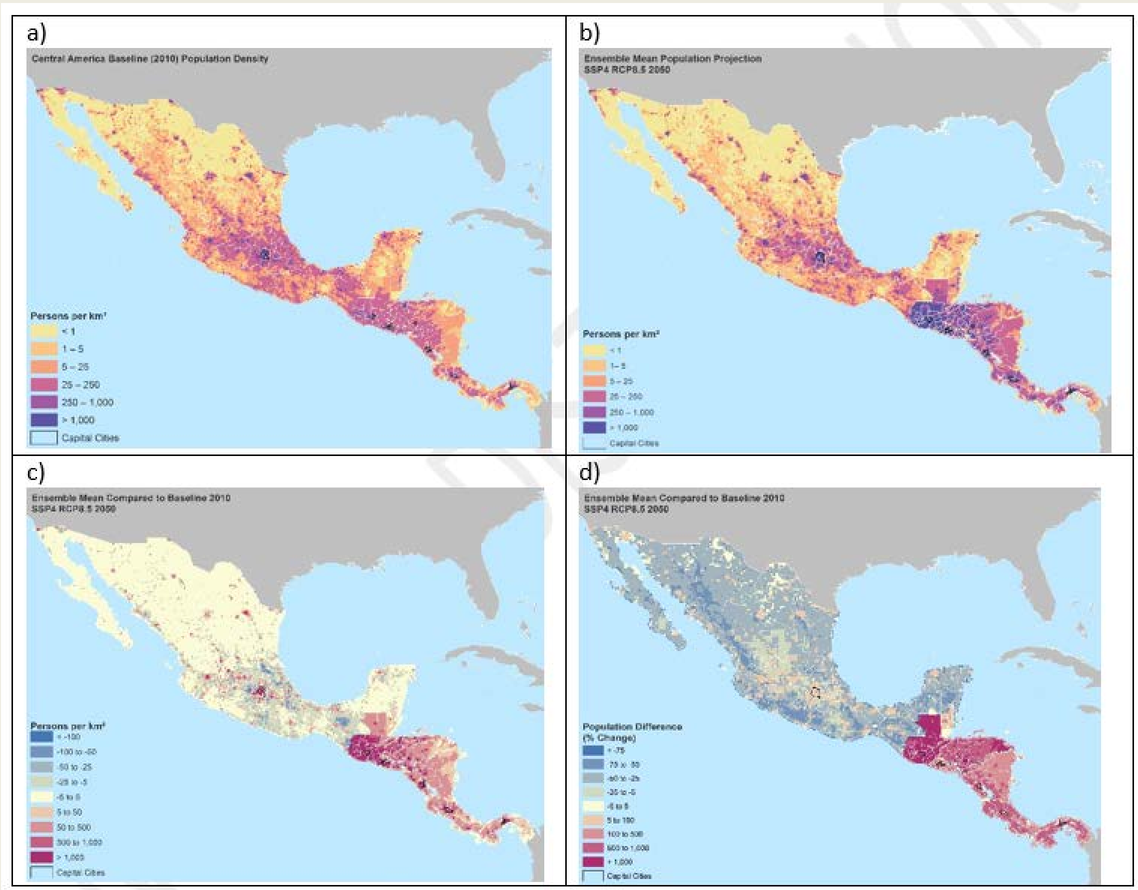




Source: Rigaud, K.K., A. de Sherbinin, B. Jones, J. Bergmann, V. Clement, K. Ober, J. Schewe, S. Adamo, B. McCusker, S. Heuser, and A. Midgley. 2018. *Groundswell: Preparing for Internal Climate Migration*. Washington DC: World Bank.

Comparison between the reference scenario for 2050 and the 2010 baseline population

The draft report included far too many map arrays, confusing the readers…

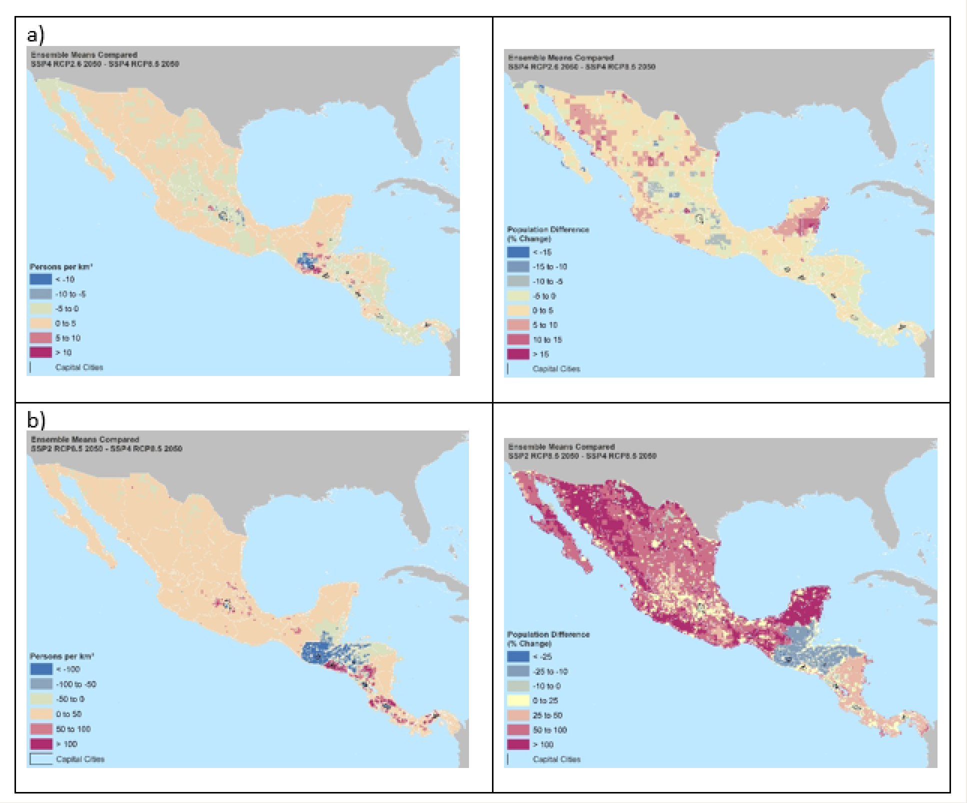


Population density for (a) 2010 baseline population and (b) 2050 under the SSP4-RCP8.5 reference scenario, (c) the change in population density during 2010-2050 under the reference scenario, and d) the percent change in population during 2010-2050 under the reference scenario

The draft report included far too many map arrays, confusing the readers…

Comparison between two alternative scenarios and the reference scenario

Difference between (a) SSP4-RCP2.6 climate friendly and reference scenarios, and (b) SSP2-RCP8.5 more inclusive development and reference scenarios, with difference in population density (left) and percent difference (right)

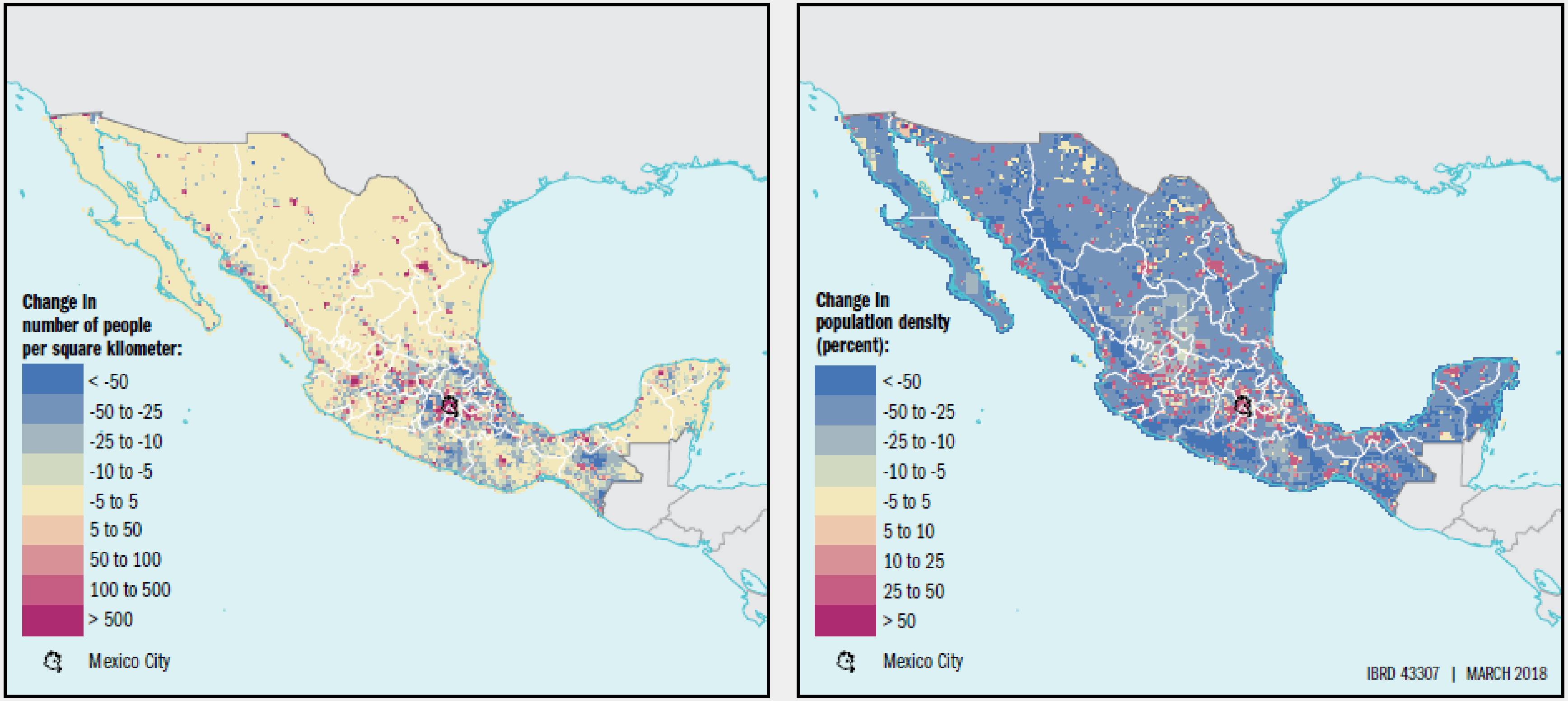


The final report reduced the number of maps, and sought to employ some methods to simplify interpretation of results

Figure 5.23: Absolute and percentage change in population density in Mexico under the pessimistic reference scenario, 2010-50

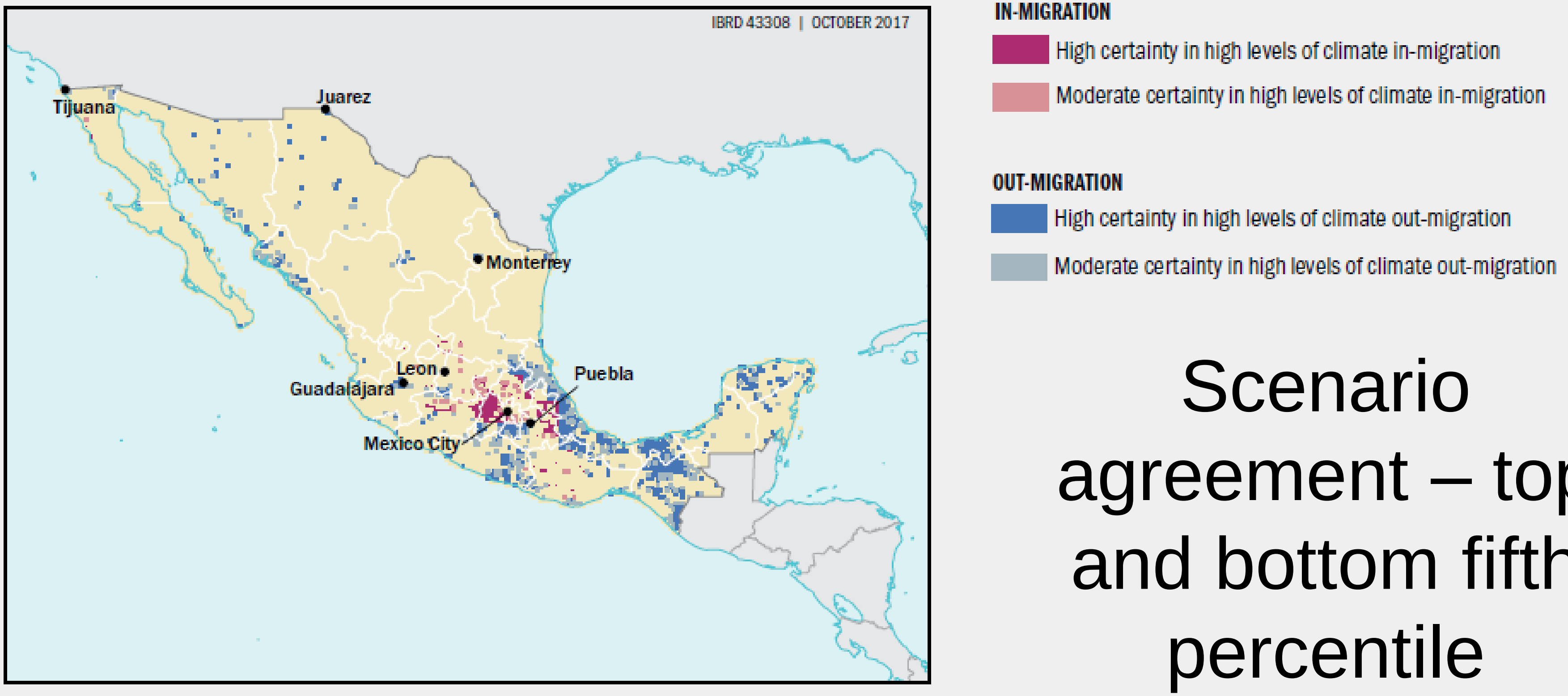
a. Change in population density

b. Percentage change in population density



The final report reduced the number of maps, and sought to employ some methods to simplify interpretation of results

Figure 5.24: Hotspots projected to have high levels of climate in-migration and climate out-migration in Mexico, 2030 and 2050



Scenario agreement – top and bottom fifth percentile

Conclusions

- There are a number of challenges in visualizing future scenarios through maps
- Pre-eminent among them is the need to **convey a wide range of scenarios** in an easily understandable way **while also conveying uncertainty**
- Research in cognitive science suggests that viewers have a **limited capacity to store multiple pieces of information** in working memory and use that information to **make decisions**
- Visual communication of information needs to take into account **cognitive capacity limits** when presenting a wide range of scenarios
- **No clear guidelines** have been proposed for visualizing future scenarios that incorporate human cognitive and decision-making processes
- We don't provide definitive answers, but do **underscrore the issues** and suggest fruitful **future research directions**