

Vulnerability

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- the interface between exposure to physical threats and the capacity of systems to resist, cope or adapt to such threats.
- Reducing vulnerability: identifying points of intervention in the causal change between hazard and human consequences.



Impacts (hazards)

- extreme events
 - variation in climate patterns
 - Cause: storms, dry climate
 - Outcome: floods, mudslides, drought, fire etc.
- "external" processes

Physical/Biophysical Vulnerability (risk)

- Exposure: amount of (potential) damage caused to a system by a particular climate-related event or hazard
- Vulnerability = $I(\text{impacts}) - R$
(resilience)
- IPCC: Vulnerability f (hazard, sensitivity, adaptive capacity)

Social Vulnerability

(vulnerability/sensitivity)

- as a state that exists within a system before it encounters a hazard event
- An inherent property of a system arising from its internal characteristics (e.g. poverty, inequality, entitlements, institutional landscape, etc)
- Generic and specific

Adaptive capacity

"The ability of a system to adjust to climate change (including climate variability and extremes), to moderate potential damages, to take advantage of opportunities, or to cope with the consequences." (IPCC 2001).

Realized adaptation: an equal or better situation

Table 1: Determinants of Adaptive Capacity

| Determinant: | Encompasses: |
|--|--|
| Human capital | Knowledge (scientific, "local", technical, political), education levels, health, individual risk perception, labor |
| Information & Technology | Communication networks, freedom of expression, technology transfer and data exchange, innovation capacity, early warning systems, technological relevance |
| Material resources and infrastructure | Transport, water infrastructure, buildings, sanitation, energy supply and management, environmental quality |
| Organization and social capital | State-civil society relations, local coping networks, social mobilization, density of institutional relationships |
| Political capital | Modes of governance, leadership legitimacy, participation, decentralization, decision and management capacity, sovereignty |
| Wealth & financial capital | Income and wealth distribution, economic marginalization, accessibility and availability of financial instruments (insurance, credit), fiscal incentives for risk management |
| Institutions and entitlements | Informal and formal rules for resource conservation, risk management, regional planning, participation, information dissemination, technological innovation, property rights and risk sharing mechanisms |

Sensitivity

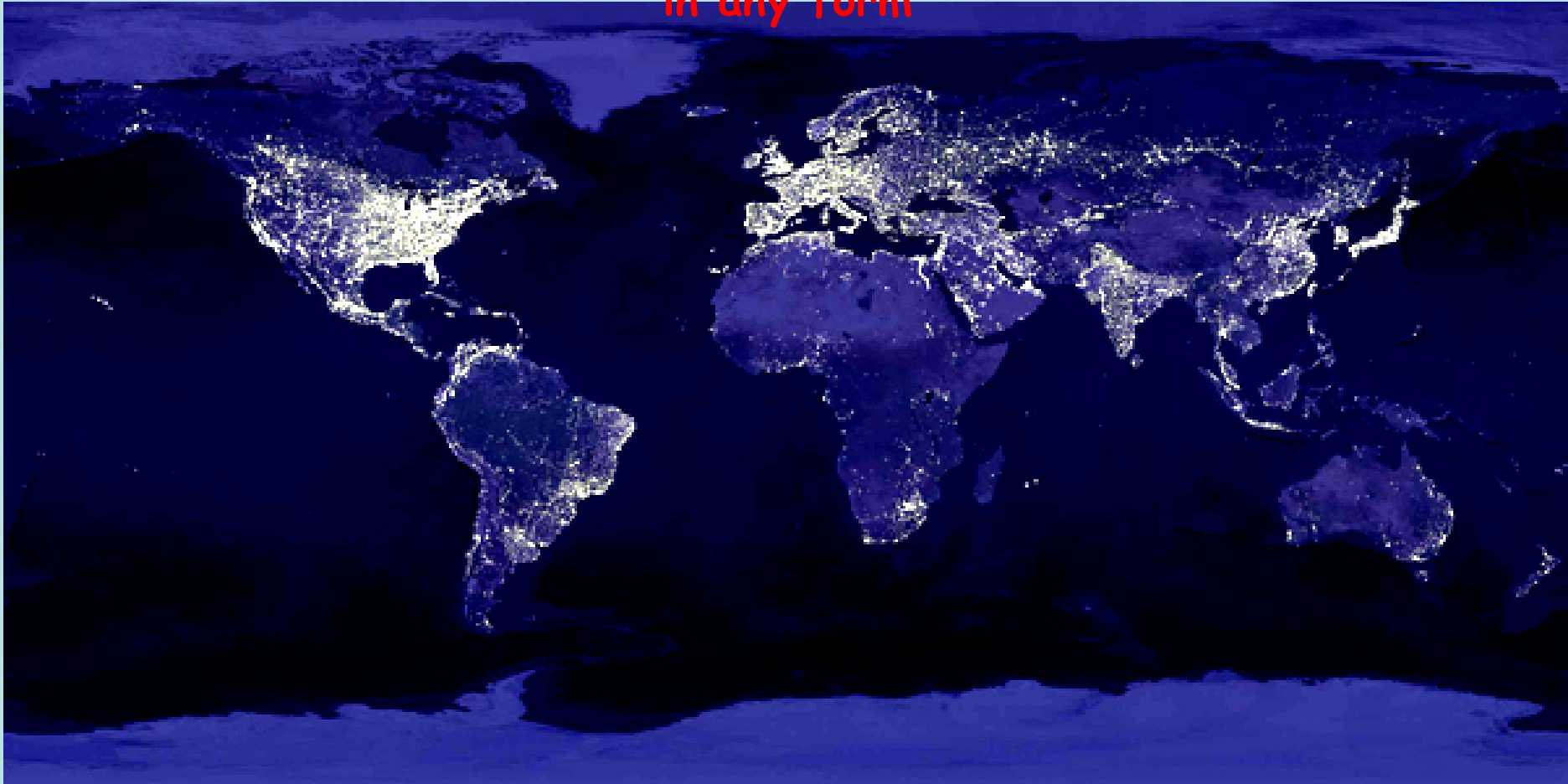
- Sensitivity: different geographical scales, time scales, degrees of exposure and levels of predictability

What is the connection between human induced environmental change and vulnerability?

- Human induced changes have reduced the environment's capacity to absorb the impacts of change and to deliver the goods and services to satisfy human needs.
- Global climate change is likely to exacerbate the severity and frequency of impacts
- Examples: mudslides, land-use change, coastal degradation, etc

Who are the debtors? The energy case (I)

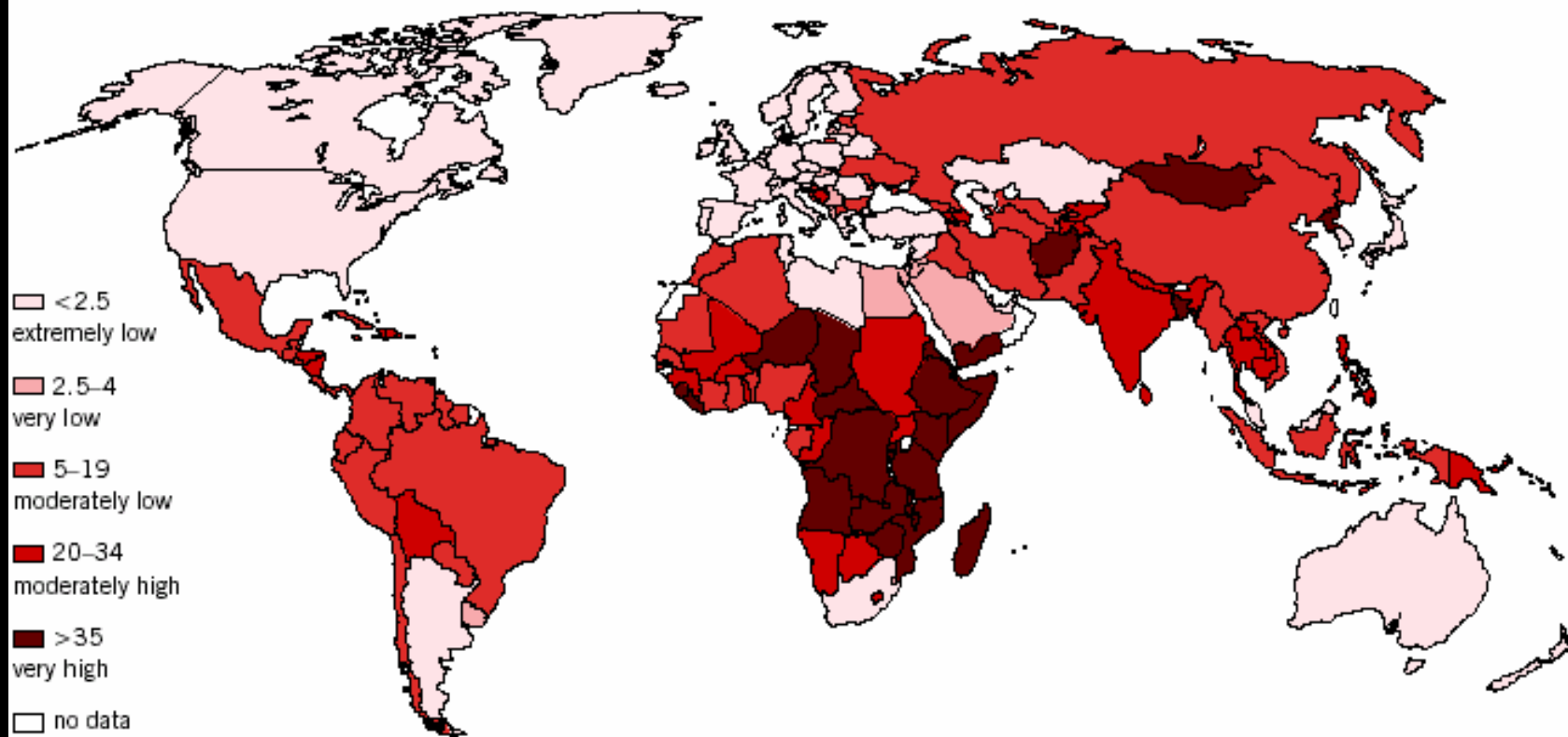
The environmental impacts caused by the extraction of natural resources necessary for the production of energy are not compensated in any form



Who owes who?

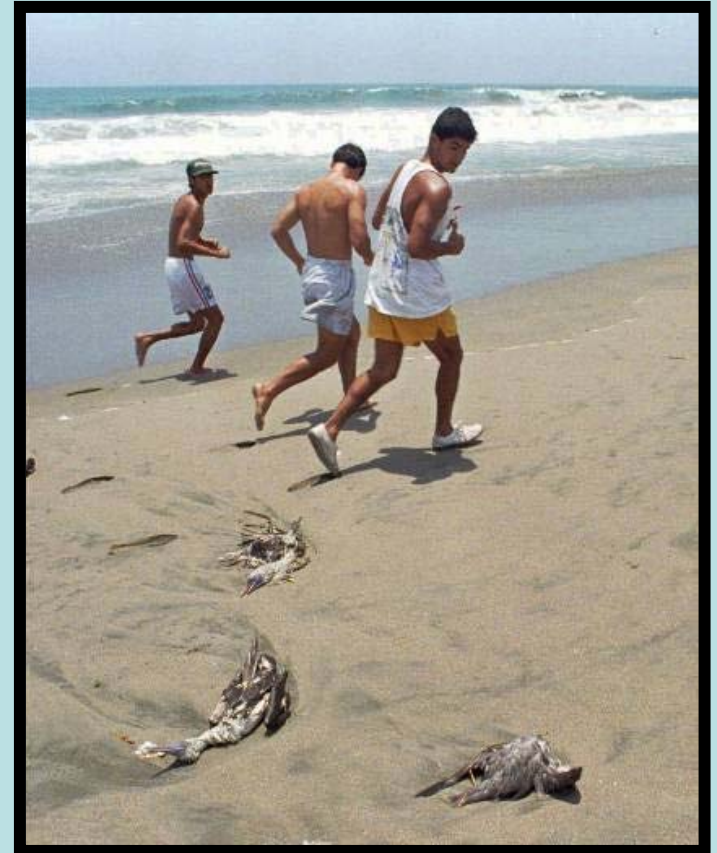
Amigos de la Tierra Int. y
Acción Ecológica 2002.

Undernourishment by country (% of population undernourished)





El Niño in Peru





Resilience

- Ability of people and societies to mitigate, cope and adapt to hazard
- Highly variable among countries, groups, gender, etc.
- Coping capacity: “combination of all the natural and social characteristics and resources available in a particular location that are used to reduce the impacts of hazards” (UNDP Report).
- “internal” processes, entitlements, income access to resources, institutional and market structures



Policy Response

- Reactive rather than proactive
- “downstream” measures: designed to mitigate effects rather than interventions intended to modify basic driving forces ahead of crisis.
- Reducing the severity of impact (reducing risk, or the probability that damage will occur) or decreasing levels of vulnerability among affected groups

Climate Injustice

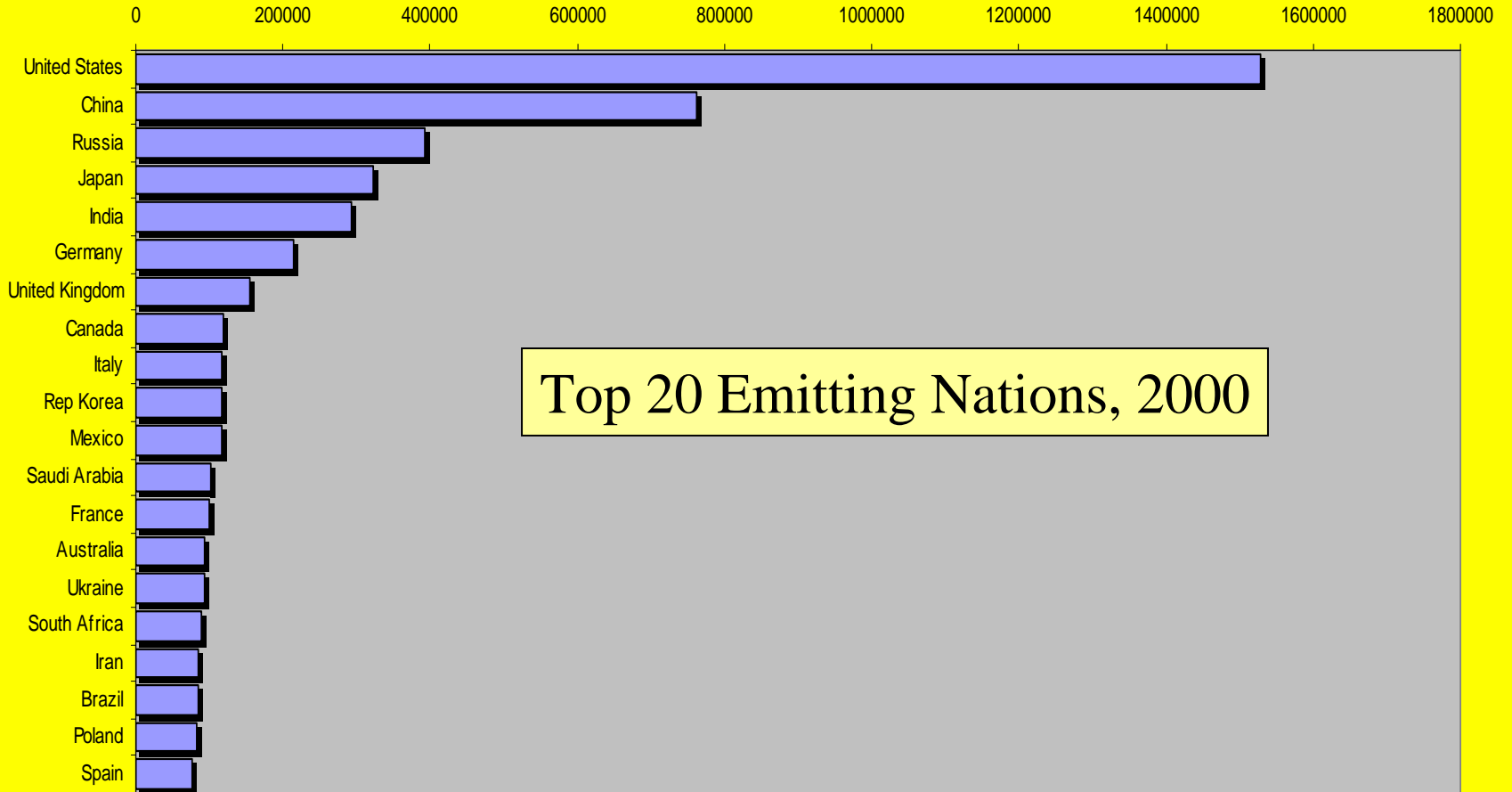
"Those who use too much of the carbon dioxide absorption capacity of the world's oceans, vegetation and soil **owe a debt to all living creatures** whose habitat is threatened. They owe a particular debt to the carbon creditors, the poor of the South who use less than their fair share of the CO₂ absorption capacity. The poor and Indigenous peoples, are among those who are likely to suffer the most severe effects of ... climate change. These consequences of global warming are **another manifestation of environmental racism.**"

(Ecumenical Coalition for Economic Justice 2001)

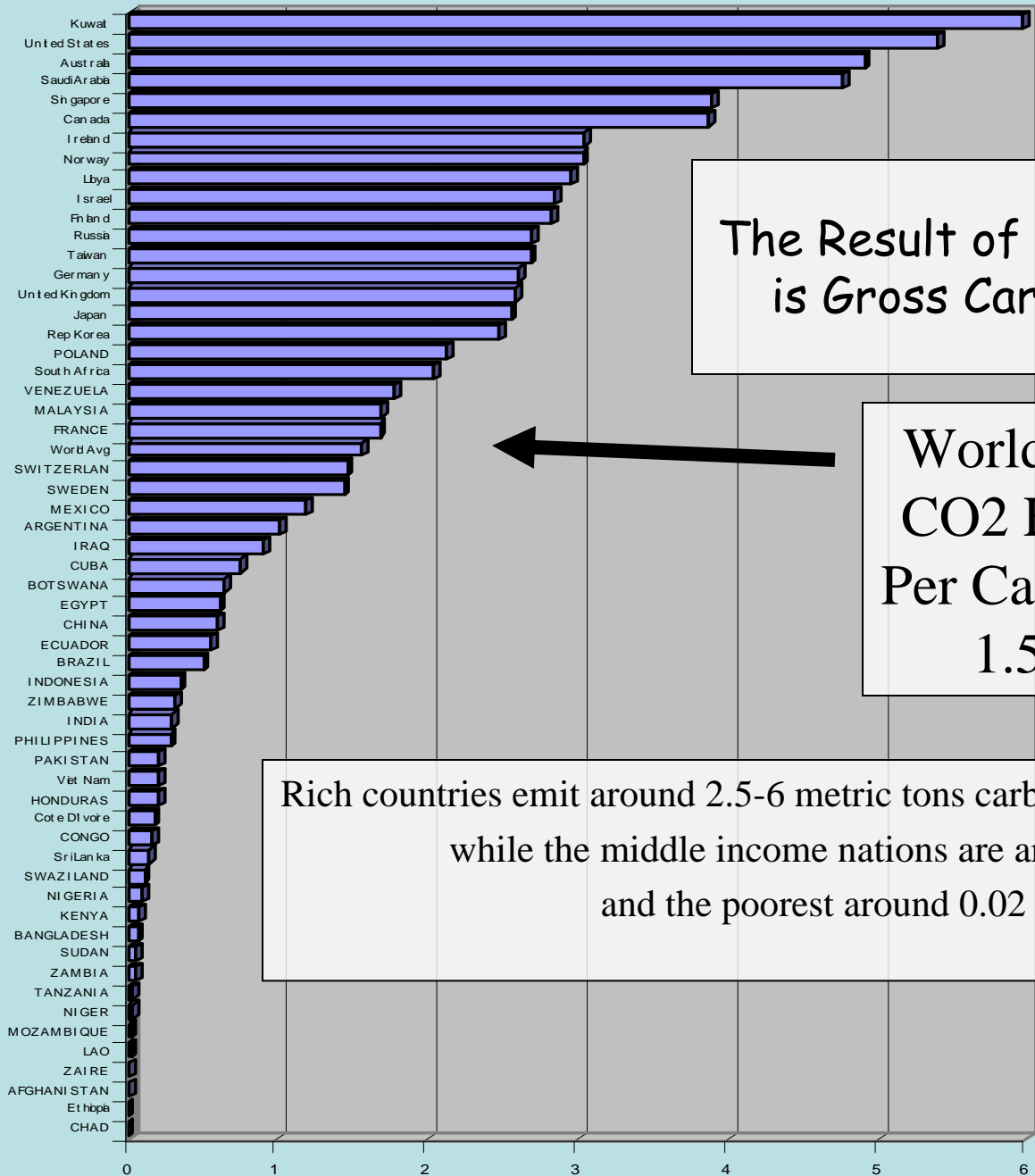
Total Carbon Dioxide Emissions from Fossil Fuel Use, 2000

(Source: Boden, 2003)

Millions of Tons of CO2 Emitted



Top 20 Emitting Nations, 2000



The Result of Global Inequality
is Gross Carbon Inequality

World Average
CO2 Emissions
Per Capita, 2000:
1.56 Tons

Rich countries emit around 2.5-6 metric tons carbon annually per person,
while the middle income nations are around 0.6 mT
and the poorest around 0.02 mT

Source: Boden, 2003



Measuring vulnerability

- Top-down vs. bottom up information
- Outside vs. inside process
- Vulnerability indices
- Quantitative vs. qualitative information
- Vulnerability mapping

Scale

- What is the best scale to measure vulnerability/adaptive capacity?
- National:
 - inform states on needed policy response; allow for better decisionmaking; allows for comparison of differential vulnerability
- Regional
 - Impacts are likely not to be defined by national borders
- Local
 - Ground truth
 - Allows for the understanding of the local factors that mediate sensitivity and resilience

Challenges

- Measuring social and cultural processes
- Data availability and reproduction
- Trade-off between model that better depict reality and usable policy tools
- Consideration of equity and ethical issues

Brooks, Adger and Kelly (2005)

- $\text{risk} = \text{hazard} \times \text{vulnerability}$
- Risk: numbers of people killed by climate-related disaster per decade per national population.

Table 1
Potential proxies for national-level vulnerability to climate change

| Category | Variable | Proxy | Source |
|--------------------------|--|---|-----------|
| Economy | National wealth | GDP per capita (US\$ PPP) | WB |
| | Inequality | GINI coefficient | WIID |
| | Economic autonomy | Debt repayments (% GNI, averaged over decadal periods) | WB |
| | National wealth | GNI (total, PPP) | WB |
| Health and nutrition | State support for health | Health expenditure per capita (US\$ PPP) | HDI |
| | State support for health | Public health expenditure (% of GDP) | HDI |
| | Burden of ill health | Disability adjusted life expectancy | WHO |
| | General health | Life expectancy at birth | HDI |
| | Healthcare availability | Maternal mortality per 100,000 | HDI |
| | Removal of economically active population | AIDS/HIV infection (% of adults) | HDI |
| | Nutritional status | Calorie intake per capita | GRID |
| | General food availability | Food production index (annual change averaged over 1981–90 and 1991–99) | WB |
| | Access to nutrition | Food price index (annual change averaged over 1981–90 and 1991–99) | WB |
| Education | Educational commitment | Education expenditure as % of GNP | HDI |
| | Educational commitment | Education expenditure as % of government expenditure | HDI |
| | Entitlement to information | Literacy rate (% of population over 15) | HDI |
| | Entitlement to information | Literacy rate (% of 15–24 year olds) | HDI |
| | Entitlement to information | Literacy ratio (female to male) | HDI |
| Infrastructure | Isolation of rural communities | Roads (km, scaled by land area with 99% of population) | WB/CISEIN |
| | Commitment to rural communities | Rural population without access to safe water (%) | HDI |
| | Quality of basic infrastructure | Population with access to sanitation (%) | HDI |
| Governance | Conflict | Internal refugees (1000s) scale by population | WB |
| | Effectiveness of policies | Control of corruption | KKZ |
| | Ability to deliver services | Government effectiveness | KKZ |
| | Willingness to invest in adaptation | Political stability | KKZ |
| | Barriers to adaptation | Regulatory quality | KKZ |
| | Willingness to invest in adaptation | Rule of law | KKZ |
| | Participatory decision making | Voice and accountability | KKZ |
| | Influence on political process | Civil liberties | FH |
| | Influence on political process | Political rights | FH |
| Geography and demography | Coastal risk | km of coastline (scale by land area) | GRID |
| | Coastal risk | Population within 100km of coastline (%) | GRID |
| | Resource pressure | Population density | CIESIN |
| Agriculture | Dependence on agriculture | Agricultural employees (% of total population) | WB |
| | Dependence on agriculture | Rural population (% of total) | WB |
| | Dependence on agriculture | Agricultural employees (% of male population) | WB |
| | Dependence on agriculture | Agricultural employees (% of female population) | WB |
| | Agricultural self-sufficiency | Agricultural production index (1985, 1995) | WB |
| Ecology | Environmental stress | Protected land area (%) | GRID |
| | Environmental stress | Forest change rate (% per year) | GRID |
| | Environmental stress | % Forest cover | GRID |
| | Environmental stress | Unpopulated land area | CIESIN |
| | Sustainability of water resources | Groundwater recharge per capita | GRID |
| | Sustainability of water resources | Water resources per capita | GRID |
| Technology | Commitment to and resources for research | R&D investment (% GNP) | WB |
| | Capacity to undertake research and understand issues | Scientists and engineers in R&D per million population | WB |

Note: The data sources are: the World Bank (WB); Human Development Index (HDI); UNEP/GRID-Geneva (GRID); Kaufmann, Kray and Zoido-Lobaton governance data set; Center for International Earth Sciences Information Network (CIESIN) at Columbia University; United Nations World Income Inequality Database (WIID).

Significant variables

- (1) population with access to sanitation,
- (2) literacy rate, 15-24-year olds,
- (3) maternal mortality,
- (4) literacy rate, over 15 years,
- (5) calorific intake,
- (6) voice and accountability,
- (7) civil liberties,
- (8) political rights,
- (9) government effectiveness,
- (10) literacy ratio (female to male),
- (11) life expectancy at birth.

vulnerable

| | | | |
|-------------------------------------|----|--------------------------|----|
| Afghanistan | 13 | <i>Cote d'Ivoire</i> | 10 |
| <i>Angola</i> | 13 | Qatar | 10 |
| <i>Burundi</i> | 13 | <i>Kenya</i> | 9 |
| <i>Central African Rep.</i> | 13 | Laos | 9 |
| <i>Democratic Republic of Congo</i> | 13 | North Korea | 8 |
| <i>Eritrea</i> | 13 | Yugoslavia | 7 |
| <i>Ethiopia</i> | 13 | <i>Nigeria</i> | 7 |
| <i>Equatorial Guinea</i> | 13 | <i>Benin</i> | 6 |
| | | Turks and Caicos | 6 |
| | | Islands | |
| <i>Gambia</i> | 13 | Bosnia Herzegovina | 5 |
| <i>Guinea Bissau</i> | 13 | <i>Congo</i> | 5 |
| Haiti | 13 | <i>Mali</i> | 5 |
| <i>Mauritania</i> | 13 | Guadeloupe | 5 |
| <i>Mozambique</i> | 13 | <i>Senegal</i> | 5 |
| <i>Niger</i> | 13 | Tonga | 5 |
| Pakistan | 13 | Nepal | 4 |
| <i>Rwanda</i> | 13 | <i>Djibouti</i> | 3 |
| <i>Sierra Leone</i> | 13 | <i>Zimbabwe</i> | 3 |
| <i>Somalia</i> | 13 | Azerbaijan | 2 |
| <i>Sudan</i> | 13 | Puerto Rico | 2 |
| <i>Togo</i> | 13 | Bangladesh | 1 |
| Turkmenistan | 12 | Bhutan | 1 |
| <i>Chad</i> | 12 | Estonia | 1 |
| <i>Gabon</i> | 12 | Cambodia | 1 |
| Iraq | 12 | <i>Uganda</i> | 1 |
| <i>Liberia</i> | 12 | United Arab Emirates | 1 |
| <i>Malawi</i> | 11 | French Guiana | 1 |
| Brunei Darussalam | 11 | Morocco | 1 |
| <i>Burkina Faso</i> | 11 | Wallis and Futuna | 1 |
| | | Islands | |
| <i>Guinea</i> | 11 | | |
| Yemen | | | |

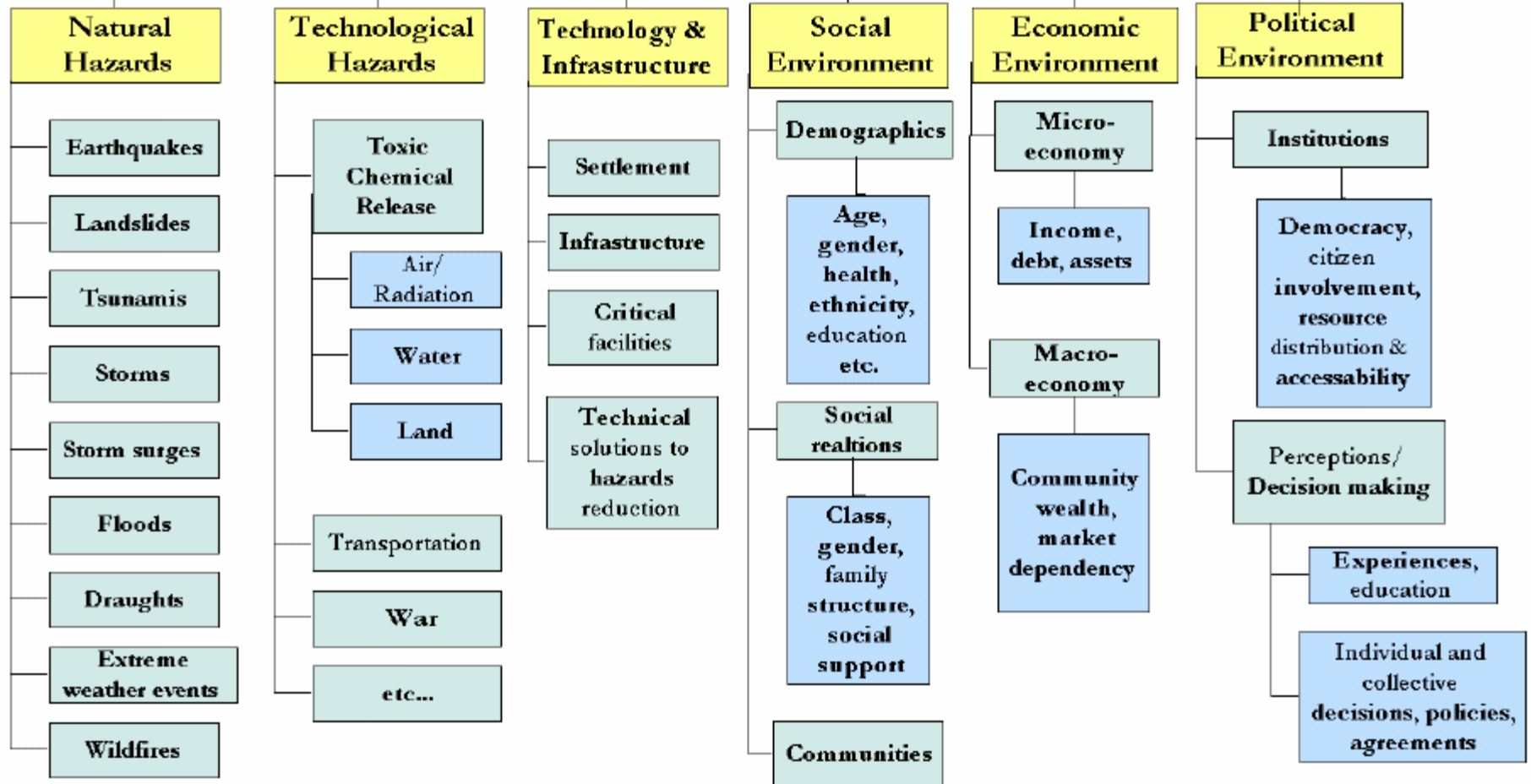
Note: Countries in continental sub-Saharan Africa are highlighted in red, small island states or territories in blue.

Most Vulnerable

Vulnerability

Exposure

Coping Ability



Vulnerability

Exposure

Coping Ability

Natural Hazards

Earthquakes

Landslides

Tsunamis

Storms

Storm surges

Floods

Draughts

Extreme weather events

Wildfires

Floodplains

Frequency & extent

Snow, hail, heavy rainfall etc.

Forested area

Technological Hazards

Toxic Chemical Release

TRI sites

Superfund

RCRA sites

Transportation

Road network

Airports

Technology & Infrastructure

Settlement

Housing units

Renter's

Infrastructure

Utility networks

Critical facilities

Hospitals, police stations, fire stations, etc

Social Environment

Demographics

Age

Gender

Social realtions

Ethnicity

Single-mother households

Economic Environment

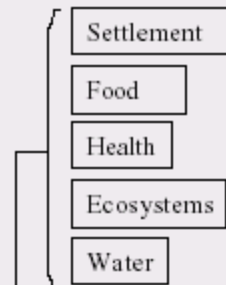
Micro-economy

Household income

House value

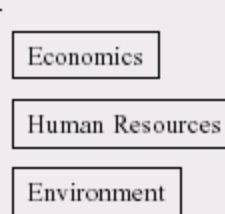
Quantifying Vulnerability and Resilience to Climate Change

Sensitivity sectors



Sensitivity Indicators

Coping and Adaptive Capacity sectors



Coping-Adaptive Capacity Indicators

National Baseline Estimates and Projections of Sectoral Indicators, Sensitivity and Coping-Adaptive Capacity, and Vulnerability-Resilience Response Indicators to Climate Change

Table ES-1. Indicators, sectors, and proxies used in the vulnerability-resilience indicator prototype (VRIP) model

| Sensitivity or Adaptive capacity category | Proxy variables | Proxy for | Functional relationship |
|---|---|---|--|
| Settlement/ infrastructure sensitivity | Population at flood risk from sea level rise Population without access to clean water/sanitation | Potential extent of disruptions from sea level rise Access of population to basic services to buffer against climate variability and change | Sensitivity ↑ as population at risk ↑ Sensitivity ↑ as population with no access ↑ |
| Food security | Cereals production/area Animal protein consumption/capita | Degree of modernization in the agriculture sector; access of farmers to inputs to buffer against climate variability and change Access of a population to markets and other mechanisms (e.g., consumption shift) for compensating for shortfalls in production | Sensitivity ↓ as production ↑ Sensitivity ↓ as consumption ↑ |
| Ecosystem sensitivity | % Land managed Fertilizer use | Degree of human intrusion into the natural landscape and land fragmentation Nitrogen/phosphorus loading of ecosystems and stresses from pollution | Sensitivity ↑ as % land managed ↑ 60-100 kg/ha is optimal. X < 60 kg/ha, sensitivity ↑ due to nutrient deficits and potential cultivation of adjacent ecosystems. X > 100 kg/ha (capped at 500 kg/ha), sensitivity ↑ due to increasing runoff |
| Human health sensitivity | Completed fertility Life expectancy | Composite of conditions that affect human health including nutrition, exposure to disease risks, and access to health services | Sensitivity ↓ as fertility ↓ Sensitivity ↓ as life expectancy ↑ |
| Water resource sensitivity | Renewable supply and inflow Water use | Supply of water from internal renewable resources and inflow from rivers Withdrawals to meet current or projected needs | Sensitivity calculated using ratio of available water used: Sensitivity ↑ as % water used ↑ |
| Economic capacity | GDP(market)/capita Gini index | Distribution of access to markets, technology, and other resources useful for adaptation | Coping-adaptive capacity ↑ as GDP per capita ↑ At present Gini held constant |
| Human and civic resources | Dependency ratio Literacy | Social and economic resources available for adaptation after meeting other present needs Human capital and adaptability of labor force | Coping-adaptive capacity ↓ as dependency ↑ Coping-adaptive capacity ↑ as literacy ↑ |
| Environmental capacity | Population density SO ₂ /area % Land unmanaged | Population pressure and stresses on ecosystems Air quality and other stresses on ecosystems Landscape fragmentation and ease of ecosystem migration | Coping-adaptive capacity ↓ as population density ↑ Coping-adaptive capacity ↓ as SO ₂ ↑ Coping-adaptive capacity ↑ as % unmanaged land ↑ |

Vulnerability-Resilience Indicators in 1990

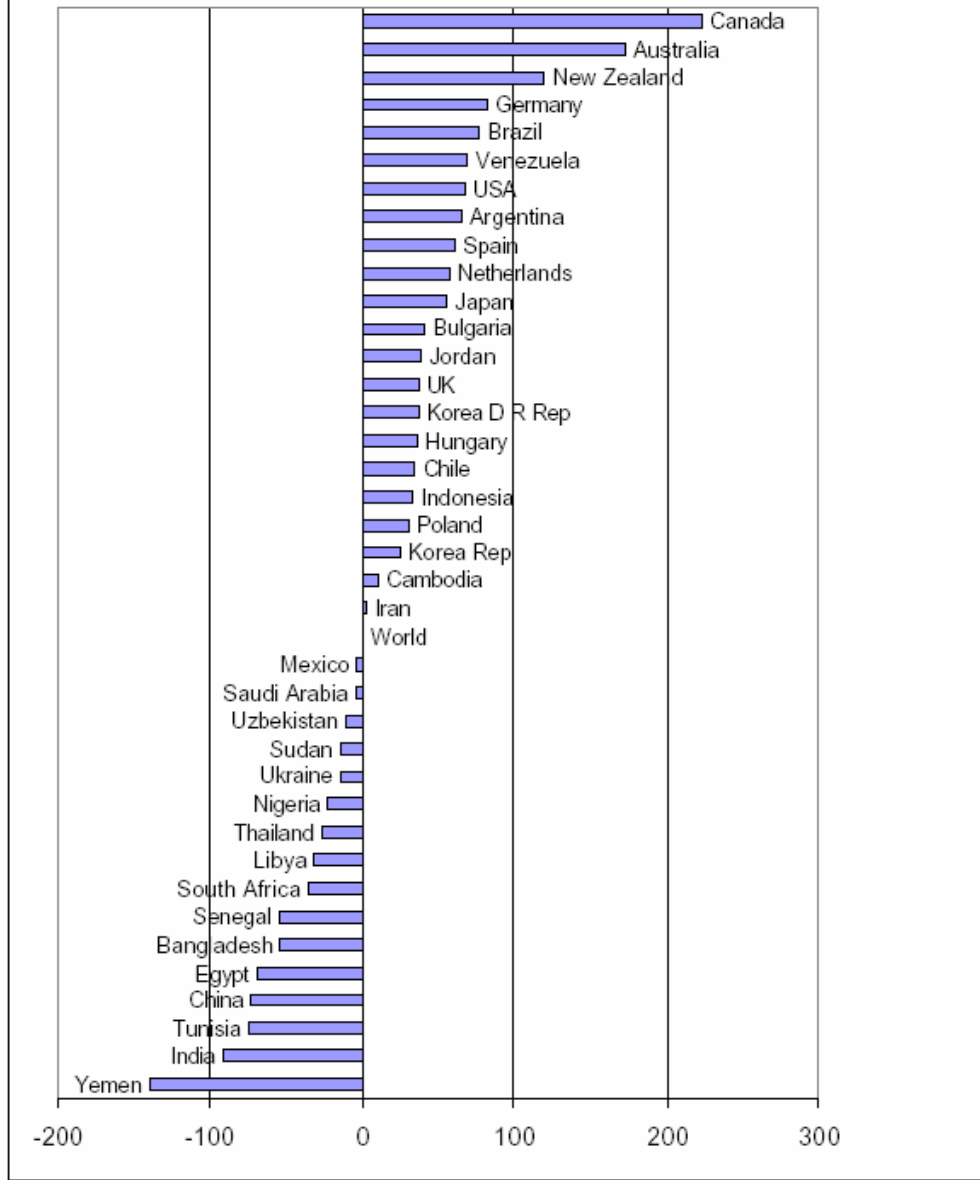


Figure ES-2. Vulnerability-Resilience Indicators; proxies indexed against world data

Discussion themes

1. Scale issues: what is the best scale for measuring and intervening?

- Capacity building:

- Neoliberal institutionalism vs. state-led redistribute reform
- No-role for the state? Is there such a thing as building adaptive capacity beyond generic capacity building at different scales?

- Bottom up or top down?

- Scale dilemma

2. The nature of coupled systems

- analytical category or depiction of reality?

3. Equity issues in measuring vulnerability