Introduction to climate change risk assessment

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Darren Lumbroso
Climate change background
Climate change impacts in Mauritius
Impacts, adaptation and vulnerability assessment methods
Conclusions
The greenhouse effect

1. Solar radiation passes through the clear atmosphere. 
   - Incoming solar radiation: 343 Watt per m²
   - Outgoing solar radiation: 103 Watt per m²

2. Net incoming solar radiation: 240 Watt per m²

3. Some solar radiation is reflected by the atmosphere and earth’s surface.
   - Outgoing solar radiation: 103 Watt per m²
   - Net outgoing infrared radiation: 240 Watt per m²

4. Solar energy is absorbed by the earth’s surface and warms it...
   - 168 Watt per m²

5. Some of the infrared radiation is absorbed and re-emitted by the greenhouse gas molecules. The direct effect is the warming of the earth’s surface and the troposphere.

6. Some of the infrared radiation passes through the atmosphere and is lost in space.

Sources: Okanagan university college in Canada, Department of geography, University of Oxford, school of geography; United States Environmental Protection Agency (EPA), Washington; Climate change 1995, The science of climate change, contribution of working group 1 to the second assessment report of the intergovernmental panel on climate change, UNEP and WMO, Cambridge university press, 1996.

http://maps.grida.no/go/graphic/greenhouse-effect
Mitigation is vital, but we need to prepare for inevitable climate change.

We are already committed to this from past emissions alone.
Climate variability and change

Climate vs. weather

> Climate describes long term (30-year) average conditions

> Climate change assessments use baseline of 1961 to 1990

> Weather is the daily variation in conditions

The Earth’s climate has changed in the past from “natural” causes e.g.

> Variations in solar radiation (cycles, orbit …)

> Atmospheric composition (volcanic activity)
Climate variability is large and complex

Detection

> There are clear trends in recent global temperature but less evidence for increased rainfall and river flows

Attribution

> We can not attribute individual extreme events to climate change but changing patterns of these events can be linked to warmer conditions (see IPCC SREX reports)
Natural catastrophes worldwide 2010

960 loss relevant events in 2010

- Volcanic eruption
  - Island, March/April
- Winter Storm Xynthia, storm surge
  - Western Europe, 26 – 28 Feb.
- Heat wave/Wildfires
  - Russia, July - Sept.
- Earthquake
  - China, 13 April
- Landslides, flash floods
  - China, 7 Aug.
- Floods, flash floods, landslides
  - China, 13 – 29 June
- Typhoon Megi
  - China, Philippines, Taiwan, 18 – 24 Oct.
- Floods
  - Eastern Europe, 2 – 12 June
- Floods, flash floods
  - Pakistan, July - Sept.
- Hailstorms, severe storms
  - Australia, 22 March/6 – 7 March
- Earthquake
  - New Zealand, 4 Sept.

○ Natural catastrophes
○ Selection of significant loss events (see table)
- Geophysical events
  - (earthquake, tsunami, volcanic activity)
- Meteorological events
  - (storm)
- Hydrological events
  - (flood, mass movement)
- Climatological events
  - (extreme temperature, drought, wildfire)
The climate is changing

Scientific basis

> UN Inter-governmental Panel on Climate Change (IPCC)
> Peer-reviewed science
> Special report on emissions scenarios (SRES)
> IPCC WG2 Special Report on Extremes (SREX)

Political consensus

> UNFCCC, World Bank, African Development Bank
~promotion of climate change adaptation
> National commitments, e.g. UK Climate Change Act
Mauritius climate change committee
Four SRES Climate scenarios: Summary characteristics

(A adapted from IPCC, 2007)
Effect of human activity since 1750s has been one of warming

> very high confidence (9/10)

Increased rate of rise of global average sea level from C19th to C20th

> high confidence (8/10)

Atmospheric water vapour content over land and oceans has increased since 1980s, broadly consistent with the extra vapour warmer air can hold
Some projections: Table SPM-1

Trend for 21st SRES scenarios:

- Frequency / proportion of total rainfall in heavy precipitation events increases over most areas
  - Very likely (> 90%)

- Intense tropical cyclone activity increases
  - Likely (>66%)

- Increased incidence of high sea levels
  - Likely (>66%)
Projected Patterns of Precipitation Changes
Trends in sea level

For Mauritius it has been estimated that the sea level is rising at a rate of 1.2 mm/year (comparable to global mean sea level increase of 1.0 to 2.0 mm per year during this century)

Impacts in Europe: Trends in river flows


Percent change in average seasonal trend component from 1978 to 1990 and 1991 to 2003 for different regions. The number in parentheses is the number of sites used to determine the percent change interval. (Wade et al., 2006)
Impacts in Europe: Changes in river discharge

Changes in peak discharge in Europe (2071-2100, SRES A2)

Uncertainty *****

Natural variability

> reconcile summer flooding and winter drought

Flood risk

> what about pathways and receptors?

Source: Dankers and Feyen, 2008.
Projected average changes in peak flood flows in the UK

<table>
<thead>
<tr>
<th>River Thames, England</th>
<th>Low estimate</th>
<th>Mid estimate</th>
<th>High estimate</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>p10</td>
<td>p50</td>
<td>p90</td>
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<tr>
<td>2020s</td>
<td></td>
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</tr>
<tr>
<td>Medium Emissions</td>
<td>0</td>
<td>7</td>
<td>23</td>
</tr>
<tr>
<td>2050s</td>
<td>0</td>
<td>14</td>
<td>35</td>
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<tr>
<td>Low Emissions</td>
<td>0</td>
<td>17</td>
<td>38</td>
</tr>
<tr>
<td>Medium Emissions</td>
<td>0</td>
<td>22</td>
<td>50</td>
</tr>
<tr>
<td>High Emissions</td>
<td>5</td>
<td>30</td>
<td>60*</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Solway, Scotland</th>
<th>p10</th>
<th>p50</th>
<th>p90</th>
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</thead>
<tbody>
<tr>
<td>2020s</td>
<td></td>
<td></td>
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<tr>
<td>Medium Emissions</td>
<td>6</td>
<td>15</td>
<td>24</td>
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<tr>
<td>2050s</td>
<td>11</td>
<td>22</td>
<td>35</td>
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<tr>
<td>Low Emissions</td>
<td>11</td>
<td>23</td>
<td>40</td>
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<tr>
<td>Medium Emissions</td>
<td>11</td>
<td>27</td>
<td>50</td>
</tr>
<tr>
<td>High Emissions</td>
<td>19</td>
<td>38</td>
<td>60*</td>
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</tbody>
</table>

Based on research completed by CEH (Reynard, et al., 2009; Kay et al., 2010).
Projected Climate Change in Mauritius

Trends

> Continue to get warmer

> Cyclones likely to become more intense; however, there are uncertainties regarding changes in frequencies

> Sea levels will continue to rise.

Extremes

> Some extremes become more common while others become less common

> more very hot days

> fewer very “cold” nights
http://www.geog.ox.ac.uk/research/climate/projects/undp-cp/
Changes in average precipitation
Changes in maximum daily rainfall of between -7 and +26 mm for the 2090s (low confidence)

More detailed regional climate modelling or statistical downscaling is needed
Character of change

Average annual precipitation
Seasonality – precipitation, soil moisture deficits (SMDs), flow, recharge
Rainfall intensity
Extremes – rainfall, SMD, flow, recharge

- Joint probability with pre-event conditions

Changes in Sources-Pathways-Receptors - coupling to other processes

- Vegetation and resistance
- Morphology
- Secondary influences of temperature (wetting and drying of earth embankments)

Considerable uncertainty in any risk assessment

- Scenarios, sensitivity analysis → probabilistic risk assessment??
Potential effects on structures

Bridges

- General scour exposes foundations
- Enhanced local scour from change in
  - sediment load
  - planform and angle of attack
- Increased potential for blockage

Embankments – changes in

- Velocity against embankment
- Planform leading to undercutting of toe
- Composition and resistance of natural protection
- Cracking of embankment soils
- Landslides
Potential effects on structures

Weirs and sluices

> Sedimentation upstream of weirs
> Energy dissipation at weirs and sluices (local erosion of bed and banks)

Dams

> Capacity of spillways (PMF / PMP)
> Wave overtopping (wind speed and direction)

Coastal protection

> Wave overtopping, erosion
Potential effects on road drainage

Quantity

> Increased flooding from existing systems
> Change in relative effectiveness of storage and infiltration solutions
> Erosion and landslide risks
> Reduction of dry weather flows = less dilution

Quality

> Increase in pollution from “first flush”
> Consequential impacts on water treatment requirements and receiving watercourses
Conclusions

Climate change

> more intense hydrological cycle
> sea level rise
> impacts on flood risk – surface water, fluvial, groundwater, coastal

Understand natural variability

Consider hydrological processes

Need to manage risks and uncertainties
So in the future….

Use current best science available

Adaptation

> Ensure good design to cope with current extremes
> Design for unavoidable changes
> Test sensitivity for a wide range of changes
> Consider costs and impacts

Greater resilience

> Precautionary approach
> Design to reduce flood and erosion risk
Approaches and tools

Precautionary allowances

- Extreme rainfall
- Peak flow

Local climate impacts profiles – monitoring and recording weather impacts

Risk screening and prioritisation of actions needed

Impacts and risk assessment

Guidance materials and methods for linking climate change to engineering design

Design codes and regulations (research needed first)
Decision making methods
UK Climate Impacts Programme Framework

1. Identify problem and objectives
2. Establish decision-making criteria, receptors, exposure units and risk assessment endpoints
3. Assess risk
4. Identify options
5. Appraise options
6. Make decision
7. Implement decision
8. Monitor

Problem defined correctly?
Yes

Criteria met?
Yes
African Development Bank
Climate safeguards system
http://www.climateadaptation.cc/download-center/
Questions and discussion
Understanding damages and losses due to climate change

Our economy, society and environment are all significantly affected by the climate, especially climate variability and extremes.

- Extreme events cause great social and economic disruption.
- We have cutting edge climate science, but surprisingly little good information on risks, i.e. how society, the economy and the environment will be affected.
- Knowing the risks helps us prepare and plan, i.e. to build resilience to climate risks into long-term decisions and so minimise future costs and disruption.
## Methods

<table>
<thead>
<tr>
<th>Approach</th>
<th>Impact</th>
<th>Vulnerability</th>
<th>Adaptation</th>
<th>Integrated</th>
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</thead>
<tbody>
<tr>
<td><strong>Scientific objectives</strong></td>
<td>Impacts and risks under future climate</td>
<td>Processes affecting vulnerability to climate change</td>
<td>Processes affecting adaptation and adaptive capacity</td>
<td>Interactions and feedbacks between multiple drivers and impacts</td>
</tr>
<tr>
<td><strong>Practical aims</strong></td>
<td>Actions to reduce risks</td>
<td>Actions to reduce vulnerability</td>
<td>Actions to improve adaptation</td>
<td>Global policy options and costs</td>
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<tr>
<td><strong>Research methods</strong></td>
<td>Standard approach to CCIAV</td>
<td>Vulnerability indicators and profiles</td>
<td></td>
<td>Integrated assessment modelling</td>
</tr>
<tr>
<td></td>
<td>Drivers-pressure-state-impact-response (DPSIR) methods</td>
<td>Past and present climate risks</td>
<td></td>
<td>Cross-sectoral interactions</td>
</tr>
<tr>
<td></td>
<td>Hazard-driven risk assessment</td>
<td>Livelihood analysis</td>
<td></td>
<td>Integration of climate with other drivers</td>
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<td>Agent-based methods</td>
<td></td>
<td>Stakeholder discussions</td>
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<td>Narrative methods</td>
<td></td>
<td>Linking models across types and scales</td>
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<tr>
<td></td>
<td></td>
<td>Risk perception including critical thresholds</td>
<td></td>
<td>Combining assessment approaches/methods</td>
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<td>Development/sustainability policy performance</td>
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<tr>
<td></td>
<td></td>
<td>Relationship of adaptive capacity to sustainable</td>
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<tr>
<td></td>
<td></td>
<td>development</td>
<td></td>
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<tr>
<td><strong>Spatial domains</strong></td>
<td>Top-down</td>
<td>Bottom-up</td>
<td></td>
<td>Linking scales</td>
</tr>
<tr>
<td></td>
<td>Global → Local</td>
<td>Local → Regional (macro-economic approaches are top-down)</td>
<td></td>
<td>Commonly global/regional</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Often grid-based</td>
</tr>
<tr>
<td><strong>Scenario types</strong></td>
<td>Exploratory scenarios of climate and other factors (e.g. SRES)</td>
<td>Socio-economic conditions</td>
<td>Baseline adaptation</td>
<td>Exploratory scenarios: exogenous and often endogenous (including feedbacks)</td>
</tr>
<tr>
<td></td>
<td>Normative scenarios (e.g. stabilisation)</td>
<td>Scenarios or inverse methods</td>
<td>Adaptation analogues from history, other locations, other activities</td>
<td>Normative pathways</td>
</tr>
<tr>
<td><strong>Motivation</strong></td>
<td>Research-driven</td>
<td>Research-/stakeholder-driven</td>
<td>Stakeholder-/research-driven</td>
<td>Research-/stakeholder-driven</td>
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</table>
Main elements of impacts framework (UNFCCC V&A assessment guidance)

Baseline Scenarios
- Population
- GNP
- Technology

Climate change scenarios

Biophysical impacts

Socio-economic impacts

Autonomous adaptation
Integration

Vulnerability

Purposeful adaptations
**CCRA Method Overview**

1. Choose priority risks

2. Assess sensitivity of each risk to current climate

3. Add projections of future climate/population for each risk

4. Compare by area for each risk

5. Assign magnitude (logarithmic scale) and confidence scores to each risk

6. Compare scores of all risks

<table>
<thead>
<tr>
<th>Magnitude</th>
<th>Low</th>
<th>Medium</th>
<th>High</th>
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<tbody>
<tr>
<td>Social</td>
<td>100s</td>
<td>1000s</td>
<td>Millions</td>
</tr>
<tr>
<td>Economic</td>
<td>£1 M</td>
<td>£10 M</td>
<td>£100 M</td>
</tr>
<tr>
<td>Env.</td>
<td>100km</td>
<td>1000km</td>
<td>10,000km</td>
</tr>
</tbody>
</table>

% change in DO, Dry scenario:
- -20% to -16%
- -16% to -12%
- -12% to -8%
- -8% to -6%
- -6% to -4%
- -4% to -2%
- -2% to -1%
- 0% to 1%
- 1% to 2%
- 2% to 4%
- 4% to 6%
- 6% to 10%
Stage 3: Assess Risks

- Scoping and selecting
- Understanding sensitivity
- Assessing future risks
- Reporting
Carbon Cycle

http://maps.grida.no/go/graphic/carbon_cycle
Atmospheric CO$_2$ at Mauna Loa Observatory

Scripps Institution of Oceanography
NOAA Earth System Research Laboratory

PARTS PER MILLION


YEAR

February 2010
Global temperature change: EC Ensembles Project SRES A1B scenario

Warming leads to an intensification of the hydrological cycle

4 degrees roughly equal to 5 percent increase in precipitation
European Summer 2003 heat wave

European summer temperatures

Source: Peter Stott, Hadley Centre

normal by 2040s: cool by 2080s
Analytical steps and supporting assessments

1. Scoping (Tier 1)
2. Policy risk mapping
3. Tier 2 Selection
4. Systematic mapping
5. Social vulnerability checklist
6. Adaptive capacity assessment
7. Risk metrics
8. Consequence-response functions
9. Climate projections
10. Socio-economic futures
11. Autonomous adaptation
12. Monetisation
13. Results – maps and tables
14. Report
15. Tier 3

All Tier 1 consequences retained for final reports