Floods a costly problem

Santa Catarina flood map
1 in 100 years return period

Flood maps can be used in combination with georeferenced datasets of assets of different types, like road networks, production plants, public infrastructure, real estate and so on.

As such, State or national institutions can benefit from the information provided in order to prioritize areas for DRM interventions and investment across the state or to promote private developments in safe zones, for example.
Santa Catarina is exposed to recurrent disaster events, among which floods play a major role. The economic effects of such events as indicated by a historical data base1 which shows that damage and losses are significant and, at the same time, the state’s financial response capacity is still limited. That is, while over the years the state has shown significant progress in disaster risk management (DRM) and has been, in fact, a benchmark in Brazil, still there is room to significantly improve its DRM strategy.

And while the historical records shown are extremely valuable for DRM planning, adopting a forward-looking approach is necessary for the design and update of a DRM strategy based on the following pillars of action: (i) risk identification, (ii) risk reduction, (iii) preparedness, (iv) financial protection, and (v) resilient recovery.

With the above DRM framework in mind, a study combined an investigation of the historical patterns of natural hazards (and its effects) in Santa Catarina with a catastrophe flood risk model to deliver a state-level knowledge base for DRM planning.

The Annual Average Loss (AAL) represents an average sum of the annual losses calculation. It is the mean value of a loss exceedance probability (EP) distribution. It represents the expected loss per year, averaged over many years. The one-year return period loss is expected to be equaled or exceeded every year. Its exceedance probability is therefore 100%.

Santa Catarina State in Numbers

The state of Santa Catarina in Southern Brazil may be associated with different parts of the world, with its territory size equivalent to Hungary and population size similar to Paraguay. The state is affected by a great diversity of natural adverse events: droughts, floods, flash floods, hail, mass movements, windstorm, tornado, coastal erosion and the only hurricane recorded in Brazil so far.

Note that the eastern regions of the state have the most populous municipalities of the state and concentrates over 42% of the state’s population and it is heavily impacted by natural disasters as shown latter in hazard modeling step of the study.
Floods: a costly problem

From 1995 to 2014, there were more than 2,704 reports of damages and losses due to natural disasters in Santa Catarina. There were significant annual peaks in the number of records, which reflects events of greater magnitude. On average, 135 events were recorded per year. The Western and Southern regions presented a slightly greater incidence of events.

Only in the events of Nov 2008, flooding affected about 73 municipalities and over 1.5 million people. At least 135 people were killed, over 78,700 forced to evacuate their homes, 27,400 people left homeless, 7,154 homes were completely destroyed (CEPED UFSC 2016) and 186,000 left without electricity for weeks (BBC 2008).

**Major Natural Disasters**

<table>
<thead>
<tr>
<th>Event</th>
<th>Municipalities Affected</th>
<th>Damages and Losses</th>
</tr>
</thead>
<tbody>
<tr>
<td>Catarina Hurricane 2004</td>
<td>14</td>
<td>R$ 376.6 BI</td>
</tr>
<tr>
<td>Drought 2004-2005</td>
<td>163</td>
<td>R$ 1,763.1 BI</td>
</tr>
<tr>
<td>Floods Vale do Itajaí 2008</td>
<td>73</td>
<td>R$ 4,684.2 BI</td>
</tr>
<tr>
<td>Floods September 2011</td>
<td>58</td>
<td>R$ 1,093.6 BI</td>
</tr>
<tr>
<td>Floods Vale Itapocu 2014</td>
<td>4</td>
<td>R$ 327.4 BI</td>
</tr>
</tbody>
</table>

**Impacts of Natural Disasters**

- **Population Affected**: 13.5 million
- **Housing Damage**: 746,000 people were displaced
- **Economic Losses**: $17.64 billion

**Average Annual Losses Reported as GDP % of Municipalities**

- Vargem: 10.8%
- Abdon Batista: 0.3%
- Celso Ramos: 10.1%
- Alto Bela Vista: 2.4%

**Municipalities with Greater Reported Losses**

- Joinville: R$ 340.6M
- Blumenau: R$ 3.763.1B
- Itajaí: R$ 1.4B
- Gaspar: R$ 1.8B

**Losses Reported**

- **Distribution of Damages**
  - 91% Private
  - 9% Public
  - 4% Facilities
  - 63% Infrastructure damages
  - 33% Housing damages

**Losses by Type**

- R$ 12,41 Bln
- R$ 5,23 Bln

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*National Secretariat of Protection and Civil Defense. Data from disaster records reported by municipalities to the state Civil Defence agency or the National Protection Bureau and Civil Defense - SEDEC. 6,464 records were employed, of which 2,704 informed economic losses.*
NATURAL DISASTERS  DISTRIBUTION OF DAMAGE AND LOSSES ACCORDING TO DISASTER TYPE

Hydrological disasters are related to floods, mudslides and landslides. Meteorological disasters are those of sudden origin, windstorms, tornadoes, hurricanes, among others.

Climatological disasters are related to drought.

Floods: a costly problem

The approach for this study was to use well-established Revitalised ‘Flood Studies Report / Flood Estimation Handbook’ (FSR/FEH) rainfall-runoff Method (ReFH).

Validation

The model was validated against historic data from previous flood events in the State.

The hydrological modeling, hydraulic modeling, and results validation, are the main components of a flood hazard model.

Hydrological modelling is where we use a variety of techniques or local science to figure out ‘how much water’ and ‘where to put it’ geographically speaking.

Hydraulic modeling using 2D models, which involves modeling flow over floodplain surface. After flood maps are ready, the results are validated against historical events.

TOTAL RUNOFF HYDROGRAPH FOR A 1000 YEARS RETURN PERIOD

The hydrological modelling, hydraulic modeling, and results validation, are the main components of a flood hazard model.
Flood maps provide an important visualization of the flood-prone areas. These maps are a result of the Flood Hazard Model that aims to better understand floods through a combination of historical data and computer-generated simulations. More generally, at any level, the flood maps can be used in combination with georeferenced datasets of assets of different types, like road networks, production plants, public infrastructure, and so on.

**EXPOSURE AND VULNERABILITY**

Vulnerability in the context of this study is an expression of the tendency of an element or a set of elements to suffer damage when subjected to a hazard.

The impact of a hazard will not be equal in all cases. Impact is highly dependent on the characteristics of the asset at any given location. Some property construction types are more vulnerable to flooding.

### VULNERABILITY OF VARIOUS TYPES OF BUILDING

The impact of hazard is not equal in all cases. Some property construction types are more vulnerable to flooding. The vulnerability of various property types in Santa Catarina was researched. A series of curves relating Mean Damage Ratio (MDR) to flood intensity (depth) was produced. It allows exposure portfolios to be parameterised to reflect characteristics of insured assets.

- **Mean Damage Ratio (MDR)**
  
  \[ \text{MDR} = \frac{\text{Average Cost of Repair}}{\text{Cost Replacement Value Sum}} \]

- **Percentage of the total monetary value of replacement/reconstruction.**

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*Percentage of the total monetary value of replacement/reconstruction.*
Floods: a costly problem

Exposure

Census derived economic data for regional areas, delineated in blue has been associated with urban areas and further split into a grid. This layer was intersected with Flood Hazard maps. This returned the percentage to the exposure cell is flooded and the average flood depth intensity affecting that cell.

A Catastrophe (CAT) model is an automated model that generates a set of simulated events. Each simulation carries estimations of the magnitude, intensity, and location of an event to determine the amount of damage and calculate the probable loss as a result of an extreme event. (Lloyd’s Market Association 2013).

Complementary, we intersected the flood hazard layer (map) with census derived economic data for regional areas (built value).

Delineated in blue is the flood map which is associated with urban areas and further split into a grid.

In this way the census data is finely disaggregated and the spatial resolution of the results are improved.

Floods and Financial Loss in SC

A Catastrophe (CAT) model is an automated model that generates a set of simulated events. Each simulation carries estimations of the magnitude, intensity, and location of an event to determine the amount of damage and calculate the probable loss as a result of an extreme event. (Lloyd’s Market Association 2013).

Complementary, we intersected the flood hazard layer (map) with census derived economic data for regional areas (built value).

Delineated in blue is the flood map which is associated with urban areas and further split into a grid.

In this way the census data is finely disaggregated and the spatial resolution of the results are improved.

Damage Curves for Brazil Specific Building Types

<table>
<thead>
<tr>
<th>Building OCC</th>
<th>Const.</th>
<th>Stand.</th>
</tr>
</thead>
<tbody>
<tr>
<td>RP</td>
<td>HOUSE</td>
<td>1.000</td>
</tr>
<tr>
<td>R1-B</td>
<td>HOUSE</td>
<td>0.900</td>
</tr>
<tr>
<td>R1-N</td>
<td>HOUSE</td>
<td>0.800</td>
</tr>
<tr>
<td>R1-A</td>
<td>HOUSE</td>
<td>0.700</td>
</tr>
<tr>
<td>R1-B</td>
<td>APART.</td>
<td>0.600</td>
</tr>
<tr>
<td>R1-N</td>
<td>APART.</td>
<td>0.500</td>
</tr>
<tr>
<td>R1-A</td>
<td>APART.</td>
<td>0.400</td>
</tr>
<tr>
<td>CM</td>
<td>HOUSE</td>
<td>MOSS</td>
</tr>
<tr>
<td>TA</td>
<td>HOUSE</td>
<td>CLAY</td>
</tr>
<tr>
<td>PA</td>
<td>HOUSE</td>
<td>STRAW</td>
</tr>
</tbody>
</table>

Floods and Financial Loss in SC

<table>
<thead>
<tr>
<th>Municipality</th>
<th>Average Annual Loss</th>
</tr>
</thead>
<tbody>
<tr>
<td>Curitiba</td>
<td>R$ 100,115,000</td>
</tr>
<tr>
<td>Palhoça</td>
<td>R$ 42,905,000</td>
</tr>
<tr>
<td>Blumenau</td>
<td>R$ 39,102,000</td>
</tr>
<tr>
<td>Navegantes</td>
<td>R$ 34,267,000</td>
</tr>
<tr>
<td>Gaspar</td>
<td>R$ 29,454,000</td>
</tr>
<tr>
<td>Jaraguá do Sul</td>
<td>R$ 27,507,000</td>
</tr>
<tr>
<td>Guaramirim</td>
<td>R$ 24,356,000</td>
</tr>
<tr>
<td>Jundiaí</td>
<td>R$ 20,507,000</td>
</tr>
<tr>
<td>Rio do Sul</td>
<td>R$ 19,356,000</td>
</tr>
<tr>
<td>Tijucas</td>
<td>R$ 13,357,000</td>
</tr>
<tr>
<td>Tubarão</td>
<td>R$ 13,056,000</td>
</tr>
</tbody>
</table>
Looking forward, how much do floods cost at different return periods?

The Aggregate Exceedance Probability (AEP) represents the probability that the total cost of all events within a year will combine to exceed a certain threshold. These figures should be used when assessing gross loss ratios. Bigger flood events occur (and are exceeded) less often and will therefore have a lower annual probability. Note that AEP refers to a loss being exceeded, and not the exact loss itself.

The AEP results show the probability that the total cost of all events in a given year will exceed a certain threshold. Therefore, based on these results there is a 10% chance that all events within any given year will generate losses of R$1.8 billion or more. Events with a 20-year return period could generate losses of R$2.3 billion or higher.

Policy Implications

In the context of this study, macro and complex State activities such as planning and investment decisions would benefit from additional strategic information on disaster risk management that could lead to DRM informed decision-making, inter alia:

- Recommendations on future structural and non-structural flood management options aimed at achieving a reduction in flood damage;
- Use flood maps and probabilistic loss estimates to direct future activity in flood risk reduction;
- The data products can be used to inform decision-making to avoid people settling in flood prone areas as well as to reduce flood risks at established settlements;
- Hazard maps are useful for land use planning to enable zonation of land ensuring that highly vulnerable land use types are not developed within areas which may experience significant flood hazard;
- Inhabitants within hazard zones can be educated and sensitized on the risks they are exposed to and prewarned of an impending flood;
- Hazard and loss data provided can be used to identify locations which present maximum return on investment if flood reduction strategies were to be implemented (structural risk reduction decisions); and
- Use the flood map and loss estimate products as an information source to guide better informed decisions regarding the management of reservoirs as a way of flood defense.

Sources


CEPED UFSC (2016) Relatório dos Danos Materiais e Prejuízos Decorrentes de Desastres Naturais em Santa Catarina, World Bank – Brasilia, Brazil


1.400.000.000
1.600.000.000
1.800.000.000
2.000.000.000
2.200.000.000
2.400.000.000
2.600.000.000
3.000.000.000

Losses (R$)

0
200
400
600
800
1000

Return Period

CONCLUDING REMARKS

This pilot study was part of a Non-lending Technical Assistance to the State of Santa Catarina. The State is exposed to recurrent disaster events, among which floods play a major role. The goal of this study was to capture and expose the economic effects of floods as indicated by the significant historical damage and losses.

To do so, the World Bank Team processed available data through GIS system producing thematic layers. Flood maps were generated identifying ‘hotspots’ for floods (Flood Model). The constructed built volume for the state was analyzed and a cost associated to the volume based on the main construction patterns (Exposure Model). The final step, was to run the Catastrophe (CAT) Model through 10,000 synthetic events simulating the innumerable dynamics between floods, exposure and vulnerability.

The result is seen in probability of a flood event occurring with different magnitudes and how much financial loss may result from such events. Based on these results there is a 10 percent chance that all events within any given year will generate losses of R$1.8 billion or more. Events with a 20-year return period could generate losses of R$2.3 billion or higher. The knowledge generated through this pilot study contributes to the enhancement of a disaster risk management strategy for the State of Santa Catarina.

All values were converted to 2014 values. Exchange rate from the Central Bank of Brazil of 3.2402 – as of Sep 21, 2016.
GLOBAL FACILITY FOR DISASTER REDUCTION AND RECOVERY

The Global Facility for Disaster Reduction and Recovery (GFDRR) is a global partnership that helps developing countries better understand and reduce their vulnerabilities to natural hazards and adapt to climate change. Working with over 400 local, national, regional, and international partners, GFDRR provides grant financing, technical assistance, training and knowledge sharing activities to mainstream disaster and climate risk management in policies and strategies. Managed by the World Bank, GFDRR is supported by 34 countries and 9 international organizations.

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Since 2010, the World Bank has been actively involved in the field of Disaster Risk Management (DRM) with the Government of Brazil through lending operations in the Water, Transport and Urban sectors, technical assistance and knowledge exchange activities.