Classification reliability for GIS-MCDA: AHP and sensitivity analysis

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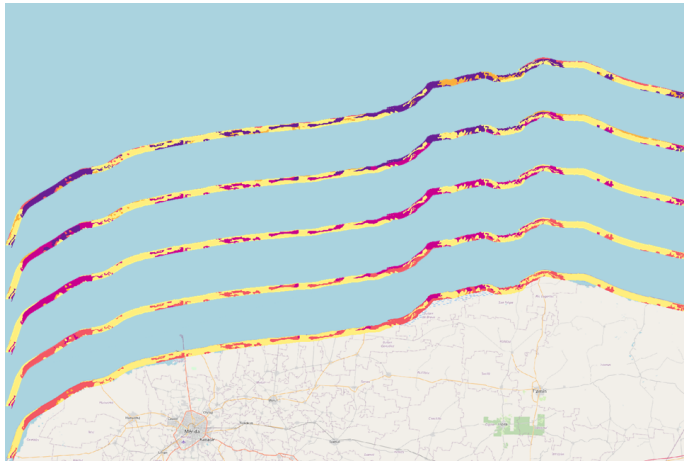
Objective

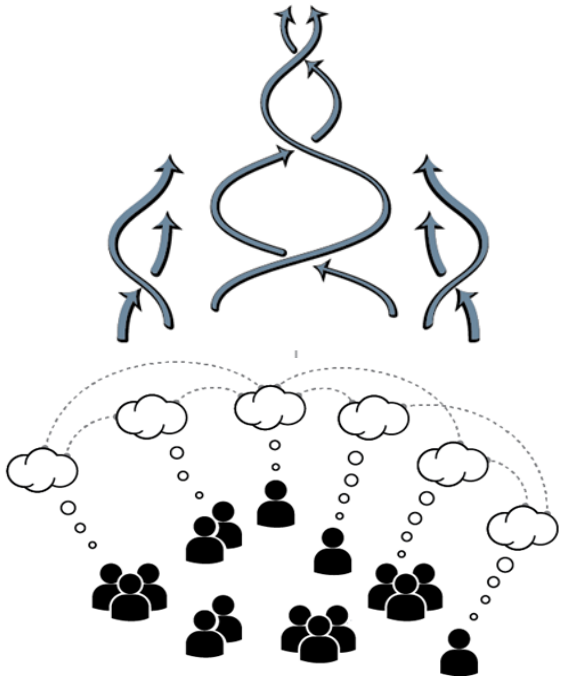
Evaluate the linguistic uncertainty
in the context of AHP-based GIS-MCDA

- This work proposes a systematic method to
  (1) select a classification scheme with spatial meaning and to
  (2) quantify the accuracy of the most sensitive layers, based on a sensitivity analysis (Triantaphyllou and Sánchez, 1997)

- The approach is illustrated through the case of study of coastal vulnerability mapping in Yucatán, México

Linguistic uncertainty





- Classification implies a set of abstractions and subjective reasoning involved in the selection of the most meaningful spatial representations
- Linguistic uncertainty in mapping arises as an outcome of map categories that not only have imprecise meanings but also there meaning is context dependent
- Linguistic uncertainty is particularly important in the context of face to face decision-making processes (Carey and Burgman, 2008).

Methodology

1. Vulnerability index calculation

2. Classification. This step entails producing alternative classification schemes that may include different number of categories and different category cuts

3. Sensitivity analysis for each category
   a) Threshold value test
   b) Feasibility range
   c) Sensitivity coefficient

4. Fine tuning sensitivity analysis for the most sensitive attributes

Vulnerability index: weighted linear combination

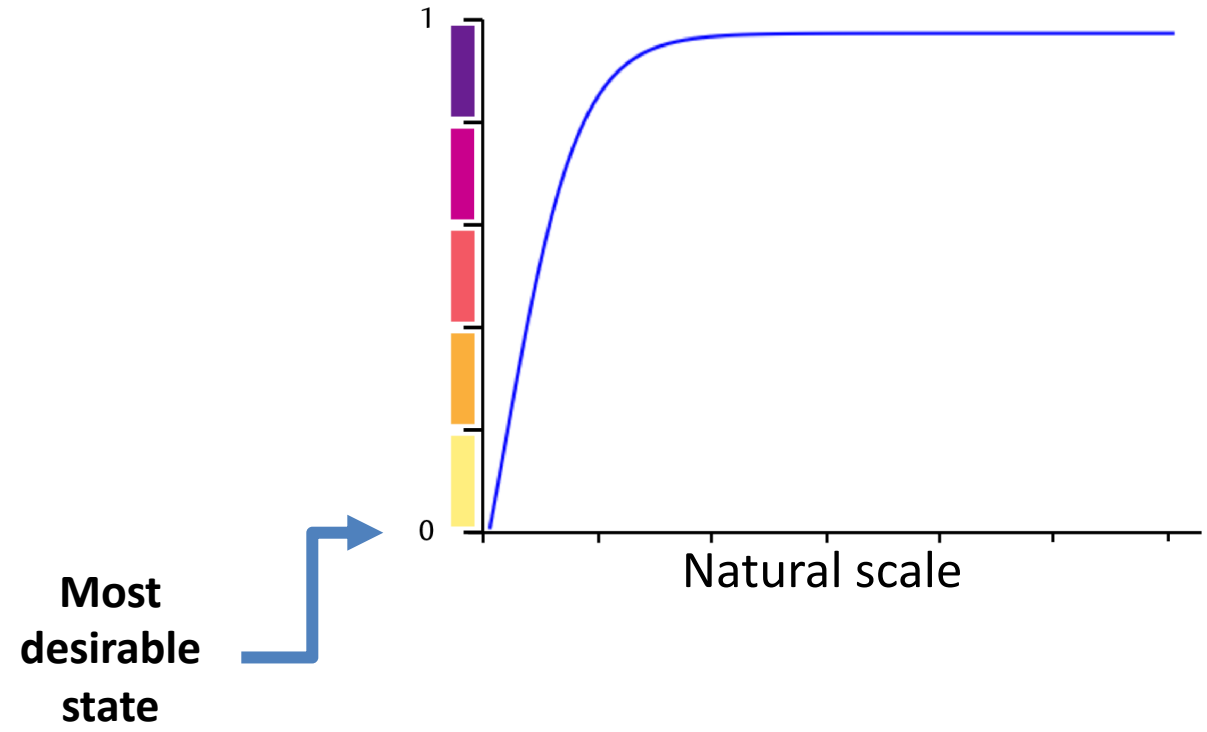
For each basic unit of observation k (i.e., polygon or pixel):

$$V_i^k = \sum_j^J w_{ij}\, x_{ij}^k$$

where

w is the weight of attribute j

x is the standardized score



Sensitivity analysis: threshold value approach

a) Considering the **mean value**, $\bar{V}_i^{\,c}$, of all the spatial units in **each category**, c, the **change** in value of a normalized attribute to be included in another category $\bar{V}_i^{\,c_\rho}$ is obtained as

$$\bar{\tau}_{ij}^{c} = \frac{\bar{V}_i^{c} - \bar{V}_i^{\,c_\rho}}{w_{ij}} \qquad c_\rho \in \mathrm{C} = \{c_1, \ldots, c_n\}$$

where w is the weight of attribute j.

* Based on the work by Triantaphyllou (Triantaphyllou and Sánchez, 1997)

Sensitivity analysis: threshold value approach

b) The **feasibility range** of category switching, in terms of mean normalized score of each land attribute, $\bar{x}_{ij}^{c}$ is given by

$$\bar{x}_{ij}^{c} - 1 \leq \bar{\tau}_{ij}^{c} \leq \bar{x}_{ij}^{c},$$

for attribute j, and category c.

c) The **sensitivity coefficient** is calculated by

$$s_{\mathrm{ij}}^{c} = \frac{1}{|\bar{\tau}_{ij}^{c}|}$$

4. Sensitivity analysis for the most sensitive attributes.

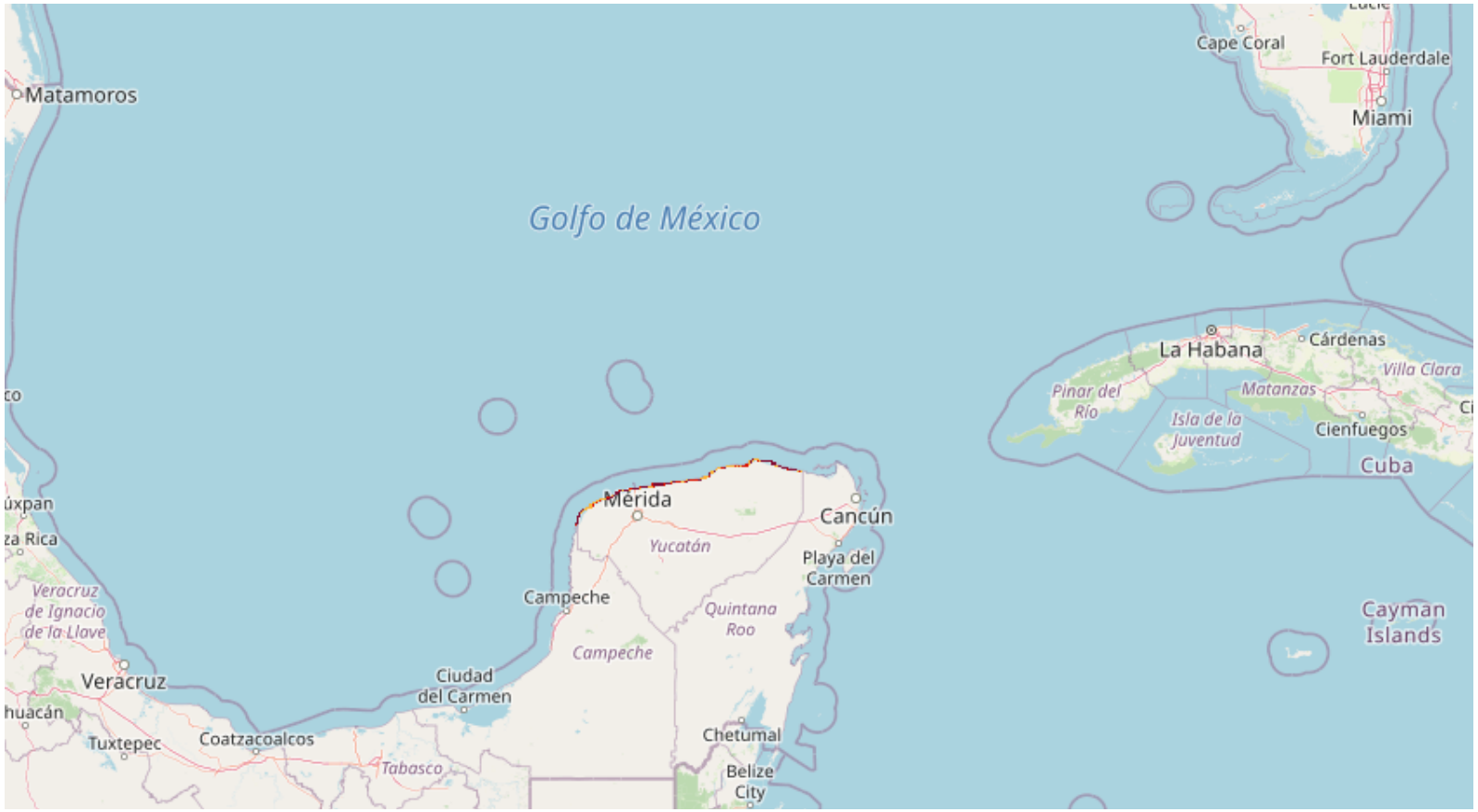
   a) The category with the highest sensitivity coefficient $c^* \in C$ is identified and then is used as input for the sensitivity analysis. For each unit of observation, k, contained in c^*

$$\tau_{ij}^{k} = \frac{V_i^k - V_i^{k_\rho}}{w_{ij}}$$

   where the reference value $V_i^{k_\rho}$ is taken as the minimum value of the reference class, c^ρ.

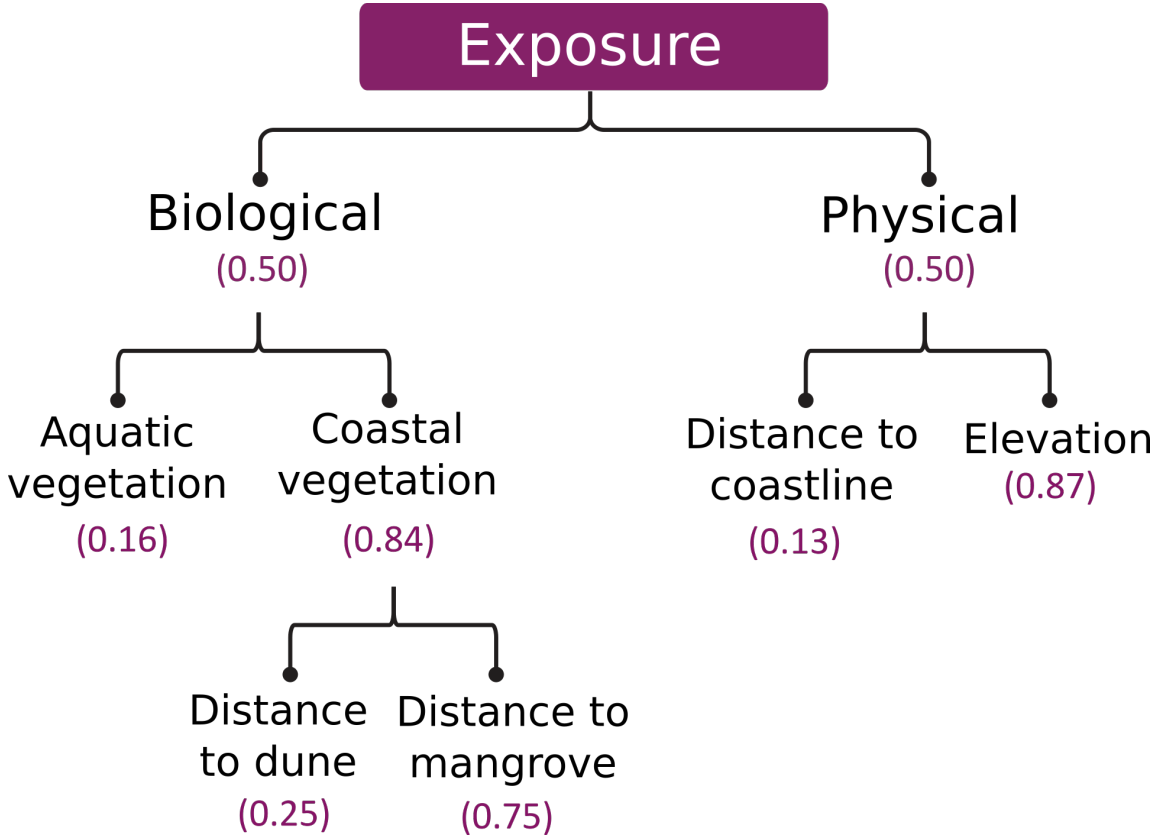
   b) The confusion matrix between the categories $c^*$and c^ρ is used to estimate the errors of omission and commission.

Case of study: Coastal vulnerability index for Yucatán, México



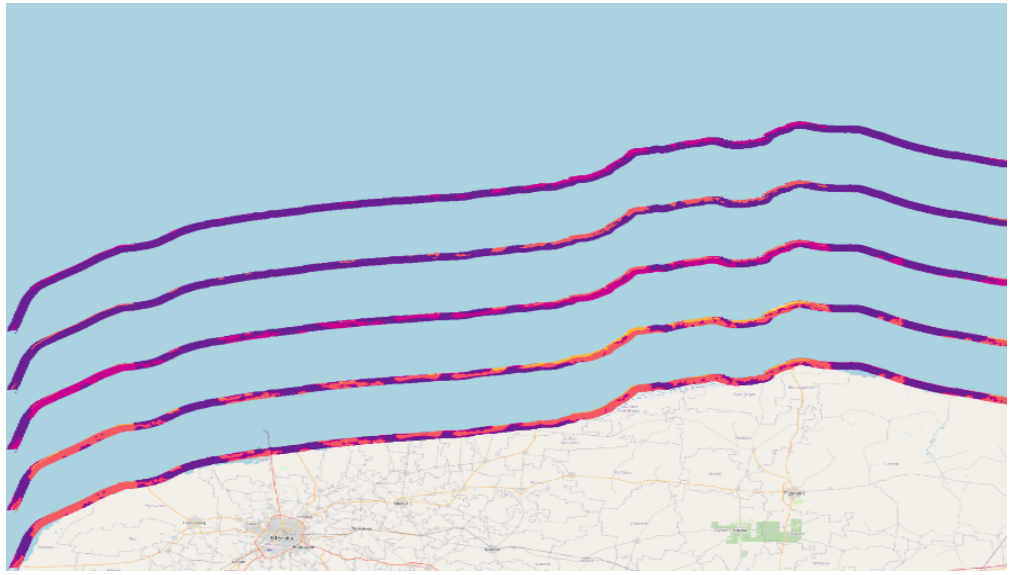
The AHP was applied to generate vulnerability indices for the three components of vulnerability: exposure, sensitivity and resilience

AHP model for exposure to hurricanes

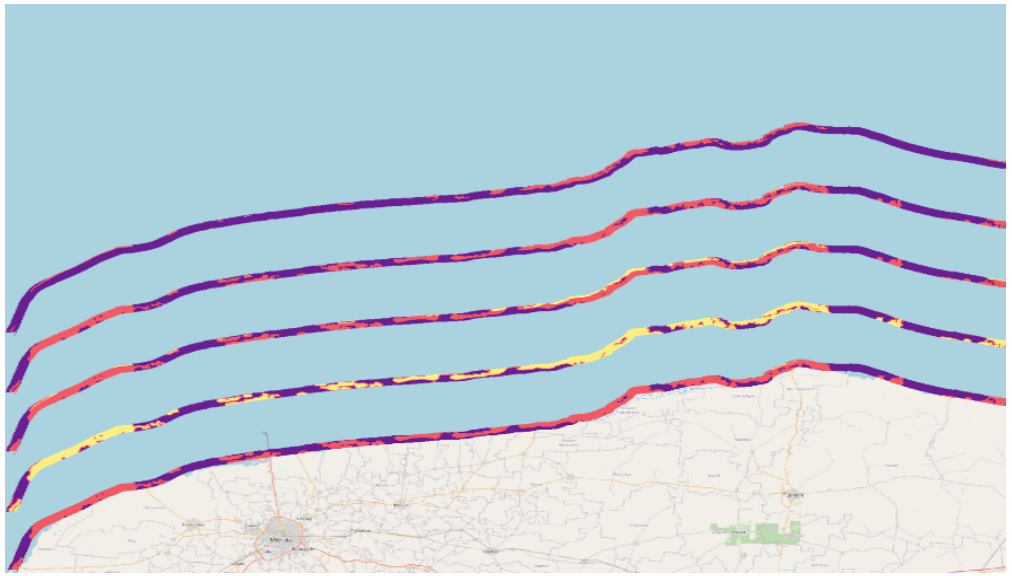


Exposure maps for different classification methods

5 categories



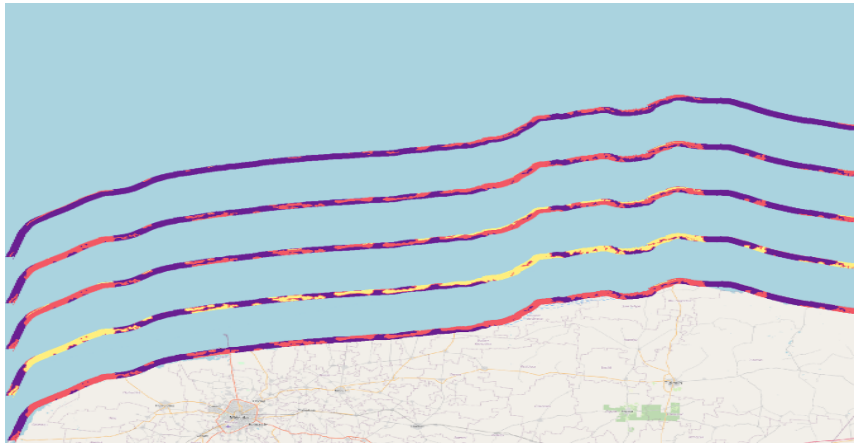
3 categories



Exposure maps for different classification methods

Progression factor	Class	Number of pixels	min	max	mean	median
1.3	Low	44668	0.307	0.717	0.658	0.675
	Medium	14126	0.717	0.84	0.777	0.776
	High	38870	0.84	1	0.950	0.968
1.5	Low	7000	0.307	0.615	0.589	0.598
	Medium	43917	0.615	0.769	0.681	0.68
	High	46747	0.769	1	0.926	0.948
1.7	Low	521	0.307	0.546	0.522	0.53
	Medium	43793	0.547	0.714	0.659	0.675
	High	53350	0.714	1	0.903	0.928
2	Low	26	0.307	0.479	0.431	0.455
	Medium	14454	0.481	0.653	0.613	0.616
	High	83184	0.653	1	0.823	0.817

3 categories



Sensitivity analysis: WF-1.5

The sensitivity test was applied in order to consider the switching between categories:
low and high
and
medium and high

Progression factor	Category switching		Attribute				
	From	to	Aquatic vegetation	Distance to mangrove	Distance to dune	Elevation	Distance to coastline
1.3	Low	High	NF	1.079	NF	NF	NF
	Medium	High	NF	1.821	NF	NF	NF
	High	Low	NF	NF	NF	1.490	NF
	High	Medium	NF	1.821	NF	2.513	NF
1.5	Low	High	NF	NF	NF	NF	NF
	Medium	High	NF	1.285	NF	NF	NF
	High	Low	NF	NF	NF	1.290	NF
	High	Medium	NF	1.285	NF	1.776	NF

Sensitivity coefficient and feasible changes

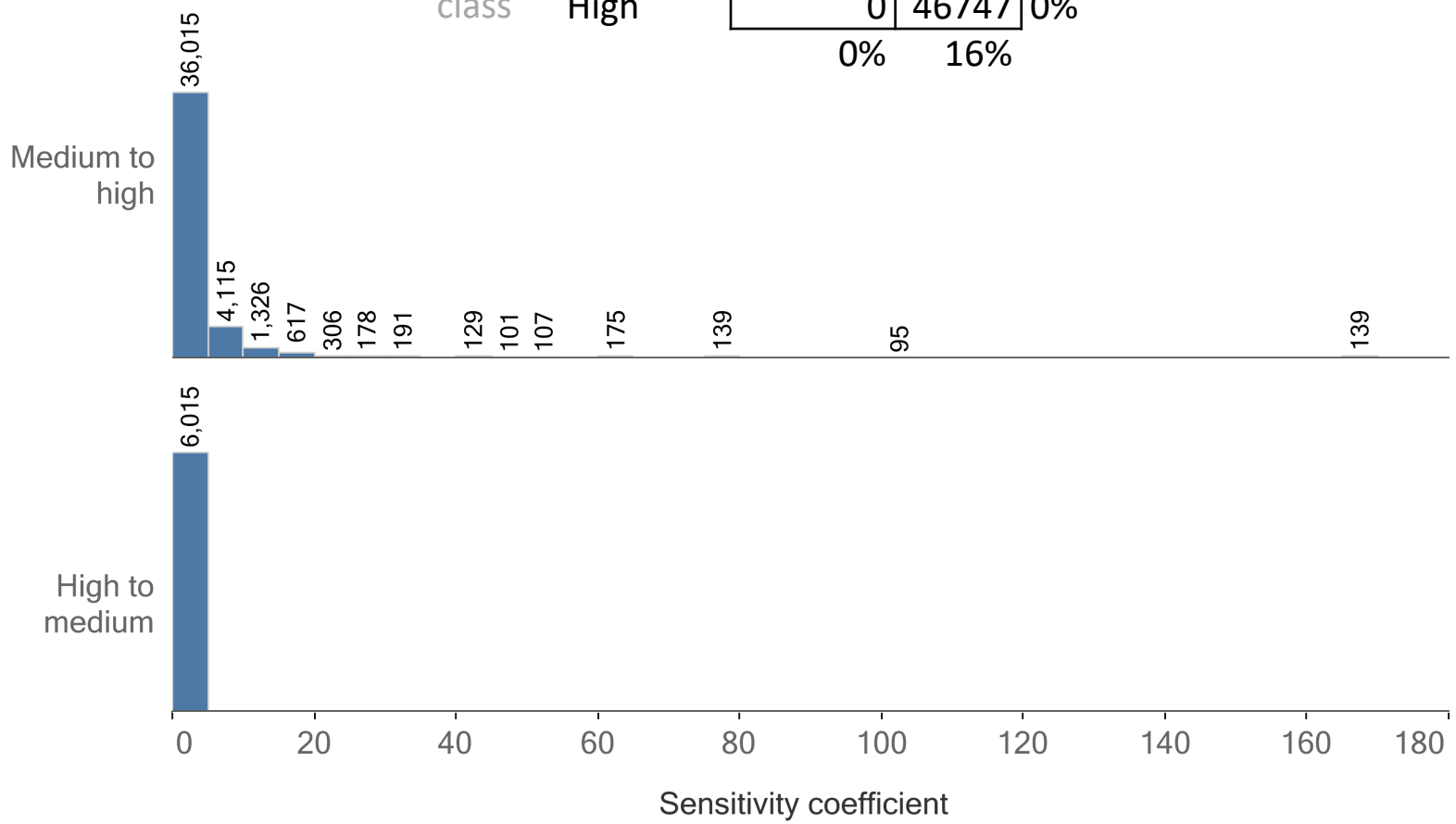
Sensitivity analysis: Distance to mangrove attribute

Progression factor	Category switching		Attribute				
	From	to	Aquatic vegetation	Distance to mangrove	Distance to dune	Elevation	Distance to coastline
1.3	Low	High	NF	1.079	NF	NF	NF
	Medium	High	NF	1.821	NF	NF	NF
	High	Low	NF	NF	NF	1.490	NF
	High	Medium	NF	1.821	NF	2.513	NF
1.5	Low	High	NF	NF	NF	NF	NF
	Medium	High	NF	1.285	NF	NF	NF
	High	Low	NF	NF	NF	1.290	NF
	High	Medium	NF	1.285	NF	1.776	NF

WF 1.5

Confusion matrix for distance to mangrove

Switching class	Reference class: Medium	Reference class: High	
Medium	36299	7618	17%
High	0	46747	0%
	0%	16%	



Conclusions

- The linguistic uncertainty inherent to the participatory workshop was addressed by applying sensitivity analysis to the land classifications.

- Results proved to be useful to the stakeholders in identifying the classification scheme that best conveyed the coastal zone's differential exposure to hurricanes.

- Even though the approach presented here was applied to vulnerability indicators, it can be implemented to any AHP-based GIS-MCDA to

  (1) identify how measurement errors of land attributes affect the classification of maps, and

  (2) select the nominal map that conveys the best representation of a geographic phenomenon

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