Object-oriented Representation and Analysis of Coastal Changes for Hurricane-induced Damage Assessment

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Abstract

Hurricanes and tropical storms represent severe threats to coastal properties, settlements, and infrastructure. The research objects are to:

- Develop an object-oriented conceptual framework for representing hurricane-induced damages
  - Much more concise and explicit representation of damages than grid-based raster representation.
- Develop algorithms to numerically detect and quantify change objects
  - Extract quantitative spatial distributed information about damages for supporting hazard mitigation and recovery activities

Introduction

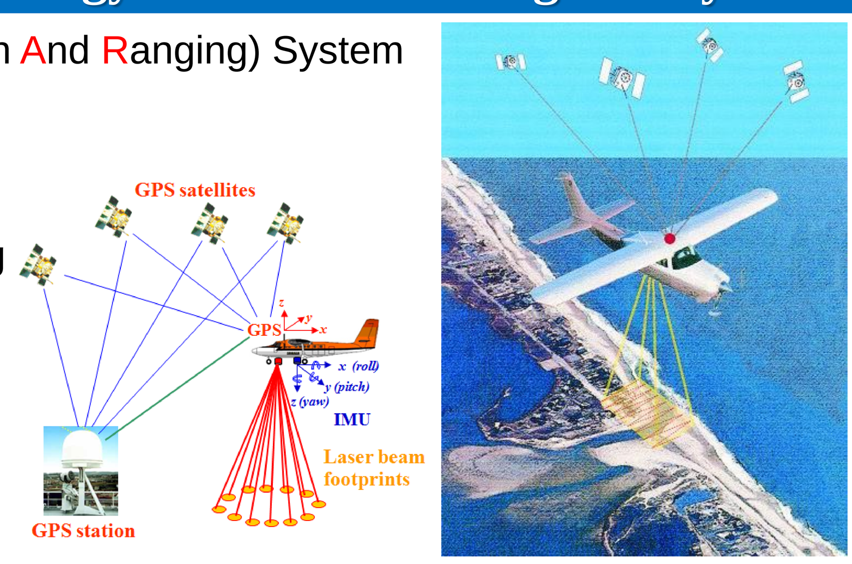
Conventional Methods for Coastal Change Analysis

Ground surveys
- Accurate measurements
- Small spatial coverage
- Time-consuming
- Difficult in inaccessible and hostile environments

Digitizing and interpreting aerial photographs
- High spatial resolution
- Costly and time-consuming
- Labor-intensive

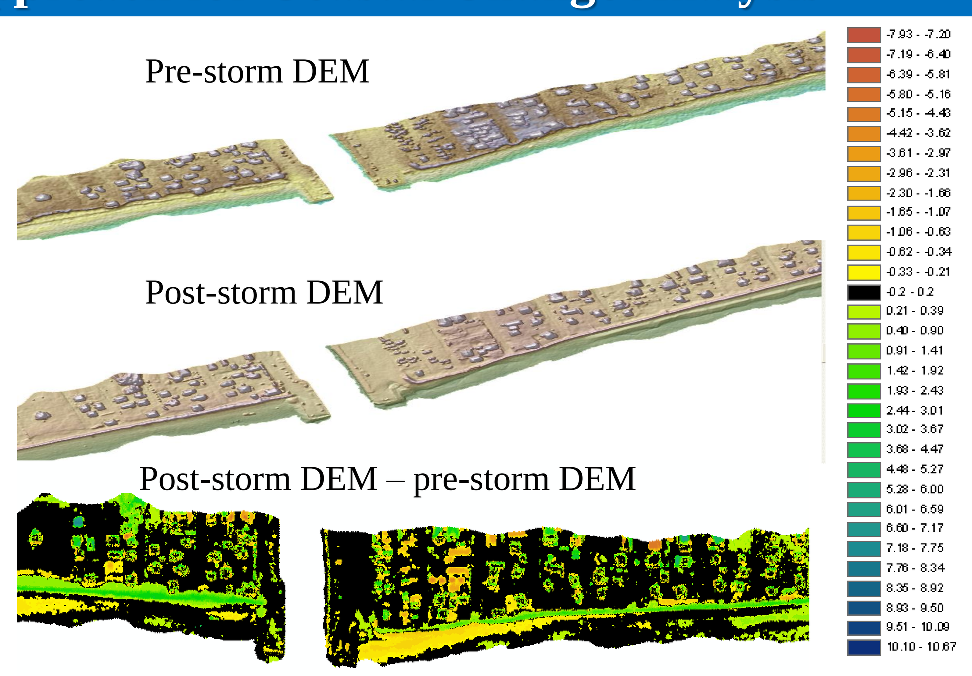
Airborne LiDAR Technology for Coastal Change Analysis

Airborne LiDAR (Light Detection And Ranging) System
- 15 cm vertical accuracy
- 1-2 m spatial resolution
- Cost-effective, rapid mapping



Cell-based Approach for Coastal Change Analysis

Problems:
- Large volume of data associated with raster representation
- No much explicit information about damages
- Difficult to be used for hazard mitigation and post-hurricane recover decision making

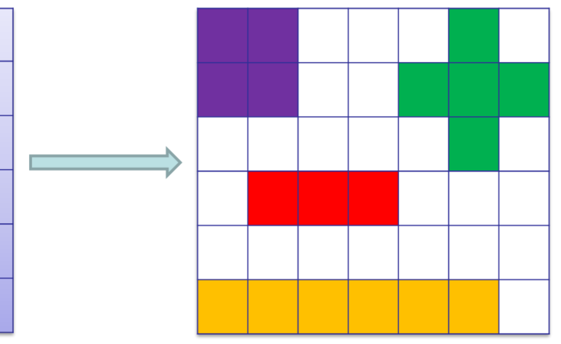


Methodology

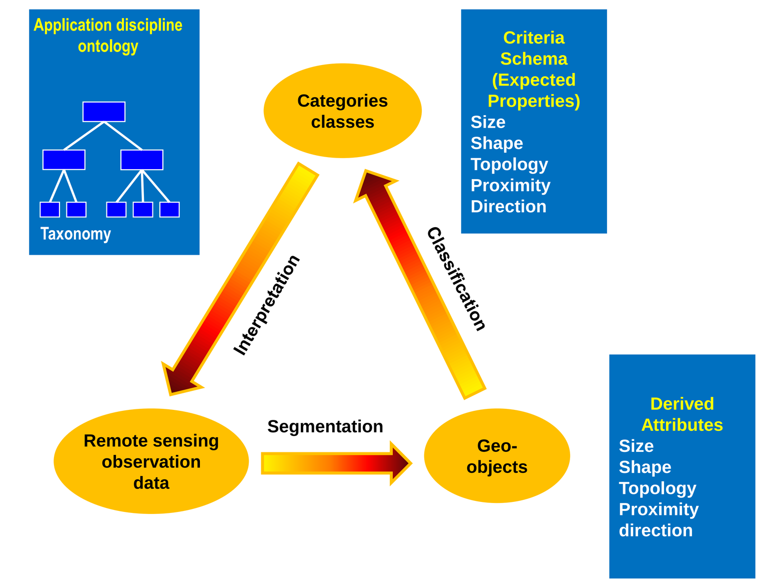
Object-oriented Representation of Change Objects

- Based on elevation difference grid
- Group grid cells into individual change objects based on
  - spatial connectivity (spatially adjacent cells)
  - similarity (similar positive or negative change cells)

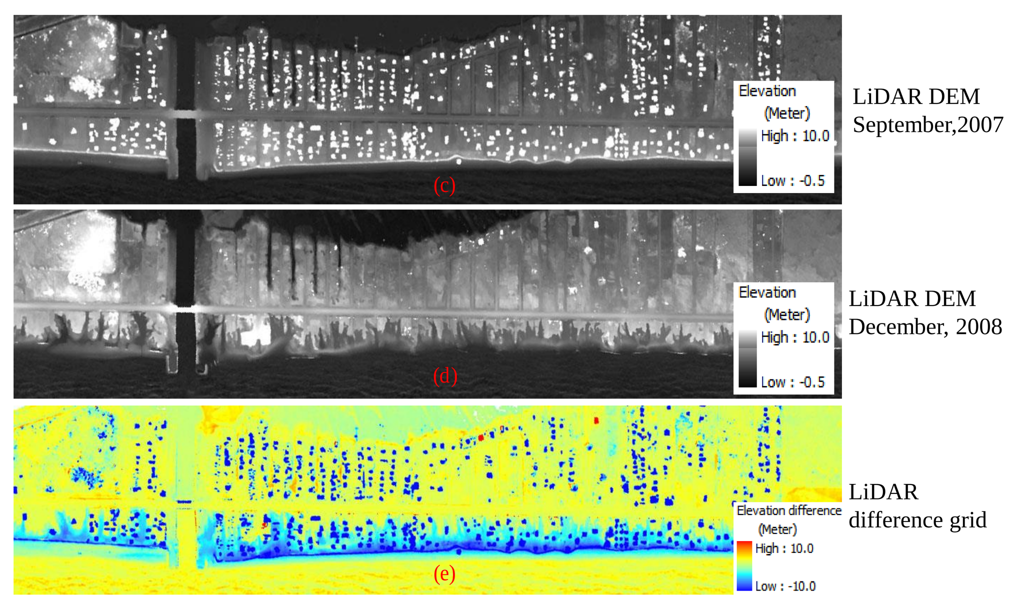
-4	-4	0	0	0	-5	0
-4	-4	0	0	-5	-6	-5
0	0	0	0	0	-5	0
0	2	1	1	0	0	0
0	0	0	0	0	0	0
-1	-2	-2	-2	-2	-2	0



Ontology-driven Pattern Recognition

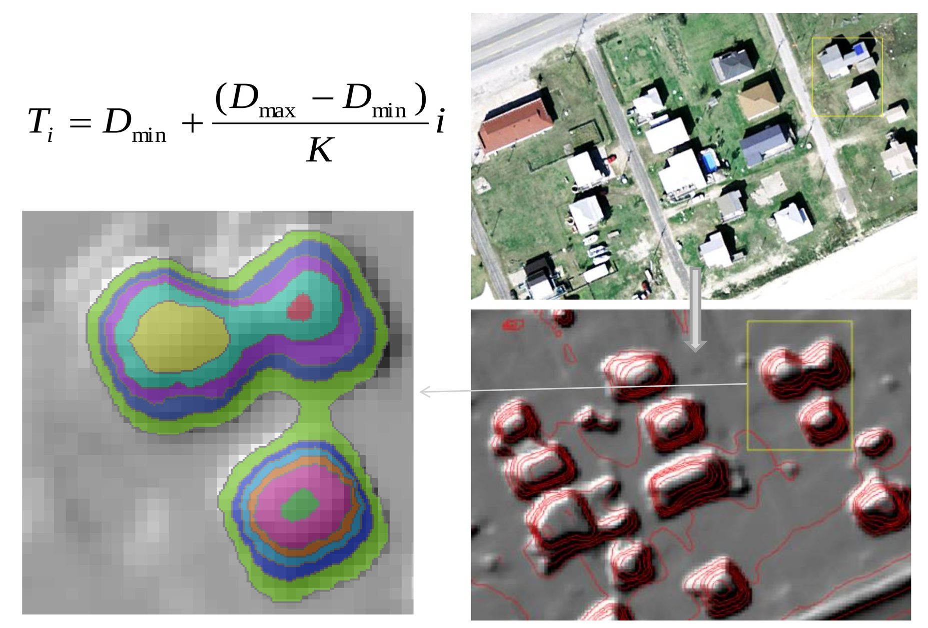


1. Generating an Elevation Difference Grid

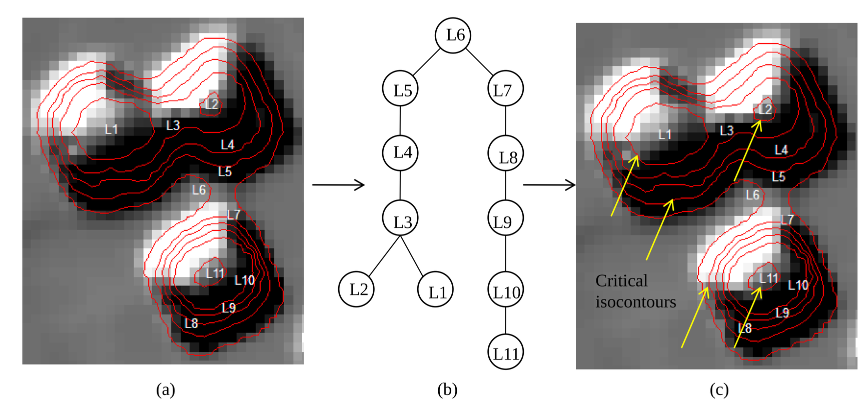


2. Performing Multi-level Slicing

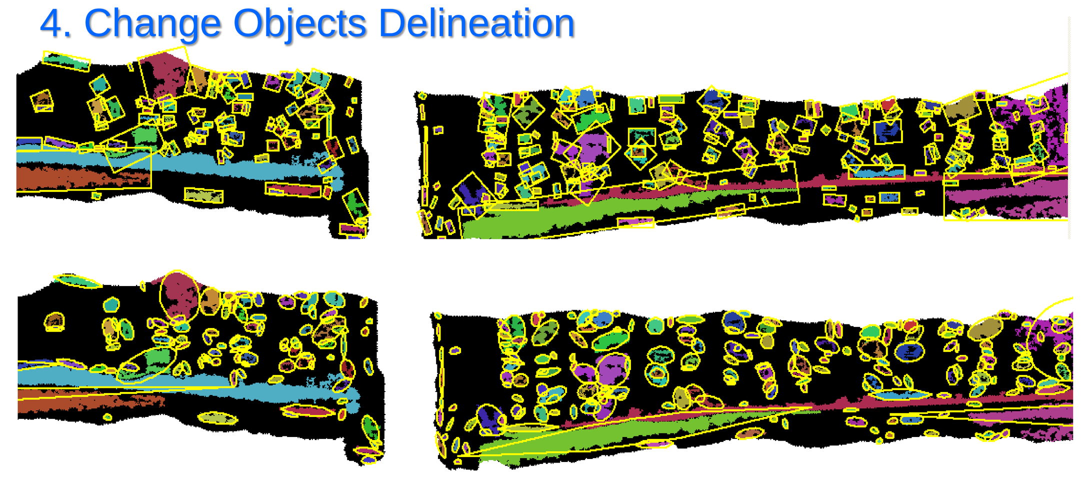
$$T_i = D_{\min} + \frac{(D_{\max} - D_{\min})}{K} i$$



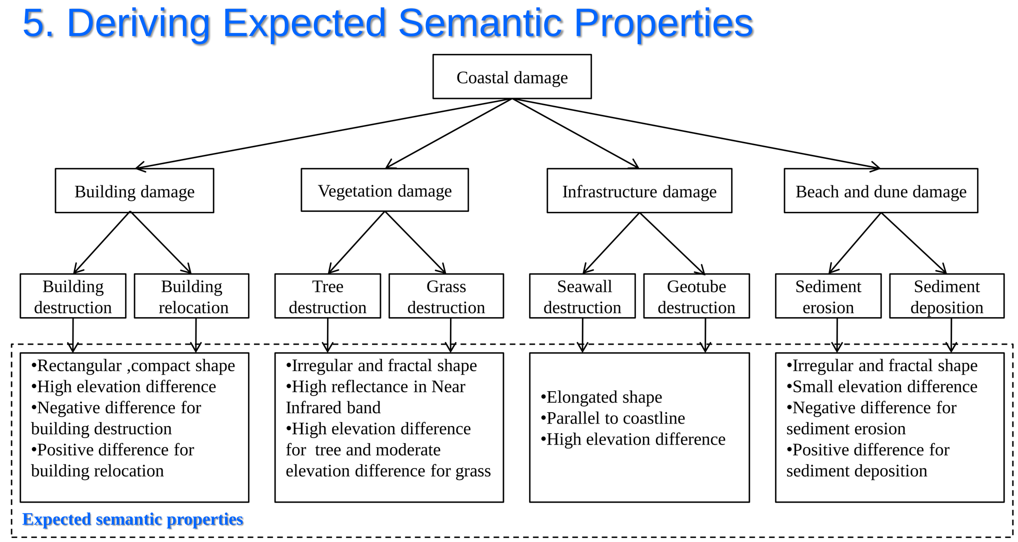
3. Contour-tree based Graph Theory

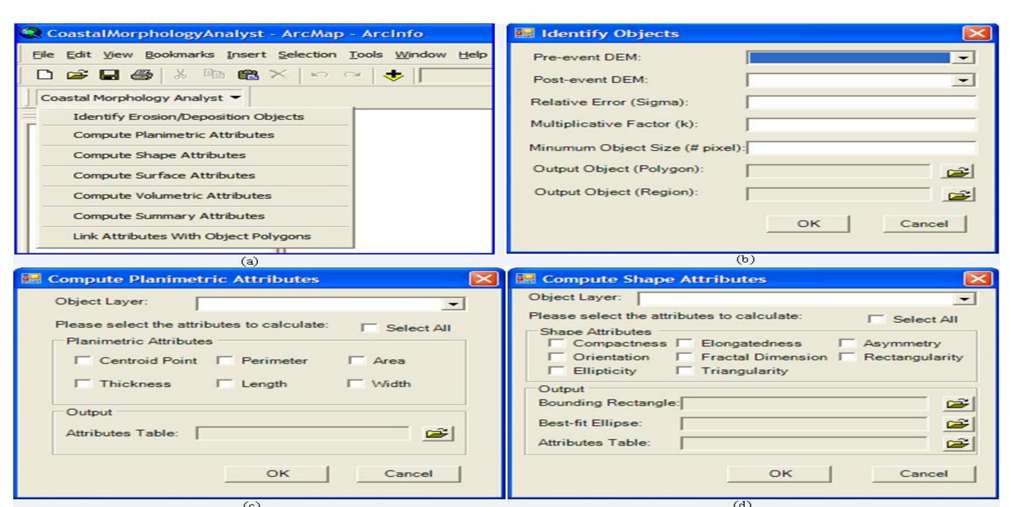


4. Change Objects Delineation

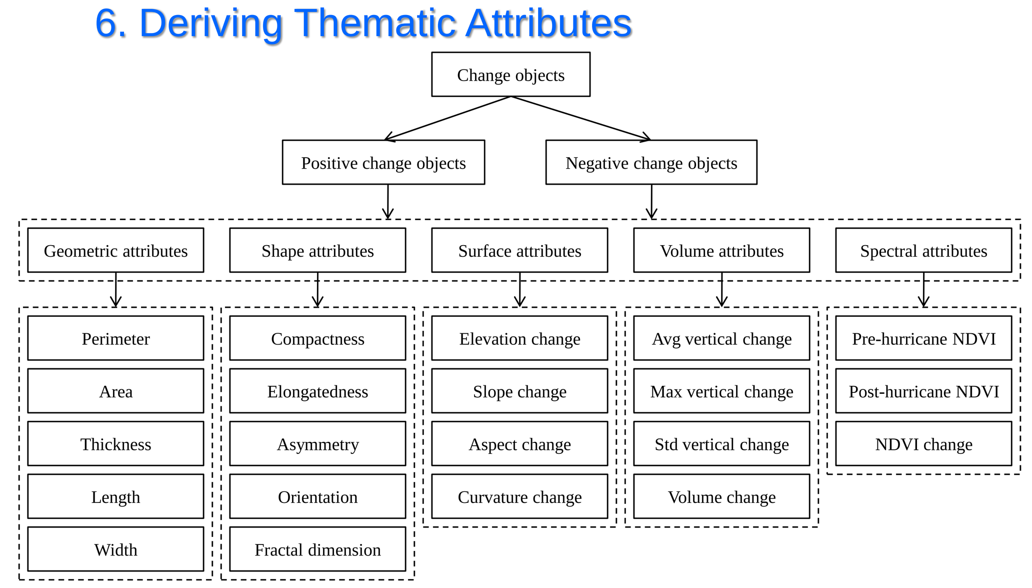


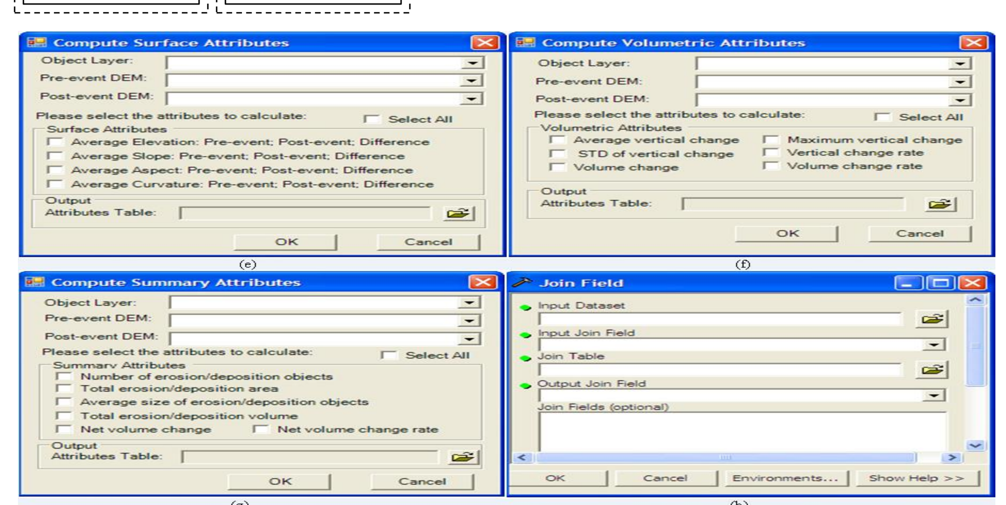
5. Deriving Expected Semantic Properties





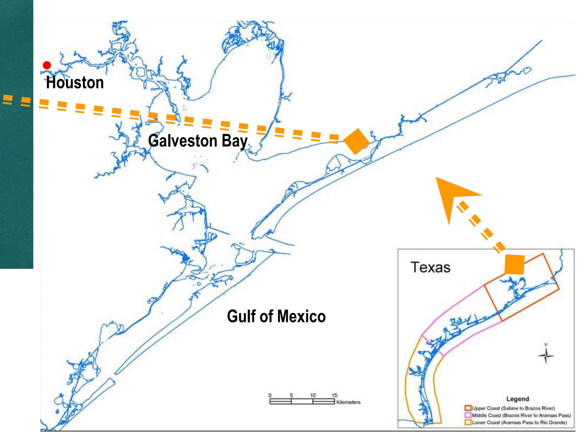
6. Deriving Thematic Attributes



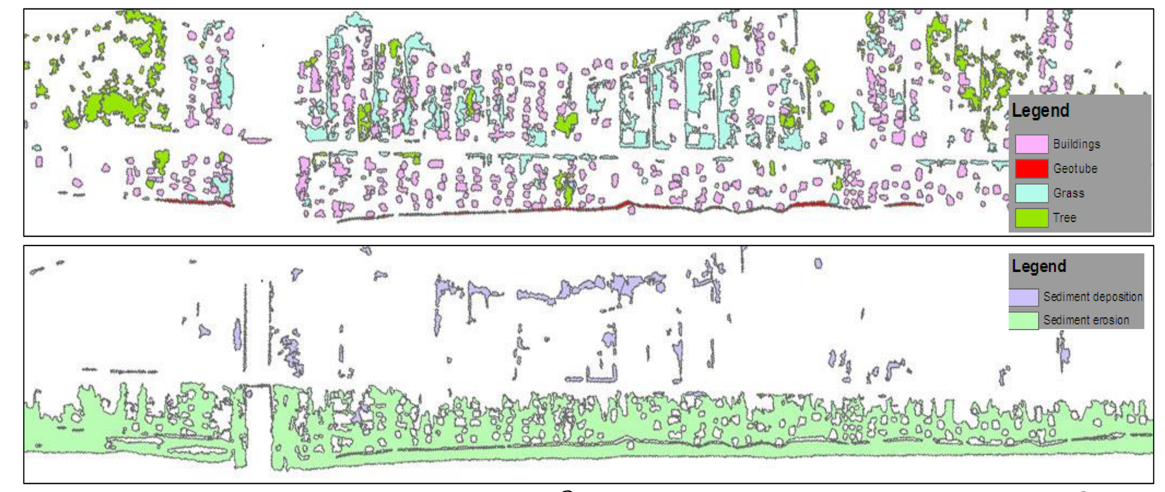


Results

Case Study Area



Classification & Damage Assessment



Buildings: 86947 m^2 Trees: 6082 m^2 Sediment erosion: 271022 m^3

Geotube: 1.818 km Grass: 16400 m^2 Sediment deposition: 22361 m^3

Shoreline: pushed landward by 15.2 m

Table 1. Classification error matrix — Overall accuracy: 95.9%

	Buildings	Trees	Grass	Geotubes	Sediment erosion	Sediment deposition	Row totals
Buildings	62	1	0	0	2	0	65
Trees	1	69	3	0	0	0	73
Grass	0	2	44	0	1	0	47
Geotubes	0	0	0	10	0	0	10
Sediment erosion	1	0	1	0	46	0	48
Sediment deposition	0	0	0	0	0	52	52
Column totals	64	72	48	10	49	52	295

Conclusion

- An object-oriented analytical framework for representing morphological changes for damage assessment
- Object-oriented representation provides explicit and quantitative damage information for supporting hazard mitigation and post-storm recovery effort
- An effective change object detection algorithm based on multi-level slicing and contour-tree graph theory
- A software tool for automatically deriving quantitative attributes for change objects
- Taxonomy and rule-based approach for classifying change and damage types

References

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- Liu, H., et al., 2010. An object-based conceptual framework and computational method for representing and analyzing coastal morphological changes. *International Journal of Geographical Information Science*
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