Spatial Appraisal and Valuation of Environment and Ecosystems (SAVEE)

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Agenda

- Introduction/Problem Statement
- Goal and Objectives
- Methodology
- Case Study: Galveston Coastal Communities
- Preliminary Results
- Future Work
Introduction/Problem Statement

- Importance of ecosystem valuation in monetary terms
  - Create monetary values of ecosystem as a common reference
  - Allow for better perceptions by stakeholders
  - Enable calculations of environmental impacts
  - Help justify budgets for environmental projects
  - Expedite goals and progresses; more definitive management plans
Introduction/Problem Statement

- Numerous studies on ecosystem valuation
  - Some are spaghetti-type.
  - Some lack system/unified paradigm.
  - Some lack considerations for current and future needs.

- SAVEE is an attempt to consolidate these various paradigms toward a more tangible approach.
Introduction/Problem Statement

- Since the 1992 Earth Summit, sustainable development has been the utmost guideline in the pursuit of sustainability.

- Sustainability calls for a balance between the development and environment.
Introduction/Problem Statement

- The pillar of development has been well defined and measured.

- For environments and ecosystem, the similar scheme seems to be missing.

- SAVEE research is conducted in light of the sustainable development framework.
Goal and Objectives

- **Overall goal:**
  - Define “Spatial acre” that attaches monetary values to a geographic span of interest

- **Objectives:**
  - Develop SAVEE framework that links development and environment
  - Enable mapping of values of development and its environmental counterparts
Methodology: SAVEE Framework

SAVEE Framework has two components:

1. Development, hereafter referred to as, “Developmental Intensity Index” or DI
   - Based on real estate values, which are commonly agreed upon by people

2. Environment, hereafter referred to as, “Ecosystem Sustainability Index” or SI
   - Commonly acknowledged measurement is ecosystem services provided in a study area
Methodology: Defining SI

Source: National Research Council (2005)
Methodology: SAVEE Framework (Cont.)

**DI**
- By normalizing the land appraisal values, DI is generated, ranging from 0 to 1

![DI Diagram]

**SI**
- By compiling ecosystem services pertaining to a study area, SI can be calculated.

![SI Diagram]
Methodology: Determining SI

- Conventional approach assumes precise and definite numbers as indicators for ecosystem services.

- Challenges:
  - Difficulties and complications in determining and assigning indices to SI
  - Lack of systematic approach to map SI (ecosystem services) to DI (land values)

- Proposed method:
  - Fuzzy set theory to help identify the presence and weight of each ecosystem service in the study area.
Case Study: Galveston Coastal Communities

- Identified as one of the top priority ecosystems for environmental conservation by Environmental Advisory Committee
- Mainly comprised of tidal wetlands and coastal prairies
- Provides significant number of ecosystem services to the area
SAVEE Procedure for the Study Area

Step 1
- Determine ecosystem services for SI

Step 2
- Collect and manipulate spatial data for ecosystem services

Step 3
- Use fuzzy set theory to calculate SI

Step 4
- Map SI with DI
**Step 1: Determine Ecosystem Services for SI**

**Step 2: Collect Data**

Samples of ecosystem services and proxies

<table>
<thead>
<tr>
<th>Ecosystem Services</th>
<th>Proxies</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flood prevention</td>
<td>Wetlands, coastal prairie, and forests, flood risk zone</td>
</tr>
<tr>
<td>Hurricane protection</td>
<td>Wetlands, hurricane risk zone</td>
</tr>
<tr>
<td>Water quality</td>
<td>Wetlands, water quality</td>
</tr>
<tr>
<td>Erosion control</td>
<td>Soil quality, bottomland forests, coastal erosion rates</td>
</tr>
<tr>
<td>Fishing</td>
<td>Fish population and density</td>
</tr>
<tr>
<td>Wildlife watching</td>
<td>Land covers</td>
</tr>
<tr>
<td>Scenic view</td>
<td>Coastal prairie and land covers</td>
</tr>
<tr>
<td>Recreational activities</td>
<td>Coastal prairie and land covers</td>
</tr>
</tbody>
</table>
Step 3: Using Fuzzy Set theory for SI

- Fuzzy scheme employs raster data in GIS
- Raster data can be defined as a fuzzy set
- Each grid cell (pixel) is the set element
- Each grid cell can be attached with a group of membership grades, i.e., fuzzy membership values, to indicate the extent to which the cell belongs to certain attributes, i.e., different ecosystem services.
Step 3: Using Fuzzy Set theory for SI

- Eco-Logical Data Metrics as a reference
- Metrics are based on characteristics of mapped polygons within 4 ecotypes
- Composed of
  - Polygon size, polygon shape
  - Regional polygon, ecotype scarcity, and watershed ecotype scarcity
  - Polygon adjacency, isolation
  - Presence of threatened and endangered species
  - Diversity
  - Polygon quality
Step 3.1: Fuzzy Set Theory – Calculating Fuzzy Membership Values

A sample of land parcel containing pixels of various land cover classes

After calculation of fuzzy membership values
### Step 3.1: Fuzzy Set Theory – Calculating Fuzzy Membership Values

Sample table of calculation of fuzzy membership values for land cover

<table>
<thead>
<tr>
<th>Land Cover</th>
<th>No. of pixels in study area</th>
<th>Percentage of No. of</th>
<th>Percentage of Frequency</th>
<th>Fuzzy Membership Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>High Intensity Developed</td>
<td>8781</td>
<td>1.790692315</td>
<td>6646</td>
<td>1.50459347 0.840230037</td>
</tr>
<tr>
<td>Low Intensity Developed</td>
<td>14090</td>
<td>2.873346398</td>
<td>11824</td>
<td>2.676845198 0.931612422</td>
</tr>
<tr>
<td>Open Space Developed</td>
<td>7087</td>
<td>1.445238178</td>
<td>6313</td>
<td>1.429205323 0.988906427</td>
</tr>
<tr>
<td>Cultivated</td>
<td>105372</td>
<td>21.48830778</td>
<td>96880</td>
<td>21.93274381 1.020682691</td>
</tr>
<tr>
<td>Grassland/Shrub</td>
<td>51787</td>
<td>10.56082256</td>
<td>46202</td>
<td>10.45970922 0.990425619</td>
</tr>
<tr>
<td>Forest</td>
<td>7116</td>
<td>1.451152092</td>
<td>6341</td>
<td>1.435544266 0.989244528</td>
</tr>
<tr>
<td>Woody Wetland</td>
<td>33113</td>
<td>6.752669928</td>
<td>29699</td>
<td>6.723581322 0.995692281</td>
</tr>
<tr>
<td>Herbaceous Wetland</td>
<td>216969</td>
<td>44.24606776</td>
<td>197489</td>
<td>44.70969904 1.010478474</td>
</tr>
<tr>
<td>Bare</td>
<td>14211</td>
<td>2.898021694</td>
<td>12350</td>
<td>2.795926776 0.964770824</td>
</tr>
<tr>
<td>Open Water</td>
<td>31843</td>
<td>6.493681289</td>
<td>27970</td>
<td>6.332151573 0.975125093</td>
</tr>
</tbody>
</table>
Step 3.2: Fuzzy Set Theory
Fuzzy Logic Operations – Fuzzy Product
Step 3.2: Fuzzy Set Theory
Fuzzy Logic Operations – Fuzzy Sum

Legend
Fuzzy Sum
<VALUE>
- 0.999990592 - 1
- 0.997280485 - 0.999990592
- 0.994562338 - 0.997280485
- 0.991844211 - 0.994562338
- 0.981844211 - 0.991844211
- 0.995458264 - 0.981844211
- 0.999990592 - 0.995458264
Step 3.2: Fuzzy Set Theory
Fuzzy Logic Operations – Fuzzy Gamma (0.025)
Step 3.2: Fuzzy Set Theory
Fuzzy Logic Operations – Fuzzy Gamma (0.5)
Step 3.2: Fuzzy Set Theory

Fuzzy Logic Operations – Fuzzy Gamma (0.975)
Step 4: Map SI with DI
Verification Method

![Graph showing cumulative frequency with various fuzzy operations: Fuzzy Gamma (0.975), Fuzzy Gamma (0.5), Fuzzy Product, and Fuzzy Sum.](image)
Relationship of SI and DI
Preliminary Results

- Fuzzy set theory helps assign proper weights to ecosystem services with regard to their spatial contributions.
- Fuzzy gamma operation with gamma = 0.975 can best calculate SI for the study area.
- SI could be better capitalized in reference to the land appraisal values to reflect contributions of ecosystem that is equitable to developed areas with comparable DI and SI indices.
Future Work

- Model calibration
- Add human dimension
  - Socio-economic, demographics, housing characteristics
- Compare SI and DI before and after Hurricane Ike
- Compare land appraisal value vs. sales prices for DI
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