Using agent-based urban growth models to predict soil erosion and non-point source pollution in a Hawaiian river basin

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Project Objectives

- Develop an agent-based model (ABM) that will generate land use projections for a set of study watersheds under several land development scenarios
- Estimate soil erosion and pollution runoff for these areas by using the land use projections as an input to an existing model
- Compare the soil erosion and pollution estimates (i.e. water quality) of the study watersheds under the various land use development scenarios
Study Area

LULC 2001:
- High Intensity Developed
- Medium Intensity Developed
- Low Intensity Developed
- Open Space Developed
- Cultivated Land
- Pasture/Hay
- Grassland
- Evergreen Forest
- Scrub/Shrub
- Palustrine Forested Wetland
- Palustrine Scrub/Shrub Wetland
- Palustrine Emergent Wetland
- Unconsolidated Shore
- Bare Land
- Water

Elevation:
- Meters
  - High: 1547
  - Low: 0
ABM Methods - Environment

- Land Use (based on 2001 LULC dataset):
  1. Developed - high and medium intensity urban
  2. Undeveloped - all other land, including low intensity urban
  3. No data - water and areas falling outside of the study area

- Accessibility: distance to the nearest developed cell

- Scenic Beauty: a combination of distance to water and distance to an area with a view (slope $\geq 10\%$)
ABM Methods - Agents

• Agents:
  - develop one location
  - 10 introduced per tick, 1000 total agents
  - attributes include accessibility and scenic beauty preference weights

• Behavior:
  - sample 10% of undeveloped locations (bounded rationality)
  - choose a location using ideal point aggregation method
ABM - Feedback & Implementation

• Feedback:
  1. Accessibility - distance to nearest developed location is updated every tick
  2. Scenic Beauty - values for 3 x 3 neighborhood surrounding developed location are reduced by a set fraction (0.1 fraction used for this project)

• Implementation:
  - scenarios with scenic beauty feedback: 25/75, 75/25, 50/50, and random preference weights
  - scenarios without scenic beauty feedback: 50/50 and random
  - 10 model runs per scenario
ABM Land Use Output

Land Use Categories:
- Green: High Intensity Urban
- Red: Low Intensity Urban
- Others: Other land
- Blue: Water
Soil Erosion and Pollutant Modeling

- **N-SPECT**
  - Nonpoint-Source Pollution and Erosion Comparison Tool
  - ArcGIS extension developed by National Atmospheric and Oceanic Administration for coastal analyses
- Inputs: land use, precipitation, elevation, and soil datasets
- Pollutants: runoff concentrations for nitrogen, phosphorus, total suspended solids, zinc, and lead
- Soil Erosion: uses the Revised Universal Soil Loss Equation
Results

- Soil erosion and pollutant estimates averaged for each ABM scenario
- Scenario averages compared to baseline 2001 LULC estimates for overall bay watershed (% increase):
  - Nitrogen -> 12-15%
  - Phosphorus -> 16-18%
  - Total suspended solids -> 17-19%
  - Zinc -> 17-20%
  - Lead -> 25-28%
  - Soil loss -> 3-5%
Conclusions

- Increases in Hanalei Bay watershed soil loss and pollutant runoff estimates were very similar across all ABM land use scenarios -> different development patterns did not significantly change overall estimates
- ABM scenarios did produce differences in erosion/pollution estimates among contributing stream watersheds, resulting from the use/removal of scenic beauty feedback
- Combining ABM and N-SPECT provided ability to explore the impacts of various development scenarios, although it presented limitations
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