Modeling, Learning and Planning Together
Addressing Big Questions with Data, Models, and Participatory Exploration

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Motivations

Source: sanfrancisco.cbslocal.com

Source: http://www.greenpeace.org
Questions I: Tools for modeling

- Sustainable growth
- Effectiveness of green infrastructure
- Local economic interests v. regional environmental goals
- Managing flooding and drought in agriculture

Modeling coupled human-natural systems
Demo

• SOME model
Answers I: Tools for modeling

• Growth is not sustainable.
  – Zellner and Reeves (2012)

• Green infrastructure: Thresholds and layouts
  – Zellner et al. (2016)

• Collaborative conservation can arise under development pressure
  – Zellner et al. (2010)

• Adaptation can reduce crop losses but exacerbate flooding
  – Zellner et al. (2019)
Conventional planning and modeling

(Zellner 2008)
“Unconventional” planning and modeling

Co-organization of knowledge and values (process), policy exploration and adaptive implementation, further empirical investigation.

Integrated analysis and decision-making

Stakeholders

Policy-makers

Constituents

Models, participation

Scientists

(Zellner 2008)
Challenges

• Communication across expertise
• Spatial thinking and computer modeling
• Confirmatory bias
• Consensus-building and generalization
Questions II: Tools for participation

• How can complex systems modeling help us learn?
• How does learning lead to better planning deliberation and decision-making?
What we’ve learned

• It supports learning and innovation
• It’s hard!
• It’s deeply human
• Two stories:
  – Small is beautiful
  – Making the invisible visible
Water Sustainability in NE Illinois
Small is beautiful

Groundwater supply
SOME Model
(SLUCE Project)

(Zellner et al. 2012)
SOME Model

(Zellner et al. 2012)
SOME-GW Model
Detailed Model
Learning, innovation and resistance

• Transparency of assumptions
  
  There is no residential growth here... except in...
  
  “If water is not a problem, then why are communities doing conservation?”

• Mental modeling

  Lake Michigan water and groundwater effects

• Favored approaches won’t work

  “There's the idea that... we're gonna have such a big impact and it really doesn't”
  
  Couldn’t isolate themselves from the impact of growth

• Specificity of alternative solutions

  “Do we create giant recharge areas that will assist the whole region?... “
  “I think we’re learning that {regional water management} is essential for all of us”
  “I’d never bring this up in a public meeting...” but what about injection?

• And yet... rejection (Hoch et al. 2015)
  
  – Inaccuracy
Discourse analysis I

Model – Policy – Process – Use – World

(Radinsky et al. 2016)
Discourse analysis II
Simple interfaces...

(Zellner et al. In progress)
To detailed interfaces
Simple processes...
To detailed pr
Lessons

- Keep it simple
- Use intermediate tangible user interfaces (TUI)
- Interactive exercise versus instruction
- Start with more visible problems
Making the invisible visible

Flooding
An illustration in flooding

L-GrID model
(Zellner et al. 2016)
An illustration:
Rain barrels or bioswales?

<table>
<thead>
<tr>
<th></th>
<th>Baseline</th>
<th>Rain barrels</th>
<th>Bioswales</th>
</tr>
</thead>
<tbody>
<tr>
<td>Installation cost</td>
<td>$0.00</td>
<td>$14,250.00</td>
<td>$350,168.79</td>
</tr>
<tr>
<td>Damages</td>
<td>$39,062.90</td>
<td>$38,837.74</td>
<td>$34,495.24</td>
</tr>
<tr>
<td>Outflow</td>
<td>0.62</td>
<td>0.62</td>
<td>0.56</td>
</tr>
</tbody>
</table>
Things to consider

- Simulations alone are not enough
  - Tradeoffs
  - Costs and distribution
  - Spatial constraints
  - Diverse stakeholder interests

- Solution-building AND compromise
  - Awareness of preferences
  - Addressing diverse needs
    - metrics, evaluation, exploration
Workshop setup

(Zellner et al. in press)
Concern profile

Sort the items based on how important they are to you

- Maximum Flooded Area
- Damage Reduction
- Efficiency of Intervention ($/Gallon)
- Capacity Used
- Water Flow Path
- Groundwater Infiltration
- Investment
- Impact on my Neighbors

Definitions

Investment: Cost to install and maintain new green infrastructure on both city and private property. Maintenance costs are in Present Value (PV) over 20 years, at 3% discount rate.

Damage Reduction: The amount of property damages reduced by the investment.

Efficiency of Intervention: ($/Gallon) The amount of money spent per gallon of rainwater stored or infiltrated by green infrastructure installations.

Capacity Used: The percentage of capacity used by interventions over their total available capacity.
Workshop setup
Workshop setup
Workshop setup
# Sorted simulation results

## Simulation Results Sorted By Your Priorities

The Performance score is broken down into colors corresponding to the outcomes on the right.

<table>
<thead>
<tr>
<th>Sort by</th>
<th>Trial Number</th>
<th>Water Flow 0 hrs</th>
<th>Max Depth of Flooding</th>
<th>Damage Reduction</th>
<th>Impact on</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>48 hrs</td>
<td>Storm Playback: 21 hours</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Trial 2**
- **Performance:** Broken down by source:
  - Best for me
  - Worst for me

**Performance:**
- Best for me
- Worst for me

<table>
<thead>
<tr>
<th>Performance:</th>
<th>Water Flow</th>
<th>Max Depth of Flooding</th>
<th>Damage Reduction</th>
<th>Impact on</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>34</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- Rain Damage: $27,978
- Damaged Reduced by: 13%
- Sewer Load: 22.58%
- Storms like this one to recoup investment cost: 0

**Impact on**
- 100.00% flowed

**Trial 3**
- **Performance:** Broken down by source:
  - Best for me
  - Worst for me

**Performance:**
- Best for me
- Worst for me

<table>
<thead>
<tr>
<th>Performance:</th>
<th>Water Flow</th>
<th>Max Depth of Flooding</th>
<th>Damage Reduction</th>
<th>Impact on</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>34</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- Rain Damage: $18,475
- Damaged Reduced by: 61%
- Sewer Load: 18.74%
- Storms like this one to recoup investment cost: 147

**Impact on**
- 75.50% flowed

**Trial 4**
- **Performance:**
  - Best for me
  - Worst for me

**Performance:**
- Best for me
- Worst for me

<table>
<thead>
<tr>
<th>Performance:</th>
<th>Water Flow</th>
<th>Max Depth of Flooding</th>
<th>Damage Reduction</th>
<th>Impact on</th>
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</thead>
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<td>34</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- Rain Damage: $0
- Damaged Reduced by: 100%
- Sewer Load: 18.74%
- Storms like this one to recoup investment cost: 49

**Impact on**
- 7.84% flowed

You can revise your profile by returning to the "Your Survey" tab below.
Social viewer

Simulation Results of Yours and Other Users Priorities, Sorted By Your Priorities
Each color in the score breakdown is linked to an outcome measure to the left of it

Trial 1  Trial 2  Trial 3  Trial 4  Trial 5

Legend
- Investment
- Intervention Capacity
- Efficiency of Intervention
- Groundwater Infiltration
- Impact on my Neighbors
- Damage Reduction
- Max Depth of Flooding
- Water Flow

Highest priority categories:
ped  pol  ped  pol  ped  pol  ped  pol  ped  pol

You can revise your profile by returning to the "Your Survey" tab below
Condensed  Expanded
Social viewer

Simulation Results of Yours and Other Users Priorities, Sorted By Your Priorities
Each color in the score breakdown is linked to an outcome measure to the left of it

Tap to view map(s)

Legend
- Damage Reduction
- Water Flow
- Maximum Flooded Area
- Groundwater Infiltration
- Impact on my Neighbors
- Intervention Capacity
- Efficiency of Intervention
- Investment

Highest priority categories

Lowest priority categories

Pol Ped Pol Ped Pol Ped Pol Ped Pol Ped Pol Ped

Trial 1 Trial 2 Trial 3 Trial 4 Trial 5 Trial 6 Trial 7

You can revise your profile by returning to the "Your Survey" tab below
Learning, innovation, compromise

- Transparency of assumptions and tradeoffs
  
  Jo: “Oh wow, that’s much better... for you.”

  Nina: “I guess it matters what your priorities are!”

  Kevin: “Damage was reduced by 87%... but we were over budget by 1.2 million.”

- Systematic exploration
  
  “Let’s start by going crazy, putting a lot of stuff on here, and then pare back from there.”

  “We can run multiple simulations, so let’s run this one and then try that.”

- Gesturing and mental modeling

  Following the flow

  Imagining different performance

- Green infrastructure cannot locally solve the problem

  “Perhaps we need to think of moving the houses out of there”

  Green AND gray infrastructure

  Coordination with other communities
Answers II: Tools for participation

- Collaborative design
- Facilitation for synthesis
- Consensus or compromise?
- Participatory modeling as a point of entry
  - to the problem,
  - to other tools,
  - to diverse interests
  - to other problems

APA Academic Tech Innovator Award 2017  
(Zellner et al. in press)
Future plans

• Refining and extending participatory modeling and visualization
  – New domains: energy, food, air and water quality
  – New contexts: South America, Australia, Middle East
  – New tools and approaches: scaling up, data life cycle

• Contributing to communities
  – Scholarly: ComSES, CSDMS
  – Decision-making: US and State Congress, NCSE

• Interdisciplinary teaching
Why do this?

• Changing established heuristics
• Supporting the evolution of understanding and valuation
• Technology as a prosthetic device for decision-making
• Innovation is critical for **resilience** and **sustainability**
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