Urban dependence on ecosystem services: a spatially explicit analysis of a megacity riverside settlement

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Urban waterways under pressure

SWITZERLAND

INDONESIA

Population density (pax/km²)

Urban areas

Urban land within 1km of waterways

1990 1995 2000
0 500 1000 1500 2000 2500

250km

SWITZERLAND

INDONESIA

Urban areas

Urban land within 1km of waterways

1990 1995 2000
0 500 1000 1500 2000 2500
Kampung Melayu/Bukit Duri

- Population ~50,000
- Area ~1 sq km
- Mostly informal housing
- Mix of low and middle economic class

Ciliwung River, Indonesia

- Flows from Mt. Gede (>1600m) to the Java Sea
- 119 km in length
- Bisects cities of Bogor, Depok, and Jakarta
- Population of ~5,000,000 in 384km$^2$ catchment
- consumptive use
- recreation
- micro-climate regulation
- bank stabilization
- waste “assimilation”
- plant products
- non-consumptive use
Links between informal settlements, infrastructure, and rivers

• Large share of slums and informal settlements exist along urban waterways, and residents risk displacement as part of city-wide climate change adaptation strategies (UN Habitat, 2003, 2011)

• Interrelated problems of local water, waste, sanitation contribute a large share of burden of urban disease in low-income countries (McGranahan et al., 2005)

• Urban nature creates “vital” neighborhood spaces (Sullivan et al., 2004); vegetation negatively correlated with aggression in low-income neighborhoods (Kuo and Sullivan, 2001)

• Less than 45% of Jakarta residents have municipally-provided water services, and barely 2% can be classified as being “water secure” (Ali, 2010)
Summary statistics for the site

- 4 out of 5 households are not connected to municipal water supply
- Heavy reliance on private wells and vendors
- Some public wells, and provision by local mosques
- 3 out of 4 households have a toilet
- Of those, only 2 of every 3 are connected to a septic tank
- Roughly half of households discard solid waste directly to the river
- Mostly from the Kampung Melayu side
- 30% report flooding events more than once per year
- 39% have not experienced a flood at their location
Multiple uses of the river

- Mean household consumption of 2.5 services (std dev = 1.4)
- 1 of 8 households use the river rafts for washing/bathing/toilet
- 1 of 7 households harvest from plants growing along the river
- 40% of households recreate along the river
- Those who recreate are also more likely to:
  - Discharge wastewater to the river
  - Dispose of solid waste directly to the river
  - Use the river for non-consumptive purposes
## Spatial correlation among variables

<table>
<thead>
<tr>
<th>VARIABLE</th>
<th>CORRELATION WITH DISTANCE TO RIVER (SPEARMAN’S ρ)</th>
<th>MEASURE OF SPATIAL DEPENDENCE (GETIS-ORD GENERAL G STATISTIC Z-SCORE)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Years residing</td>
<td>-0.05</td>
<td>2.12*</td>
</tr>
<tr>
<td>Ownership</td>
<td>0.06</td>
<td>1.91</td>
</tr>
<tr>
<td>Consumption expenditures</td>
<td>0.31**</td>
<td>1.39</td>
</tr>
<tr>
<td>Toilet without septic tank</td>
<td>-0.16*</td>
<td>1.17</td>
</tr>
<tr>
<td>Nonrecreational use</td>
<td>-0.38**</td>
<td>7.65**</td>
</tr>
<tr>
<td>Recreational use</td>
<td>-0.32**</td>
<td>7.14**</td>
</tr>
<tr>
<td>Discarding rubbish</td>
<td>-0.56**</td>
<td>14.3**</td>
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<tr>
<td>Harvesting plants</td>
<td>-0.13*</td>
<td>3.05**</td>
</tr>
<tr>
<td>PAM connection</td>
<td>0.20**</td>
<td>4.12**</td>
</tr>
<tr>
<td>Composite services</td>
<td>-0.60**</td>
<td>11.7**</td>
</tr>
</tbody>
</table>

*Significant at the 0.05 level  **Significant at the 0.01 level

N=212
Mapping river use through indicator kriging

- Use variables are all binary
- Literally relying on “nearest neighbors” and Tobler’s First Law
- Potential for mapping *consumption* of ecosystem services
Probability maps

- Disposing rubbish to river
- Nonrecreational use of river
- Recreational use of river
- Municipal water connection
Regression analysis: influence on number of services consumed

Independent variables:
- Size of household
- Years of residence
- Ownership of dwelling
- Consumption expenditures
- Connection to PAM
- Distance to river
- Toilet in household
- Neighborhood effects

Weights matrix
\[ W = \{w_{ij}\} \text{ (threshold = 150m)} \]

Spatial lag model
\[ y = \rho Wy + X\beta + \epsilon \]

Spatial error
\[ \epsilon = \lambda We + \xi \]
Regression results: dependent variable is composite of

<table>
<thead>
<tr>
<th>VARIABLE</th>
<th>MODEL 1 (Linear)</th>
<th>MODEL 2 (Spatial lag)</th>
<th>MODEL 3 (Spatial error)</th>
<th>MODEL 4 (Conditional)</th>
<th>MODEL 5 (Spatial error)</th>
<th>MODEL 6 (Conditional)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Household size</td>
<td>.046</td>
<td>.047</td>
<td>.047</td>
<td>.040</td>
<td>.043</td>
<td>.031</td>
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<td>Years residing</td>
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<td>-.005</td>
<td>-.003</td>
<td>-.007**</td>
<td>-.005</td>
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<td>Distance from river</td>
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<td>-.005**</td>
<td>-.009**</td>
<td>-.003*</td>
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<td>Elevation</td>
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<td>Toilet in household</td>
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<td>-1.26**</td>
<td>-1.19**</td>
<td>-1.27**</td>
<td>-1.17**</td>
<td>-1.16**</td>
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<td>Neighbors using services</td>
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<td>Neighborhood effect</td>
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<td>.507**</td>
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<td>Neighbors discharging sewage</td>
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<td>Neighbors discarding rubbish</td>
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<td>1.43**</td>
<td>1.07*</td>
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<td>Neighbors recreating</td>
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<td>Neighbors using getek-getek</td>
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<td>.313</td>
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<td>R-squared</td>
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<td>.536</td>
<td>.555</td>
<td>.575</td>
<td>.576</td>
<td>.612</td>
</tr>
</tbody>
</table>

*Significant at the 0.05 level  
**Significant at the 0.01 level  
N=213
Implications and next steps

- Ecosystem service framework can help clarify the complexity of riverside settlements
- Economic valuation of ecosystem services is highly context-dependent
- Topography and sub-neighborhood have important influence
- What mix of services would residents prefer?
- What is the spatial extent of beneficiaries for a rehabilitated corridor?
- Is the Ciliwung’s future a vibrant riverfront or a fenced-off canal?
Thank you!