Strategic Use of Ecological Production Functions to Advance Policy

Christina Wong, Bo Jiang, Ann Kinzig, Kai Lee, and Zhiyun Ouyang

A Community on Ecosystem Services Meeting

Jacksonville, Florida

December 7, 2016

Outline

I. Introduction

- Policy Demands for Ecosystem Service Assessments
- Technical Problem — Defining Data Gap

II. Interdisciplinary Framework

- Ecological Production Functions
- 10-Step Approach for Measuring Ecosystem Services

III. Implementing Ecological Production Functions

- Yongding River Ecological Corridor, Beijing, China
- Methodology
- Results
- Management Recommendations

IV. Conclusions

- Lessons Learned

Policy Demands

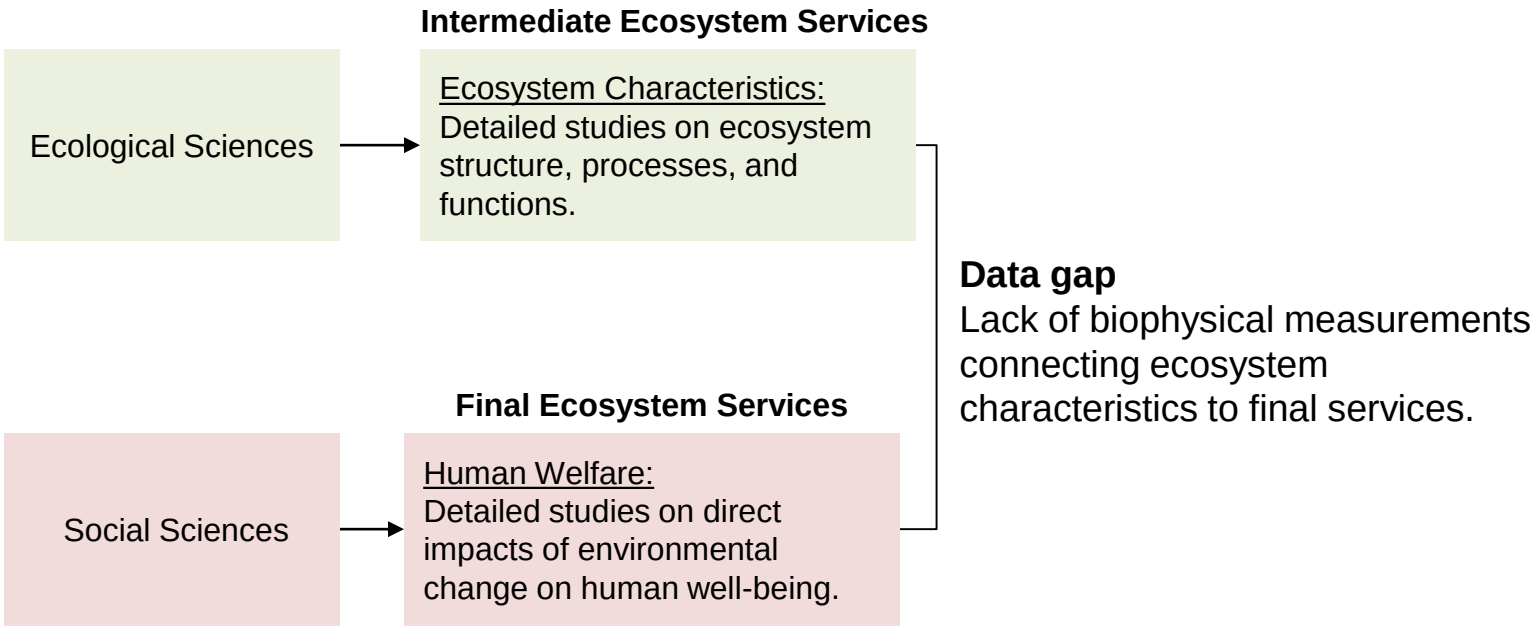
- More than $12 billion USD invested in watershed services in 2013, growing at an average rate of 12% per year.
- China, European Union, and US government agencies are pursuing ways of implementing the ecosystem services approach.

Bennett and Carroll (2014)

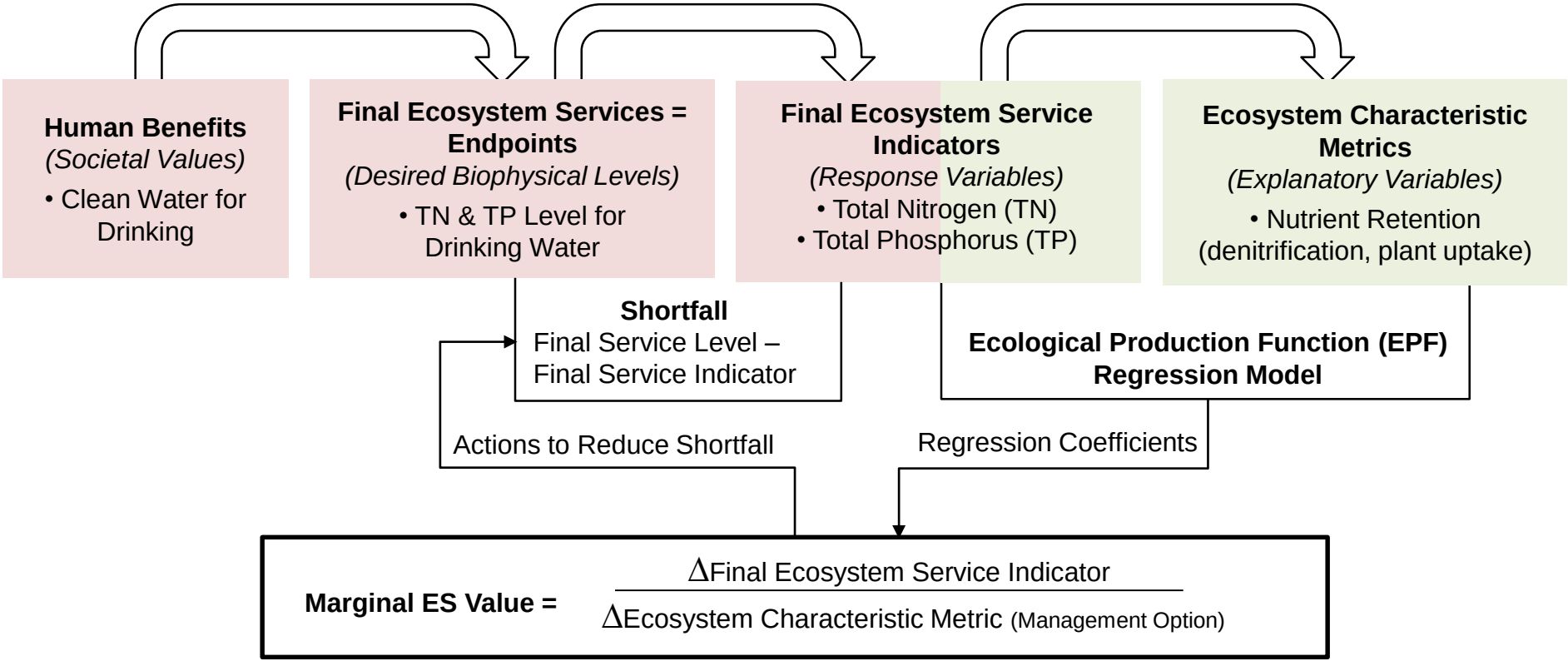
Capacity Challenges

Technical Problem: Lack of analytical frameworks to measure and evaluate ecosystem services for policy.

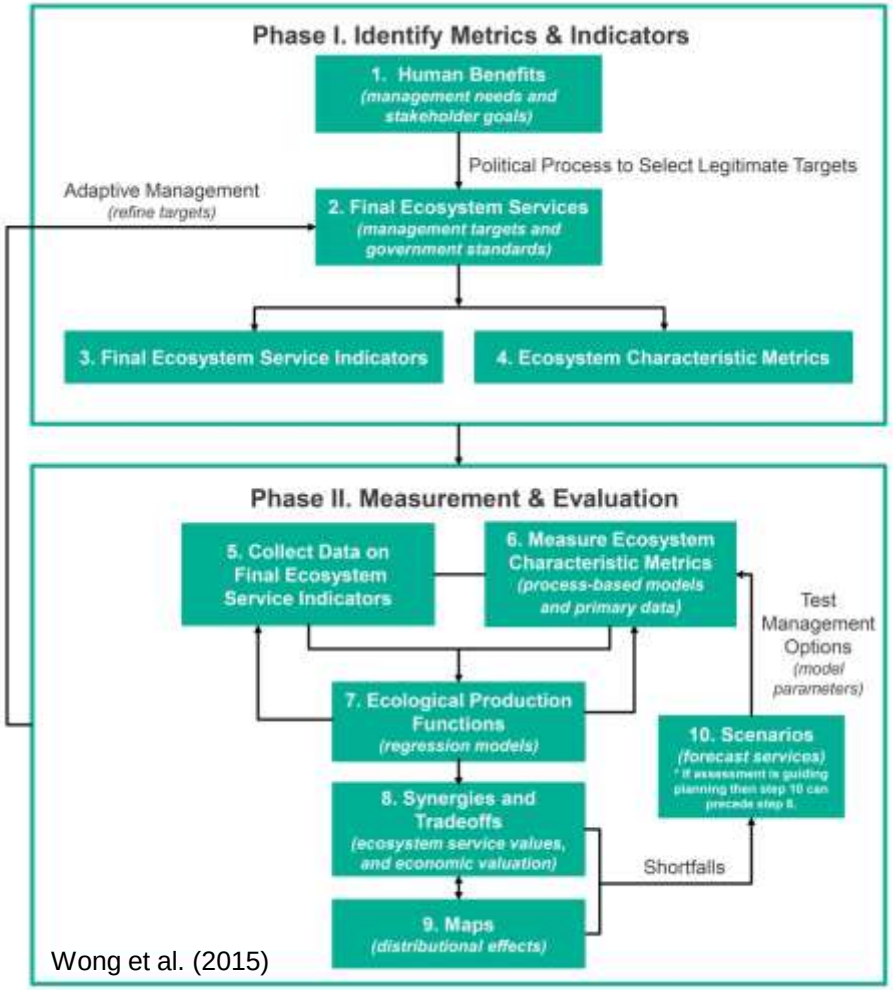
Challenge: Integrative thinking needed to overcome disciplinary barriers to address the data gap, which is impacting implementation.



Ecological Production Functions: Measurement



10-Step Approach



Wong et al. (2015)

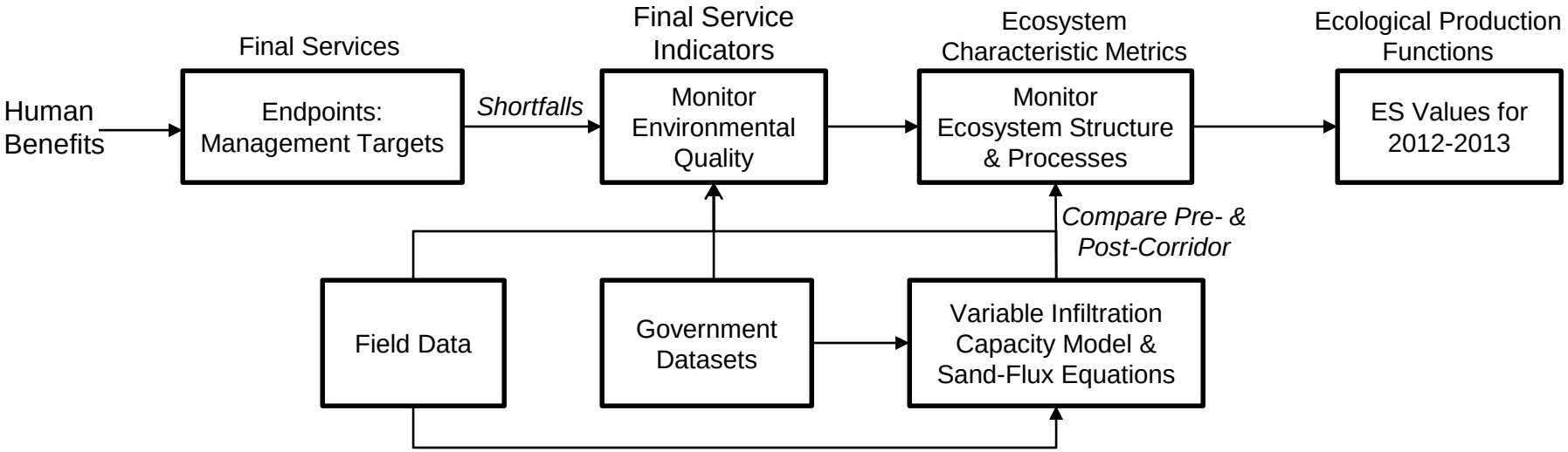
Yongding River Ecological Corridor

Large-scale Green Infrastructure: Seven lakes and wetlands as network of parks to advance socioeconomic conditions and urban livability.

Policy Objective: Enhance Five Ecosystem Services

1. **Water Storage:** Increase Groundwater Storage
2. **Local Climate Regulation:** Cooling for Human Comfort
3. **Water Purification:** Drinking Water Quality
4. **Dust Control:** Reduce PM_{10} to Improve Air Quality
5. **Aesthetics:** Recreation & Economic Development

Yongding Ecosystem Services Assessment: Methods



Stakeholders

Environmental Monitoring

Yongding ES Assessment: Indicators & Metrics

Ecosystem Service	Final Services	Final Service Indicators	Methods	Ecosystem Characteristic Metrics	Methods
Water Storage	Water Volume (million m^3) = 12.1 Water Area (km^2) = 6.5	Water Loss Factor (evaporation/volume)	Variable Infiltration Capacity Model	Lake depth (m)	Variable Infiltration Capacity Model
Local Climate Regulation	Heat Index (HI) Values Sultry = 27-28 HI<27	Air Temperature (^{0} C) Relative Humidity(%)	Hobo Data-Loggers	Evapotranspiration (mm hr^{-1})	Variable Infiltration Capacity Model
Water Purification	Drinking Water Quality (mg L^{-1}) TN = 1.0; TN<1.0 TP = 0.2; TP<0.2	TN (mg L^{-1}) TP (mg L^{-1})	Field Data	Nutrient Retention (mg L^{-1})	Field Data
Dust Control	PM_{10} (µg m^{-3}) Good Air Quality = 150; PM_{10}<150	PM_{10} (µg m^{-3})	Government Data	Sand-flux (g cm^{-2} day^{-1})	Yue et al. (2006) Equations
Aesthetics	Visitor Preferences Very Beautiful Beautiful	Landscape Aesthetic Scores	Visitor Surveys	Climate Water Quality Air Quality	Visitor Surveys

Water Storage & Local Climate Regulation

Water Storage Shortfalls: (1) -6 million m^3 yr^{-1} total lake volume and (2) -1 km^2 yr^{-1} surface water area

- EPF suggests 1 m increase in lake depth likely to lead to 38% decrease in water loss

Final Service Indicator	Lake Depth (Standard Error)	R^2	RMSE
Log Water Loss	-0.48* (0.02)	0.97	0.08

Local Climate Regulation Shortfalls (HI>26) for June 2013: Sultry events 51-98

- New ecosystems increased local ET 0.03 mm hr^{-1}
- EPF suggests a 0.01 mm hr^{-1} increase in ET would decrease HI by 0.02-0.07 for daytime in June 2013

Lake/Wetlands	ET (Standard Error)	R^2	RMSE
Mencheng Lake	-5.32 (0.55)*	0.87	1.14
Wetlands	-2.31 (0.52)*	0.84	1.17
Lianshi Lake	-7.07 (0.80)*	0.84	1.16
Xiaoyue Lake	-6.30 (1.97)*	0.76	1.77
Wanping Lake	-3.70 (0.57)*	0.81	1.33

Water Purification & Dust Control

Water Purification Shortfalls: Nutrient levels higher than Grade V (no permitted water uses)

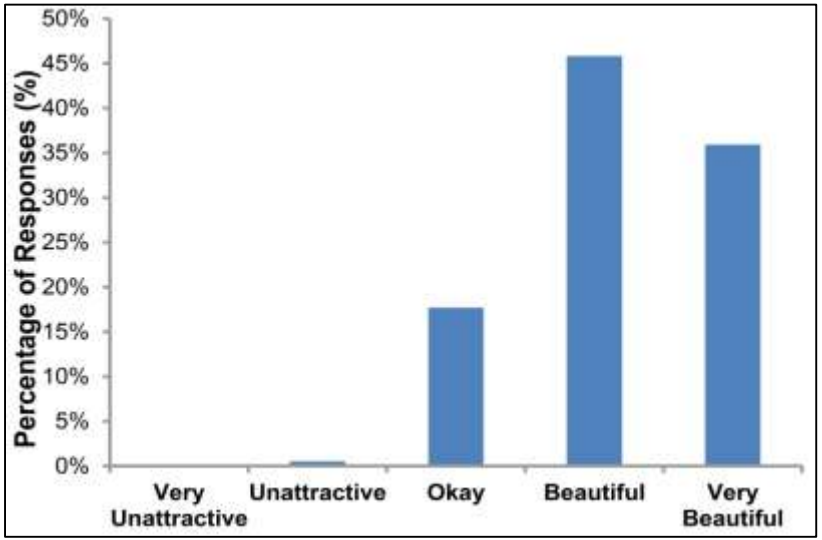
- High wetland nutrient retention (61% for TN & 66% for TP)
- EPFs suggest 50% increase in wetland area (40 ha increase) to obtain required TP level, and 75% decrease in nutrient load to obtain required TN level

Final Service Indicator	Wetland Area (Standard Error)	Nutrient Loading (Standard Error)	R^2	RMSE
Lake TN	-0.10 (0.03)*	0.41 (0.10)*	0.86	2.04
Lake TP	-0.01 (0.001)*	0.04 (0.03)	0.93	007

Dust Control Shortfalls: More PM_{10} shortfalls in Post-Corridor period, thus ecosystems are likely having minimal effect on local PM_{10} levels

- No statistically significant relationship between modeled sand-flux rates and PM_{10}

Aesthetics



Aesthetics = “Very Beautiful”

Environmental Quality (Explanatory Variables)	Predicted Probabilities
Water Quality	61%*
Climate	51%*
Air Quality	38%*

Synergies & Tradeoffs

Reduce Shortfall	Management Options	Possibility
Maintain Lakes/Wetlands (Sustain Water Supply)	↑ **1.4 m** Lake Depth ↓ **54%** Water Loss or Maintain Ideal Inflow Levels	Possible
Improve Human Comfort (Reduce Heat Index)	↑ 3,300% Evapotranspiration ↑ **168 km^2** Water Area ↑ **1 Unit** Heat Index	Unlikely
Improve Water Quality (Increase Water Purification)	↑ 50% Wetland Area ↑ **40 ha** Wetland Area ↓ **0.4 mg/L** TP	Unlikely
Improve Water Quality (Reduce Nutrient Load)	↓ 75% Nutrient Load ↓ **14 mg/L** TN Load ↓ **7 mg/L** TN	Possible
Improve Air Quality (Dust Control)	No statistically significant relationship between sand flux and PM_{10}	Uncertain
Maintain Aesthetics (Environmental Quality)	"Very Healthy" Air Quality "Very Healthy" Water Quality "Cold" Climate ↑ **38%, 61% or 51%** "Very Beautiful" Aesthetics	Possible (Water Quality/Climate)

Management Recommendations

Managers found recommendations useful since assessment clarified connections:
Ecosystems-Stakeholder Needs-Multiple Objectives-Actions

Lessons Learned

- We found progress is possible on creating ecological production functions for policy, but it requires integrative thinking
- Integrative thinking is *knowledge of how to connect issues, and skills to identify strategic actions on connections*

Main challenges are:

(1) Selecting appropriate final ecosystem services
(2) Technical expertise to perform modeling and acquire data to create EPFs for multiple services
(3) Integrating EPFs into existing regulatory and policy contexts

- To establish the ecosystem services approach we need applied examples of EPFs to create useful performance-based information that clarifies relationships to improve management for multiple societal objectives