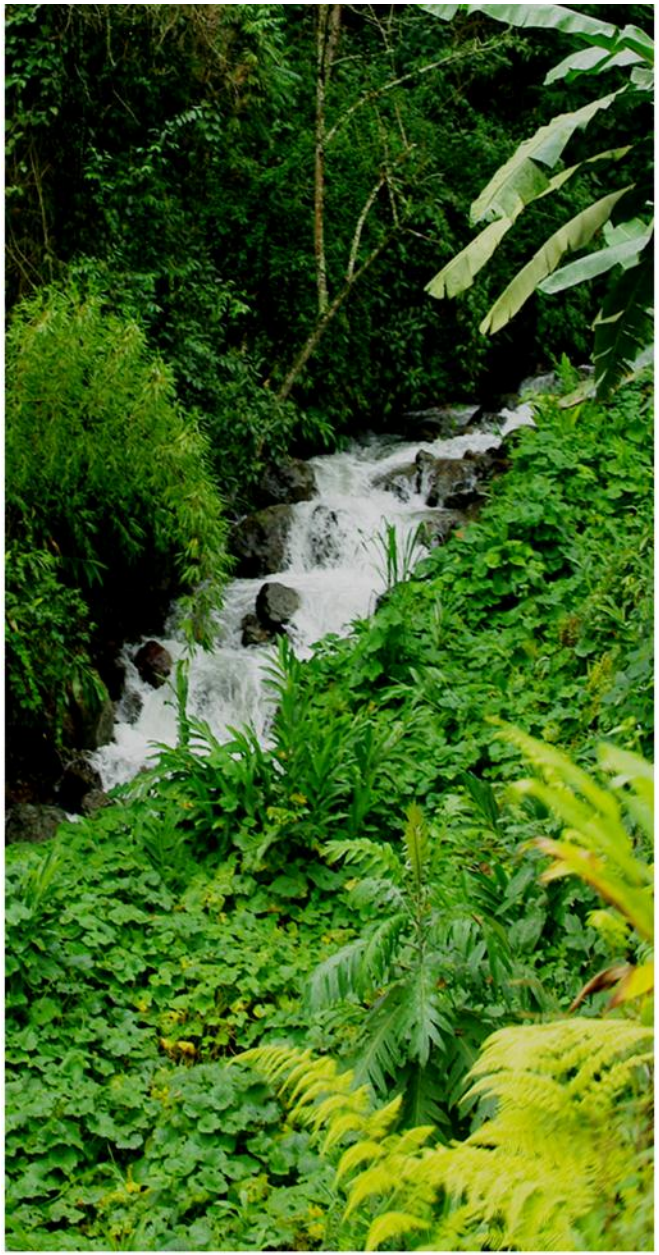


How Much is a Forest Worth?

Valuing Ecosystems for Hydropower Production in Himachal Pradesh, India

WAVES PTEC Workshop May 2013

Urvashi Narain, Adrian Vogl

Outline

- Scope of Project
- Biophysical Model
- Economic Valuation
- Scaling Up

Policy Context

- DPL to Promote Inclusive Green Growth for Sustainable Development
- One component requires the government to
  - Assess flow and value of ecosystem services
  - Design a scheme for payment of ecosystem services based on pilots

Policy Context

- Hydropower development is seen as a green growth policy
  - Number of projects under development
  - Number of payment mechanisms to compensate affected households and reduce environmental impacts, including prevention of soil erosion
- No assessment of ecosystem services or how these could be maximized through land management practices

Project Objectives

- Assess flow and value of ecosystem services and help
  - Design payment for ecosystem services scheme
  - Improve land management practices
- Which services?
  - Water supply for hydropower production
  - Sediment retention for hydropower facilities

Site Selection

- 3 pilot sites
- Selection Criteria:
  - Importance for hydropower production
  - Catchment area located within HP
  - Size (>5000 km^2)
  - Range of biophysical and **land use conditions**
  - Data Availability for calibration/validation

Site Selection – Data Issues

- Catchment size
  - InVEST (and SWAT) more accurate in large basins
  - 5000 km^2 to 500 km^2
- Data resolution
  - SWAT model for India, data at very coarse resolution
- Land use classification
  - Forest types, details on crop lands, etc.

Biophysical Model - InVEST

Steve Polasky, Peter Kareiva, Gretchen Daily, Taylor Ricketts, Mary Ruckelshaus, Erik Nelson, Adrian Vogl, Becky Chaplin-Kramer, Lisa Mandle, Yonas Ghile, Lula Gabremicheal, Guillermo Mendoza, Driss Ennaanay, Manu Sharma, Marc Conte, Jim Regetz, Derric Pennington, Anne Guerry, Spencer Wood, Katie Arkema, Gregory Guannel, Jodie Toft, Chong Ki Kim, Mike Papenfus, Apollo Qi, Gregory Verutes, Matthew Marsick, Nasser Olwero, Nirmal Bhagabati, Robin Naidoo, Eric Lonsdorf, Kai Chan, Dick Cameron, Rich Sharp, James Douglass, Doug Denu

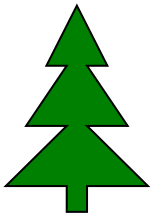
Objectives – HP Valuation Project

Phase I:

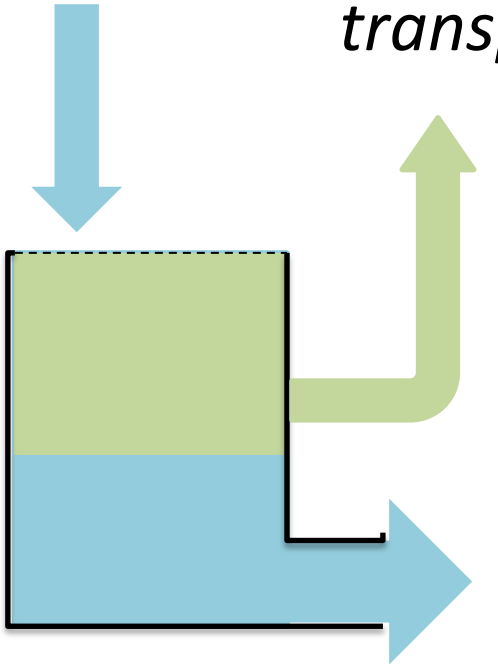
- Modeling of hydro-related services in 3 pilot regions
  - InVEST water yield model
  - InVEST sediment retention model
  - Model sensitivity/uncertainty analyses
  - Comparison with SWAT daily sediment estimation (IIT Delhi)
- Report on model outputs, comparison and applicability to ES valuation for hydropower
- Introduce technical staff to InVEST, provide capacity to continue natural capital assessments in the future

InVEST Model Details

Conceptual Model - Water Yield



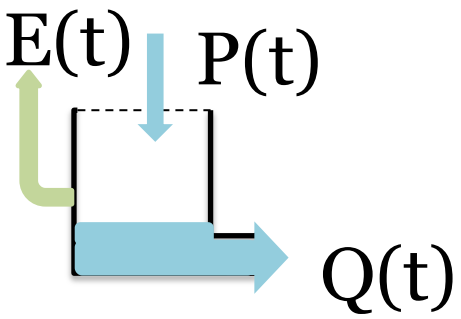
Precipitation – *Evapo-transpiration*



= Water yield

Equations – Water Yield

- Water Yield is the water depth (volume) that is NOT Evapotranspired: *WY = P – AET*



- It is the sum of Surface flow, subsurface flow and groundwater flow:

  WY = SR + SubSR + GW

- Model: ***WY = P * (1 – AET / P)***

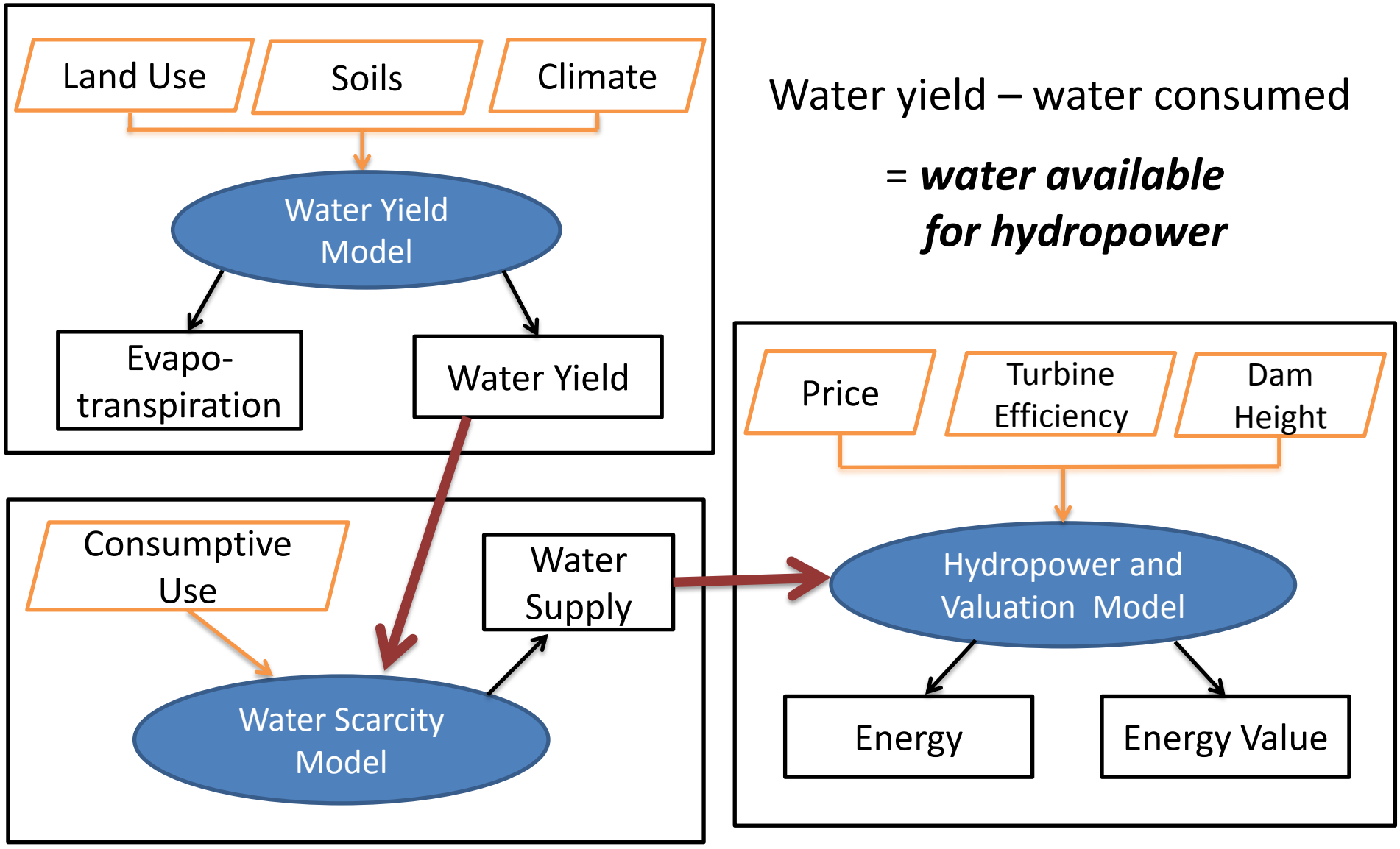
$$\frac{AET_{xj}}{P_x} = \frac{1+\omega_x R_{xj}}{1+\omega_x R_{xj}+\frac{1}{R_{xj}}}$$

where

$$\omega_x = Zhang\frac{AWC_x}{P_x}$$

$$R_{xj} = \frac{kc \cdot ETo_x}{P_x}$$

Model Architecture – Water Yield



Water yield – water consumed

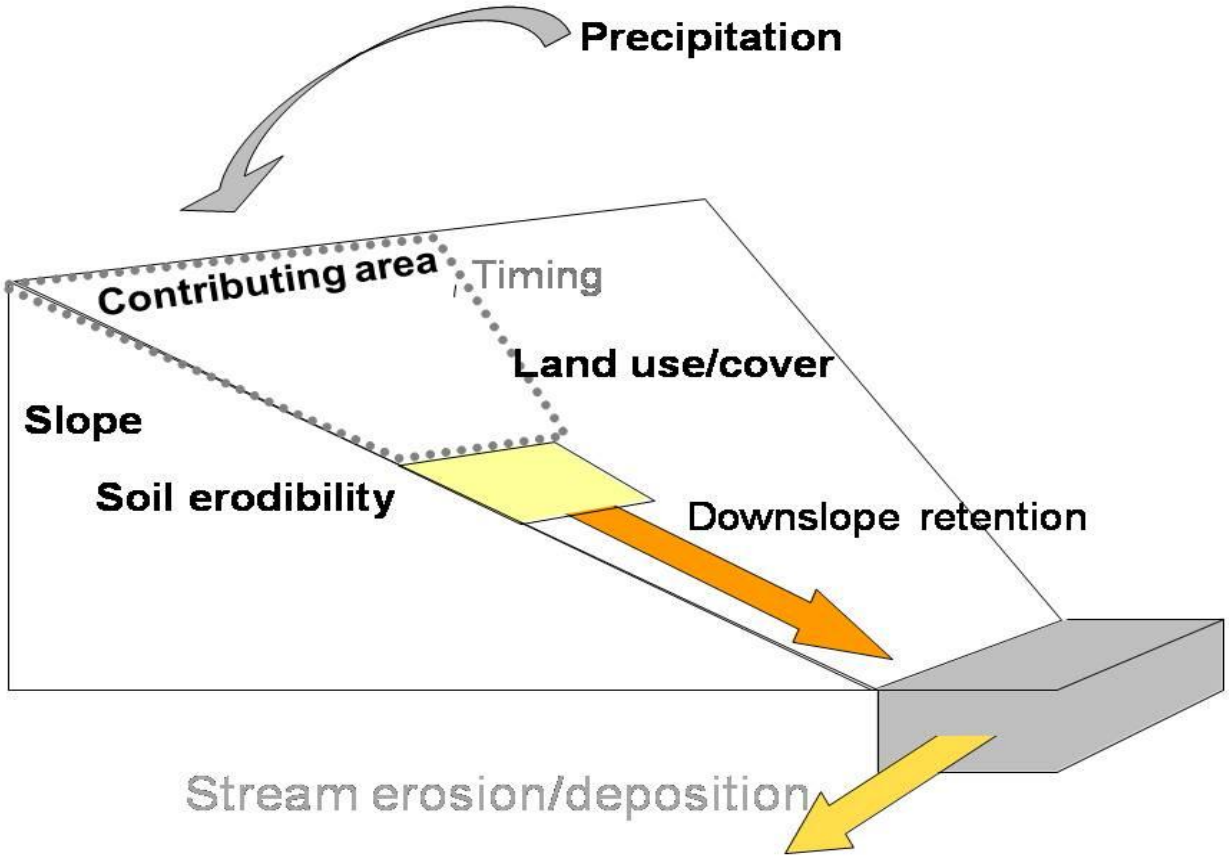
= ***water available for hydropower***

InVEST Sediment Retention

- Based on the Universal Soil Loss Equation (USLE)
  - Includes geomorphology and climate
  - Potential erosion on a parcel
- Enhanced by hydrologic connectivity
  - What happens as the parcel's sediment moves downslope?
  - Influence of intervening landcover
- Sediment retention valued as ecosystem service

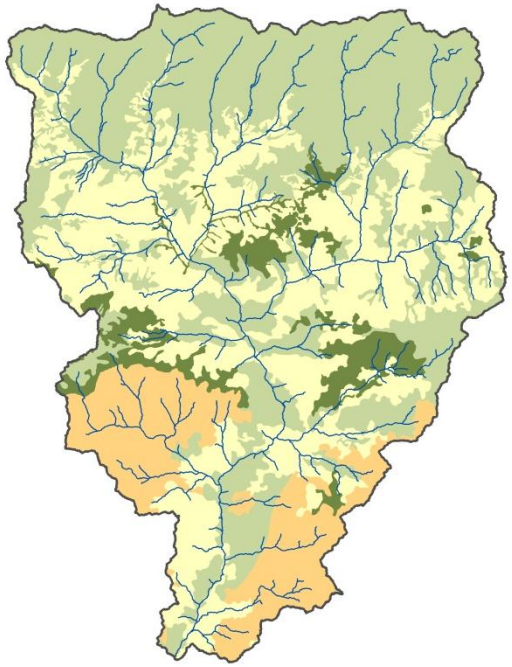
InVEST Sediment Retention

- Quantify sediment exported and retained on a landscape



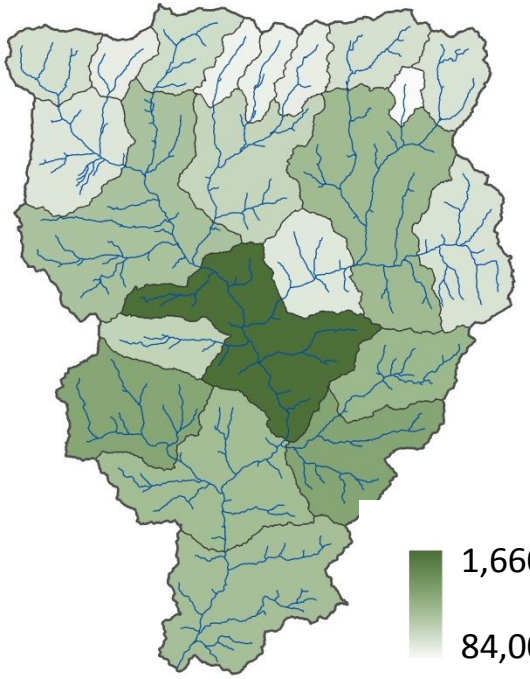
InVEST Model Outputs

Land cover



- Agriculture
- Forest
- Natural vegetation
- Pasture

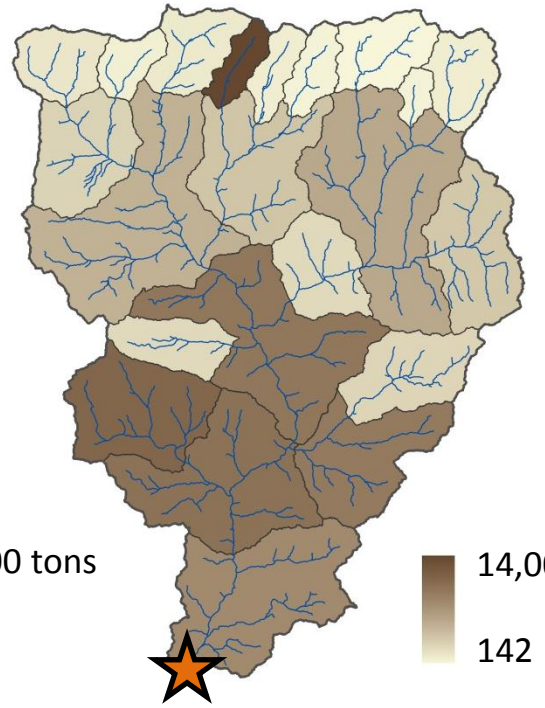
Sediment retention



1,660,000 tons

84,000

Sediment export



14,000 tons

142

+ Total export to outlet

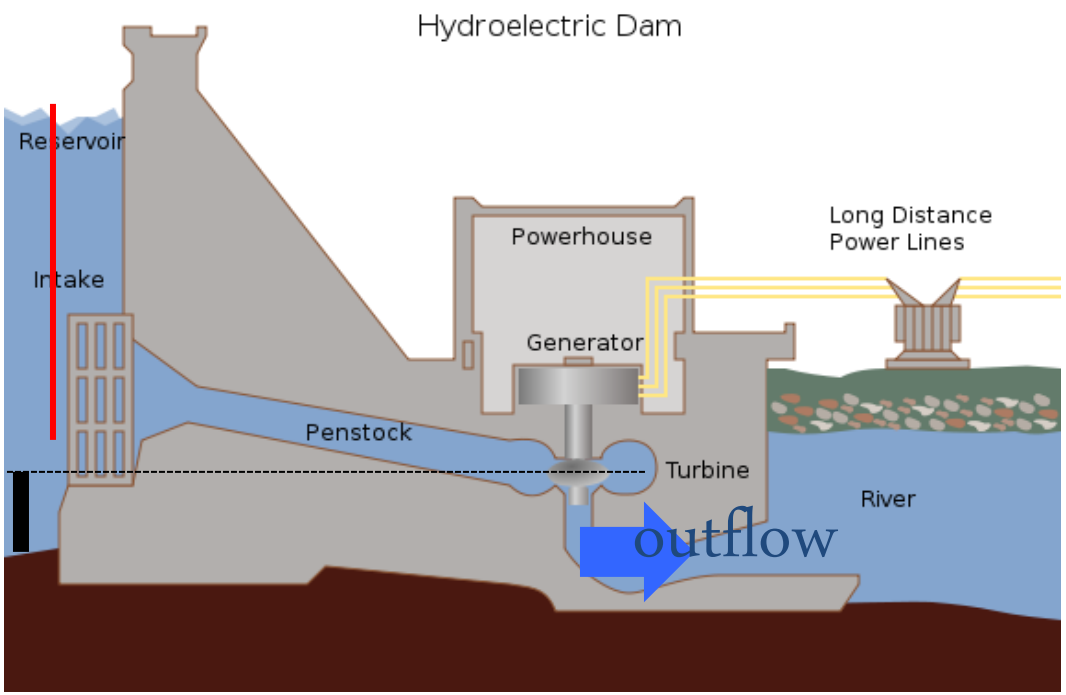
Applying InVEST in HP

Challenge	Approach
Water Yield – importance of seasonal flows & monsoonal influence	- Apply newly developed monthly water yield model to provide seasonal values of hydropower production
Run-of-river hydropower facilities	- Adjust energy production model
Sediment Yield – is annual sediment load a good proxy for daily sediment threshold exceedances?	- Compare with SWAT model, daily outputs - Cost vs benefit of running different models (time, data requirements, technical capacity)

Economic Valuation Methods

- Production function-based valuation
- Market valuation
  - Energy produced by hydropower
- Avoided damage costs
  - Avoided sedimentation
- Production Economics
  - Water for irrigation
  - Pollination of agricultural crops

Equations – Energy Production



outflow rate

head

$$p_d = d.q_d.g.h_d$$

gravity constant

water density

$$\varepsilon_d = 0.00272 * \gamma(V_{in}) * h_d * \beta$$

Valuation – Water Yield for Hydropower

- Total Value of the Hydropower:

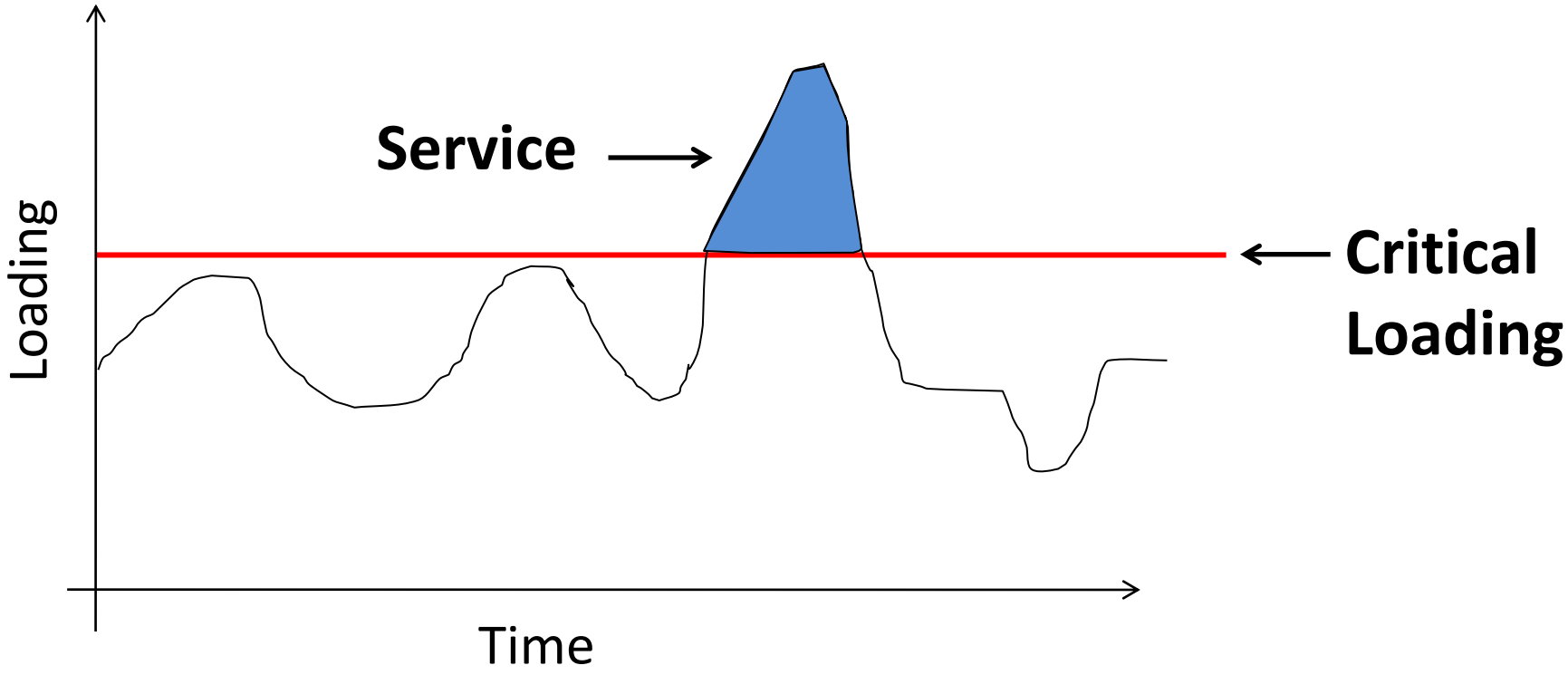
$$NPVH_d = (p_e \varepsilon_d - TC_d) \times \sum_{t=0}^{T-1} \frac{1}{(1+r)^t}$$

- The Sub-basin's Hydropower production Value:

$$NPVH_x = NPVH_d * \frac{C_x}{C_{tot}}$$

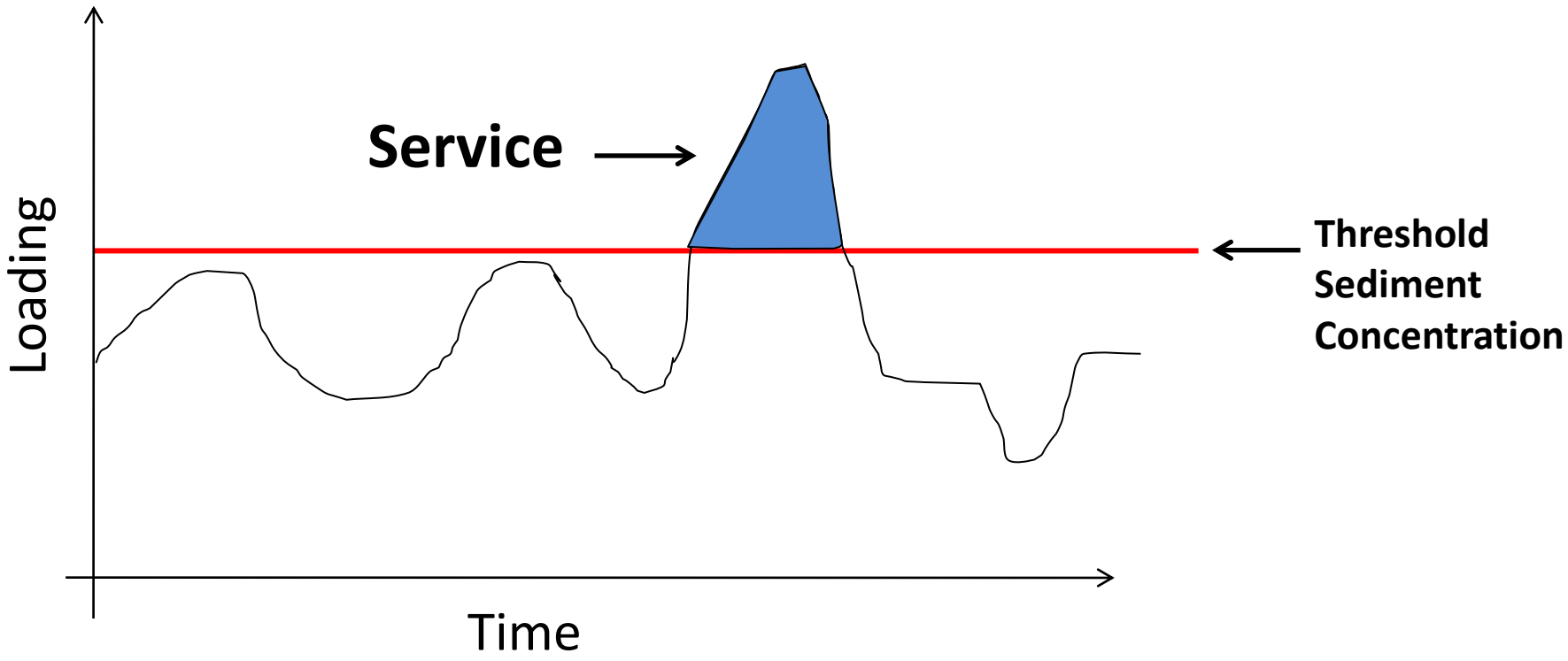
Valuation – Sediment Retention

- Based on avoided treatment costs
- Currently can value for *dredging* and/or *water quality*

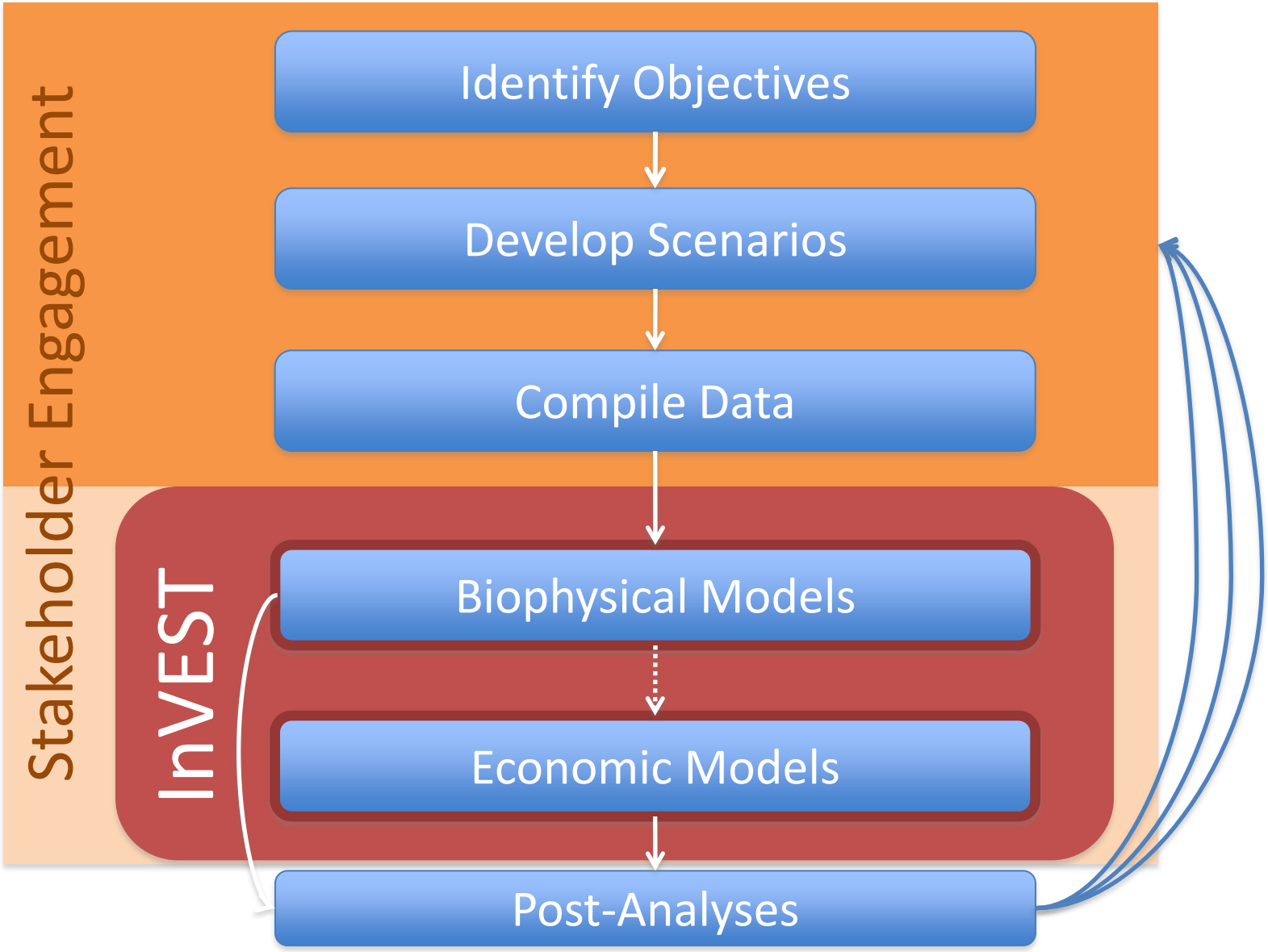


Valuation – Sediment Retention for HP

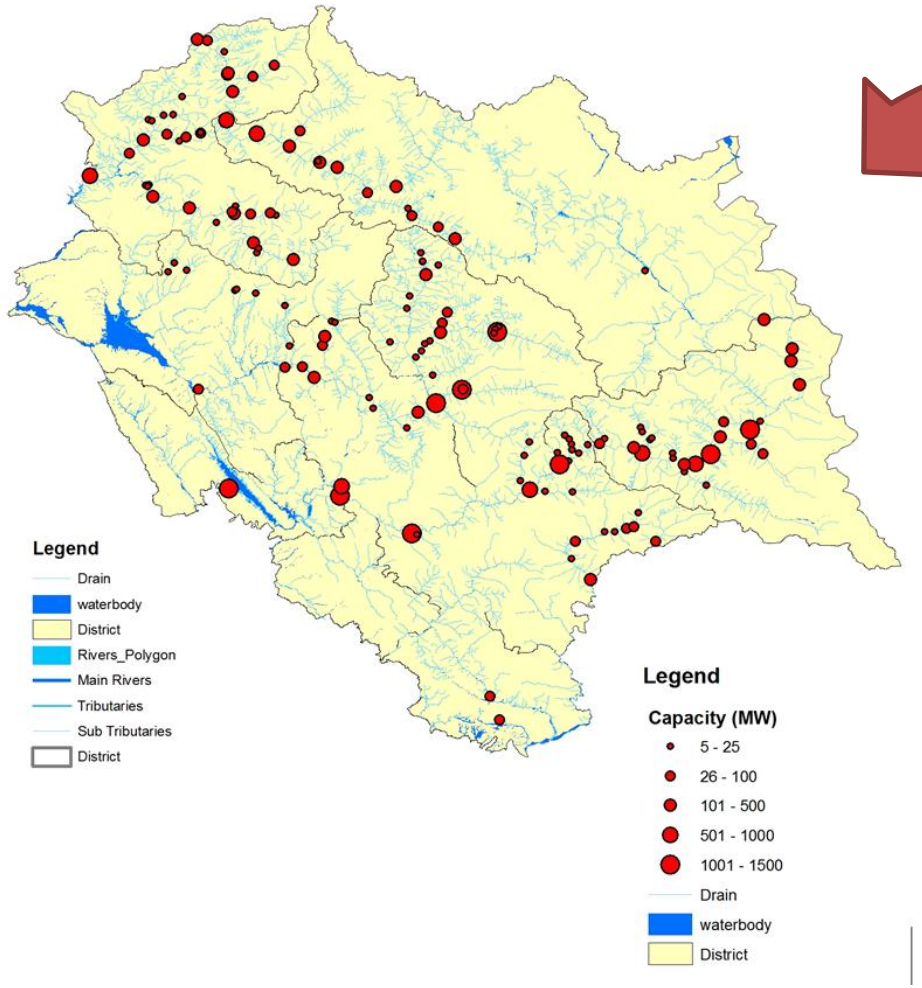
- For HP, valuation must be based on threshold of ***safe operating level*** and ***avoided production loss***

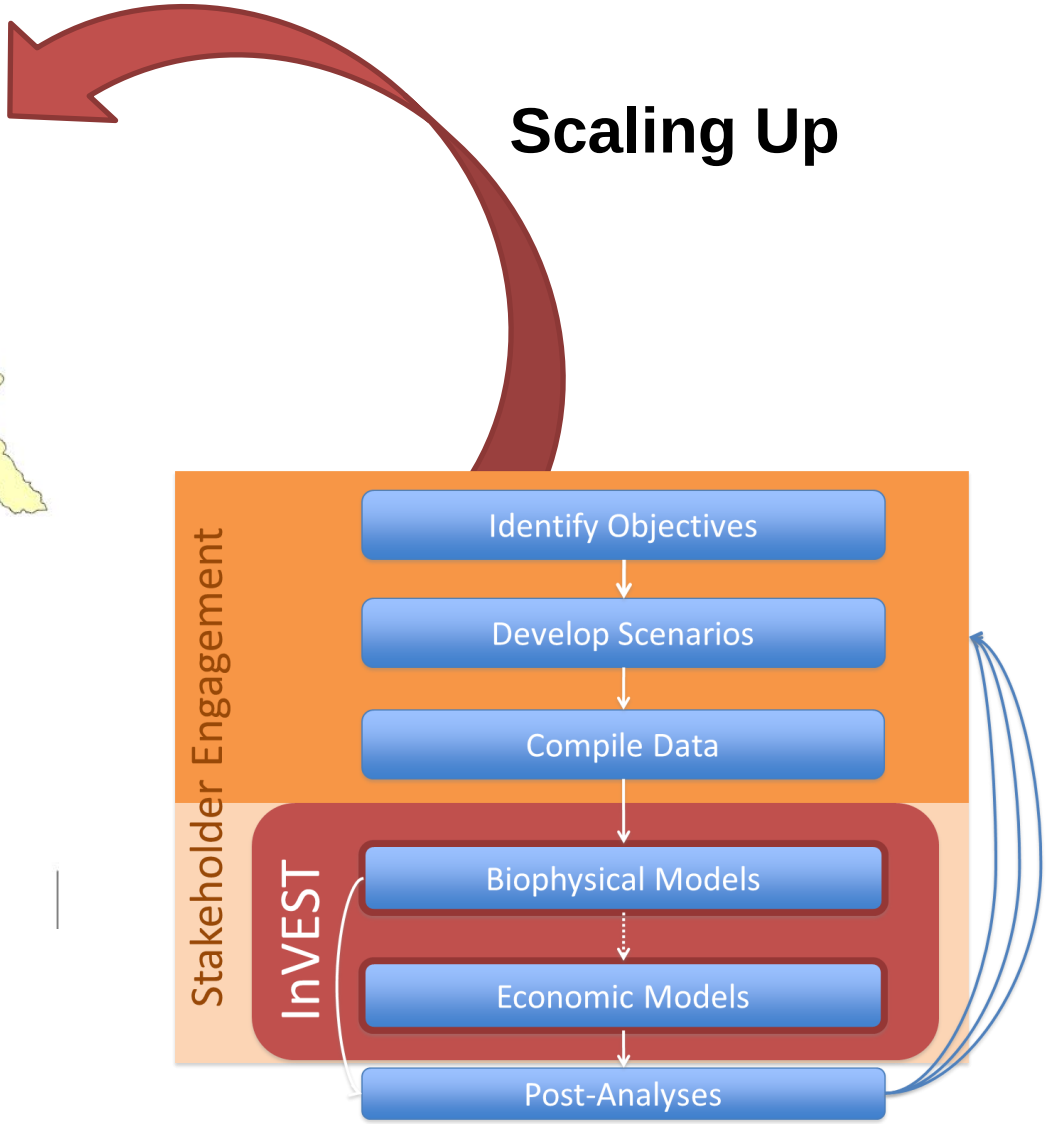


InVEST with Scenarios



Scaling up InVEST





Scaling Up InVEST

- Replicate this method in basins across HP
- Aggregate results
- Models appropriate to large basins, however:
  - Scaling up to cross-border basins
  - Data availability issues (i.e. China)
  - Technical capacity/replicability

Future Work

- Phase 2: Use results and additional modeling analysis with scenarios (InVEST, RIOS) to inform PES design in pilot basins
- Phase 3: Use scenarios, valuation and PES design to inform natural capital accounting approach for HP


Questions?