InVEST Hydropower Production

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Questions InVEST can answer

- How much water is available?
- Where does the water used for hydropower production come from?
- How much energy does it produce?
- How much is it worth?
Water Yield

- Water yield
- Inflow
  - Precipitation
    - Rain
    - Snow
    - Fog
- Root depth
- Water Availability
- Transpiration
- Evaporation
- Leaf type
- Plant type
- Seasonality
Water Yield

- Precipitation
  - Rain
  - Snow
  - Fog

- Transpiration

- Evaporation

- Inflow
  - Root depth
  - Water Availability

- Water yield

- Leaf type
- Plant type
- Seasonality
Model Architecture

- Land Use
- Soils
- Climate

Water Yield Model

Water yield – water consumed

= water available for hydropower

- Evapo-transpiration
- Water Yield
- Consumptive Use

- Water Supply

- Energy
- Energy Value

- Price
- Turbine Efficiency
- Dam Height

Hydropower and Valuation Model

- Water Scarcity Model
Model Inputs

**Climate**
Precipitation, Potential Evapotranspiration, Zhang

**Soils**
Soil depth, Plant Available Water Content

**Watersheds**
Main and sub-watersheds for point of interest

**Land Use/Land Cover**
Root depth, Evapotranspiration coefficient

**Water demand**

**Economic**
Hydropower plant data, price of energy
Obtaining Input Data

- Local: Field work, rain gauges, hydropower plant data
- Regional: National data
- Similar ecotypes: climate, elevation, vegetation
- Global: Climactic Research Unit precipitation, FAO soils, GLCF landcover
- Root depth/etk: Literature search
Model Outputs

- **Actual Evapotranspiration**
  mm/year

- **Water yield**
  mm/year

- **Water supply**
  m$^3$/year
  Used in valuation

- **Energy/value for hydropower**
  Kw/currency over timespan
Limitations

- Neglects extremes and seasonal variation of water yield
- Neglects surface-deep groundwater interactions
- Assumes hydropower production and pricing remain constant
Outlook

- Groundwater recharge index
- Automate calibration
- Monthly time step
- Regionalize the Zhang constant
- Tier 2 water yield model
Application

Predicted water yield change 1990-2060, HADCM climate change model
Predicted per capita water yield change 1990-2060, HADCM climate change model
Questions?
Nutrient Retention Model

Based on runoff and export coefficients*

- Nitrogen and phosphorus
- Includes climate and geomorphology
- Potential export from a parcel/pixel

\[
\text{Precipitation} - \text{Evapo-transpiration} = \text{Runoff (water yield)}
\]

<table>
<thead>
<tr>
<th>Landuse</th>
<th>Nitrogen Export Values (kg/ha/yr)</th>
<th>Phosphorus Export values (kg/ha/yr)</th>
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</thead>
<tbody>
<tr>
<td>Forest</td>
<td>1.8</td>
<td>0.011</td>
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<tr>
<td>Corn</td>
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<td>Cotton</td>
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<td>Soybeans</td>
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<td>Idle</td>
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<td>Business</td>
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<td>3</td>
</tr>
<tr>
<td>Industrial</td>
<td>4.4</td>
<td>3.8</td>
</tr>
</tbody>
</table>
Sediment Retention Model

Based on the Universal Soil Loss Equation (USLE)

\[
\text{USLE} = R \times K \times LS \times C \times P
\]

= potential export
Hydraulic Connectivity

Flow direction

load (N/P/sed)

to reservoir

export

Stream

Retention

Forest

Wheat

Corn
Valuation

- *Net Present Value* of retention
- Based on *avoided treatment costs*
Inputs - Nutrient

**Climate**
Precipitation, Potential evapotranspiration, Zhang

**Topography**
Digital elevation model, Threshold flow acc

**Soils**
Soil depth, Available water content

**Watersheds**
Catchments flowing into points of interest

**Land use/Land cover**
Export coefficients, retention capacity, root depth, etc

**Economic**
Critical loading, treatment cost, time, discount rate
Inputs - Sediment

**Land use/Land cover**
Vegetation retention, land practice and management

**Topography**
Digital elevation model, slope threshold, threshold flow acc

**Erosivity**
Based on intensity and kinetic energy of rainfall

**Erodibility**
Soil detachment and transport potential due to rainfall

**Streams**
Used to determine where sediment flows to

**Watershed Areas**
Catchments flowing into reservoirs

**Reservoir Features**
Dead volume, lifetime of reservoir, allowed load

**Economic**
Reservoir dredging costs Or water quality filtering costs
Outputs - Nutrient

Nutrient Exported
Kg/year

Nutrient Retained
Kg/year
*Used in valuation*

Value of Nutrient Removal for Water Quality
Currency over time period
Outputs - Sediment

**Potential Soil loss**
Calculated from USLE
Tons/year

**Sediment Retained**
Tons/year
*Used in valuation*

**Sediment Exported**
Tons/year

**Value of Sediment Removal for Water Quality/Dredging**
Currency over time period

*Total export to reservoir*
Limitations - Nutrient

- All bio-physio-chemical processes are lumped in one export coefficient
- Annual basis, no seasonality
- No in-stream processes or point sources
- Assess one pollutant per run
- No saturation in uptake
Limitations - Sediment

- Predicts erosion from sheet wash alone
- Sediment gets to outlet within a year
- No limit to retention
- Neglects the role of topography, soil, climate in the retention processes
- Accuracy limited in mountainous areas
Questions?