natural capital PROJECT

INTRO TO CORE FWAT MODELS

March 27, 2014

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InVEST MODELS

Freshwater and Terrestrial models

RESOURCES
QUESTIONS? ISSUES WITH THE MODELS?

- InVEST **User's guide**: www.naturalcapitalproject.org/ models/ models.html (latest version online, pdf version of the current release with download)
- InVEST **forums**: http://ncp-yamato.stanford.edu/natcapforums/
- **Literature**: how other people used the models!

FWAT MODELS
CURRENT SUITE OF TOOLS

ANNUAL WATER YIELD
HYDROPOWER

NUTRIENT
WATER PURIFICATION

SEDIMENT
WATER PURIFICATION

CARBON STORAGE
CLIMATE REGULATION

HABITAT QUALITY
BIODIVERSITY

HABITAT RISK ASSESSMENT

TIMBER PRODUCTION

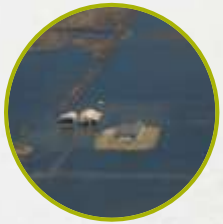
POLLINATOR ABUNDANCE
CROP POLLINATION

FWAT MODELS
IN DEVELOPMENT

MONTHLY WATER YIELD
HYDROPOWER, IRRIGATION

NUTRIENT WATER PURIFICATION

SEDIMENT WATER PURIFICATION



FLOOD MITIGATION

AGRICULTURE

CARBON STORAGE AND SEQUESTRATION

Brad Eichelberger

CARBON BACKGROUND

- Carbon dioxide is a greenhouse gas
- Terrestrial systems store 4 times more carbon than atmosphere
- Land use change can release carbon, or store it
- Whole world is impacted by release/storage anywhere

CARBON BACKGROUND

- Climate change mitigation
  - Reforestation
  - Soil management
  - Plantation practices
  - Crop practices
- Carbon markets
- Reducing deforestation and forest degradation (REDD)
- Kyoto Protocol

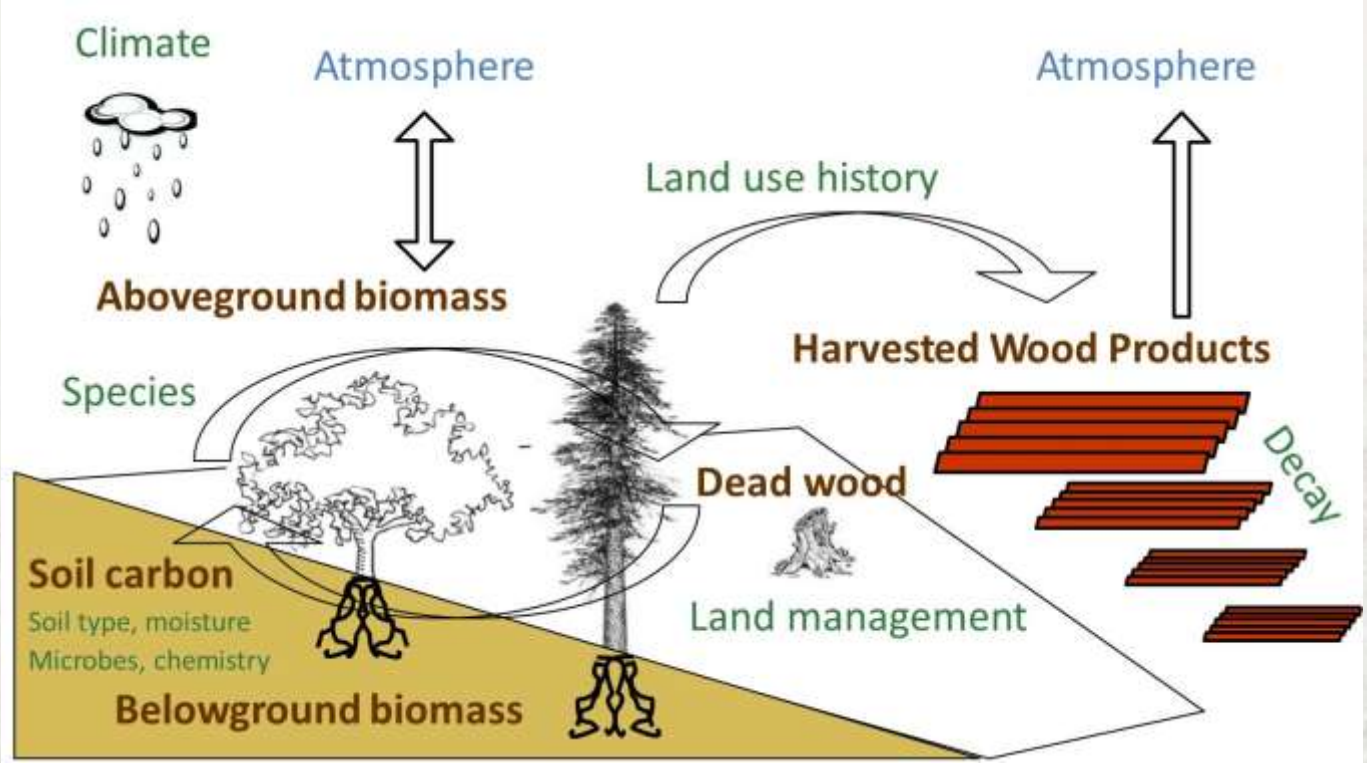
EXISTING MODELS

- U.S. Forest Service has several:
  - MC1 - global vegetation dynamics
  - FVS - tree growth and yield simulator
  - FORCARB2 - stock and change projections
  - Complex, often U.S.-centric
- CENTURY – plant-soil nutrient cycling
- LPJml – global managed vegetation and water balance
  - Very complex set of input parameters
  - More details than many users need

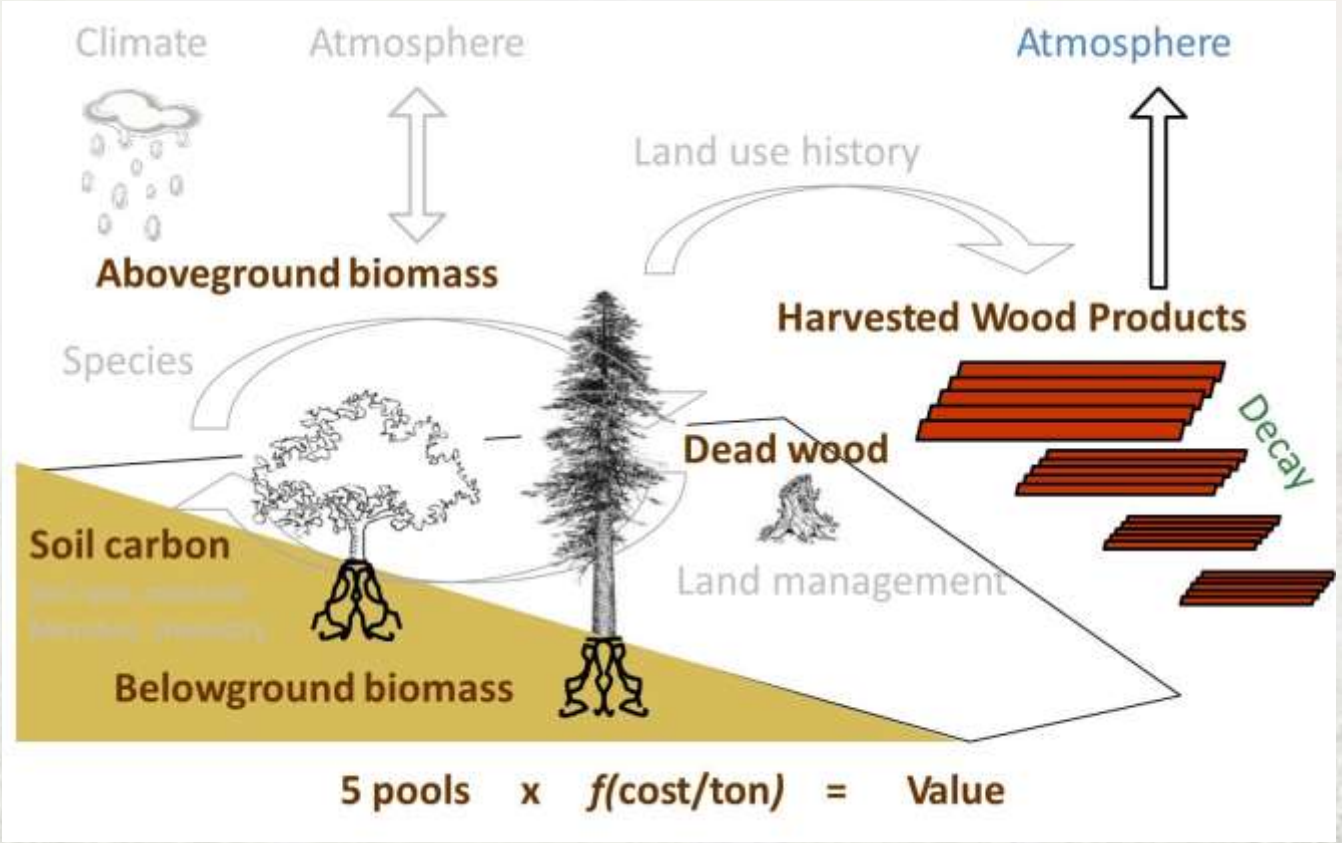
InVEST CARBON STORAGE MODEL

- In the Tier 1 model we estimate carbon stock as a function of land use/land cover.
- *Storage* indicates the mass of carbon in an ecosystem at any given point in time.
- *Sequestration* indicates the change in carbon storage in an ecosystem over time.
- Valuation is applied to sequestration.

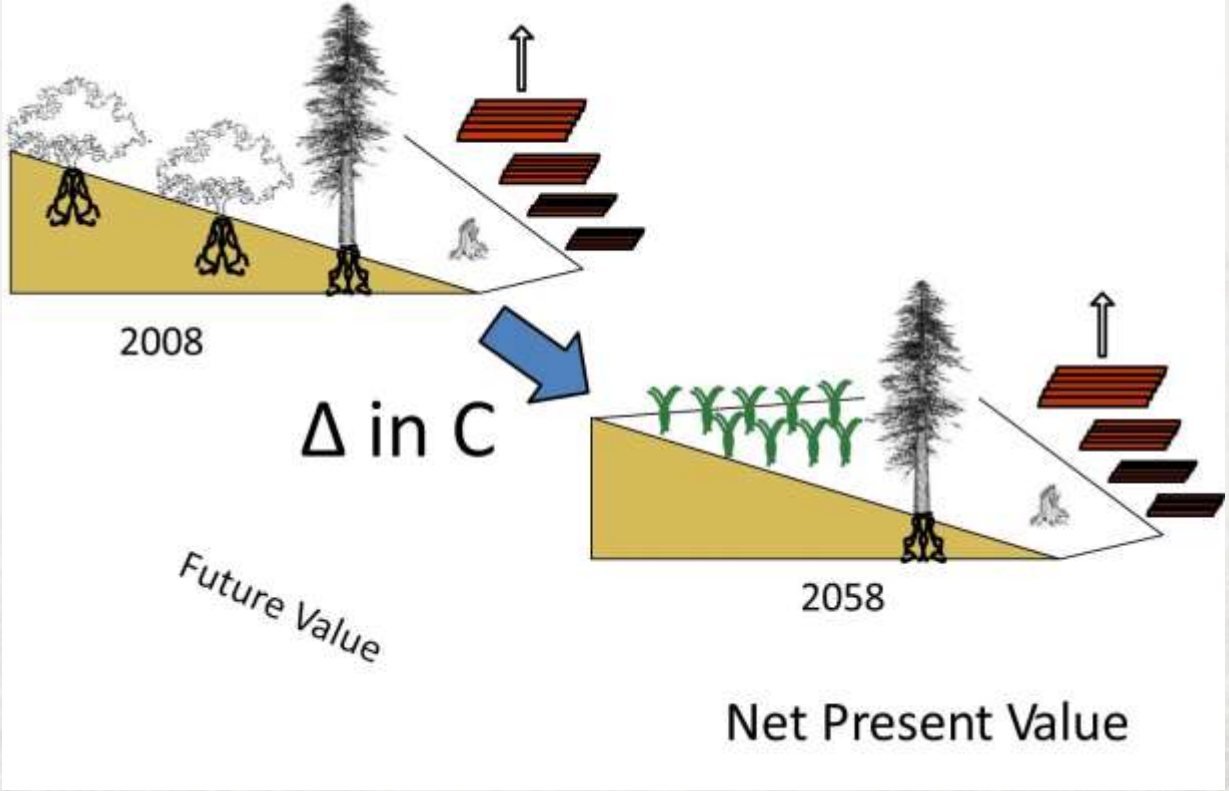
CARBON – OVERVIEW



InVEST CARBON STORAGE MODEL

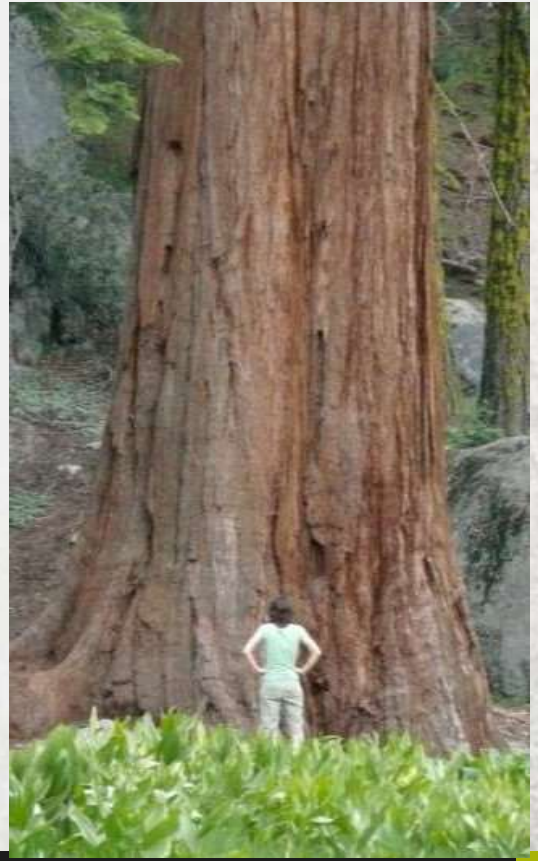


SEQUESTRATION AND VALUE



APPROACH TO VALUATION

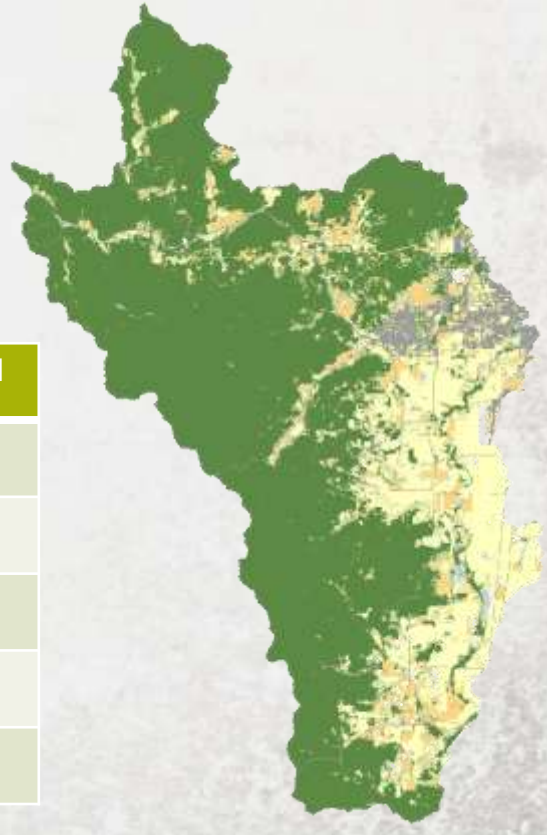
- Net Present Value is a function of:
  - Social cost or market price of carbon
  - Social or market discount rate
  - Rate of change in carbon value
- Carbon model is most appropriate for valuing **the social cost of carbon**: What is the benefit from avoiding damage from CO_2 release?



INPUT DATA

- Required data:
  - Land use/land cover (LULC map)
  - Table of carbon pools (metric tons/ha):

LULC	LULC_name	C_above	C_below	C_soil	C_dead
1	Forest	140	70	35	12
2	Coffee	65	40	25	6
3	Pasture/grass	15	35	30	4
4	Shrubs	30	30	30	13
5	Open/urban	5	5	15	2



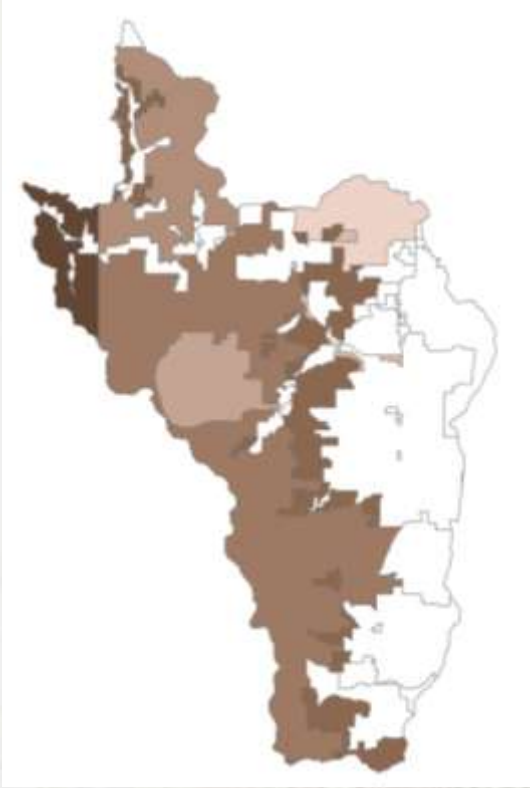
CARBON POOL DATA

- Local plot studies
- Published analysis on similar regions
- IPCC tables

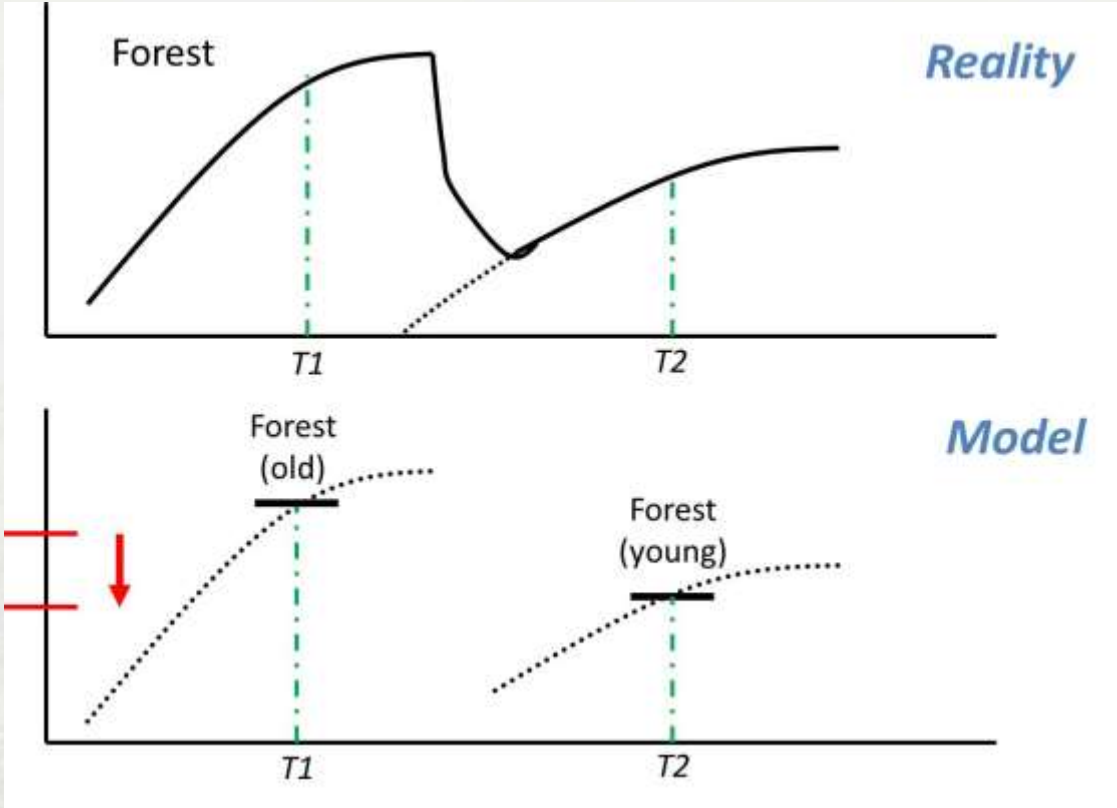
Ecological zone	Continent	Above-ground biomass (tonnes d.m. ha^{-1})
Tropical rain forest	Africa	310 (130-510)
	North and South America	300 (120-400)
	Asia (continental)	280 (120-680)
	Asia (insular)	350 (280-520)
Tropical dry forest	Africa	260 (160-430)
	North and South America	210 (200-410)
	Asia (continental)	130 (100-160)
	Asia (insular)	160

OPTIONAL DATA

- Future land use map
- Economic data (carbon value, discount rate)
- Timber harvest parcels
  - Frequency of harvest
  - Annual harvest amount
  - Decay rate of wood products
  - Density/volume factors
- REDD scenarios



LAND COVER TRANSITIONS

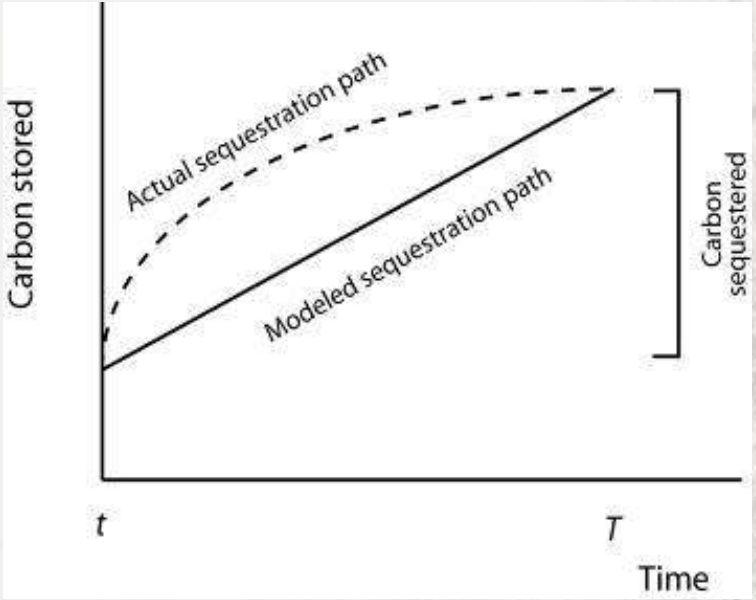


OUPUT

- Map of current carbon storage (Mg C / cell)
- Map of future carbon storage – if future land use provided
- Carbon sequestration (future – present storage)
- Map of economic value of carbon sequestered

LIMITATIONS

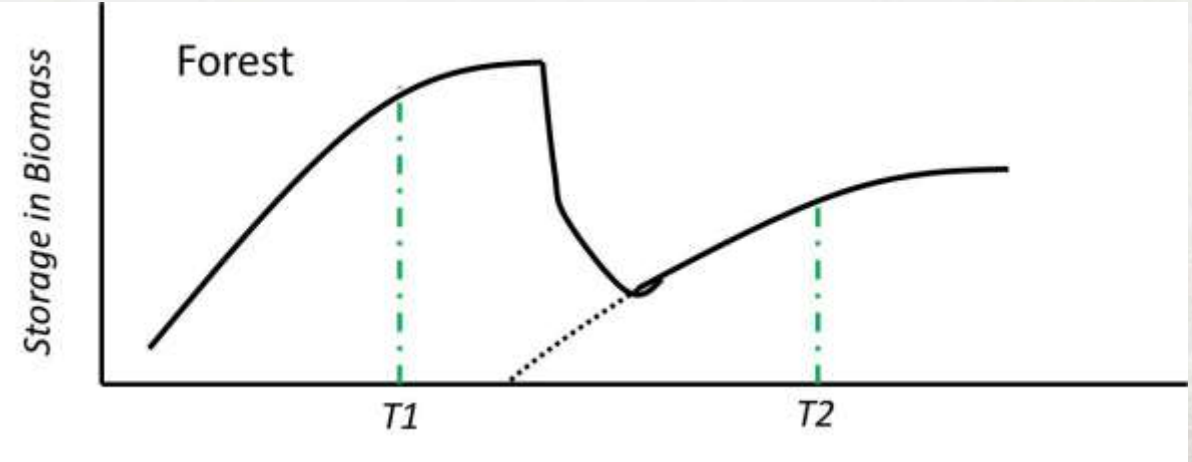
- Simplified carbon cycle
- Economic variation assumes a linear trend in sequestration over time
- Output is only as detailed and reliable as land use classes and carbon pool data
- Carbon sequestration does not occur in an area unless LULC changes over time or wood is harvested



FUTURE STEPS

- Add dynamics via time scale between current and future land uses

- Allow for an intermediate land use map to account for vegetation change dynamics



HABITAT QUALITY

Doug Denu

MODEL OVERVIEW

- Biodiversity is not treated as an ecosystem service per se
- Instead, it's used to assess overlaps and tradeoffs
- InVEST models habitat quality and rarity as indicators of the status of biodiversity
- Areas with high quality are generally better able to maintain biodiversity

MODEL OVERVIEW

Habitat Quality Depends On:

- Suitability of the habitat for the species of interest

  Does it prefer grassland, open canopy forest or closed canopy forest?

- Proximity and intensity of threats

  Proximity: *how far away is the threat?*

  Intensity: *how severe a threat is it?*

MODEL OVERVIEW

Degradation of habitat depends on:

- Distance between habitat and threat
- How quickly the impact decays with distance
- Relative weight of threat

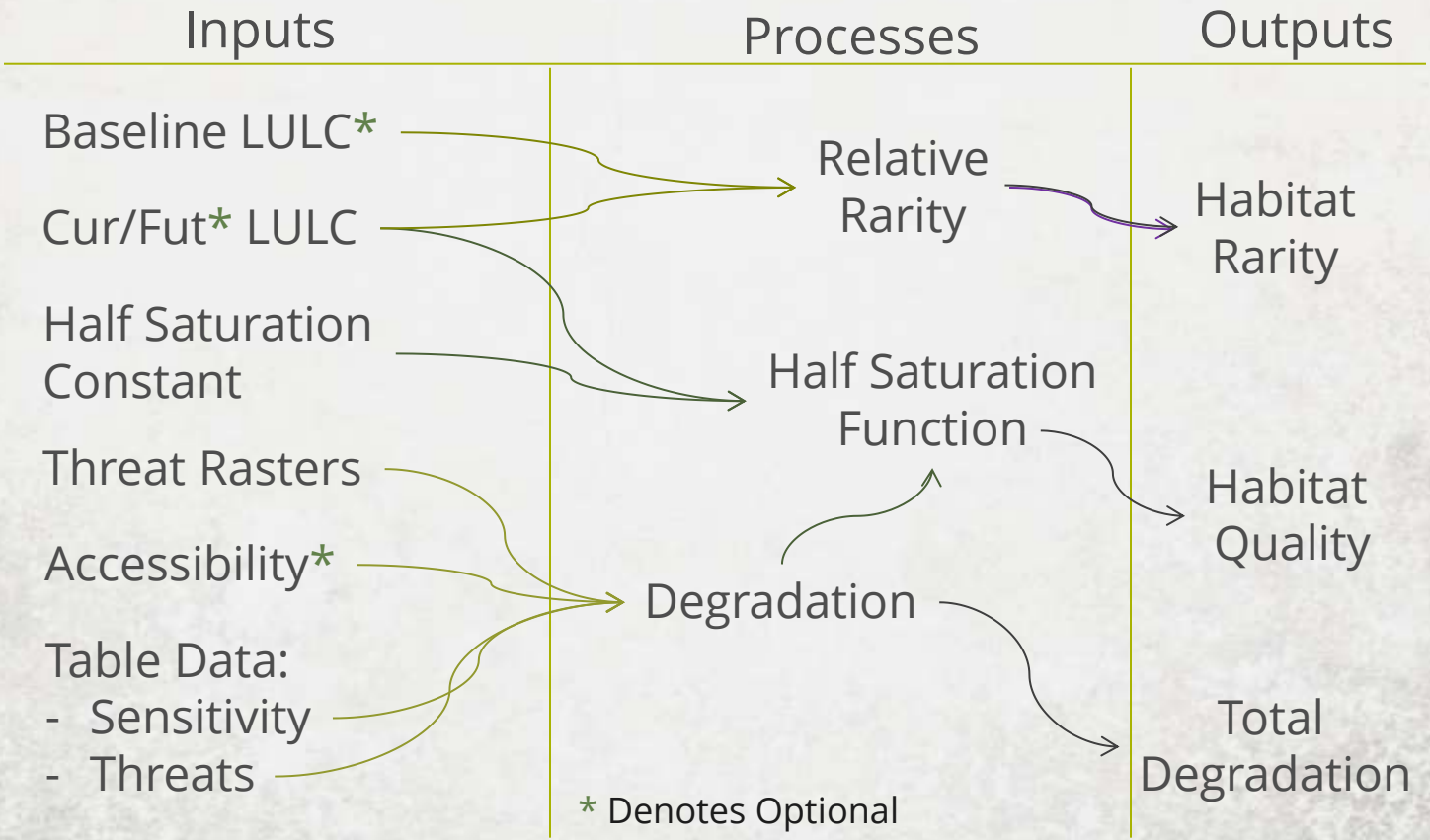
  Are highways a greater threat than dirt roads?

- Sensitivity of habitat to the threat

  Is forest more sensitive to roads than a grassland would be?

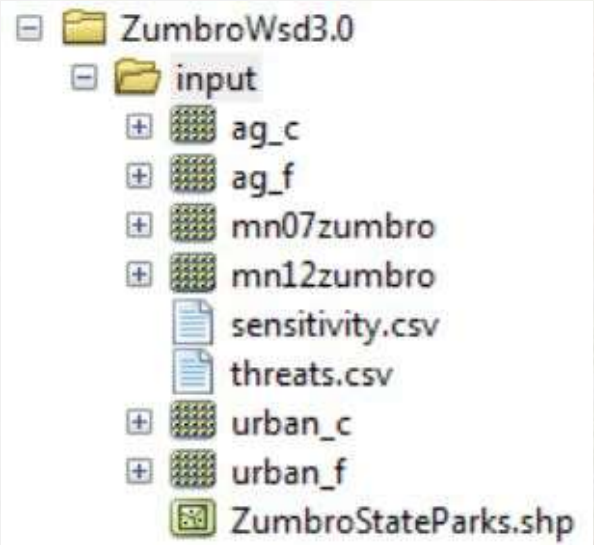
- Accessibility / Protection status

INPUTS, PROCESSES AND OUTPUTS

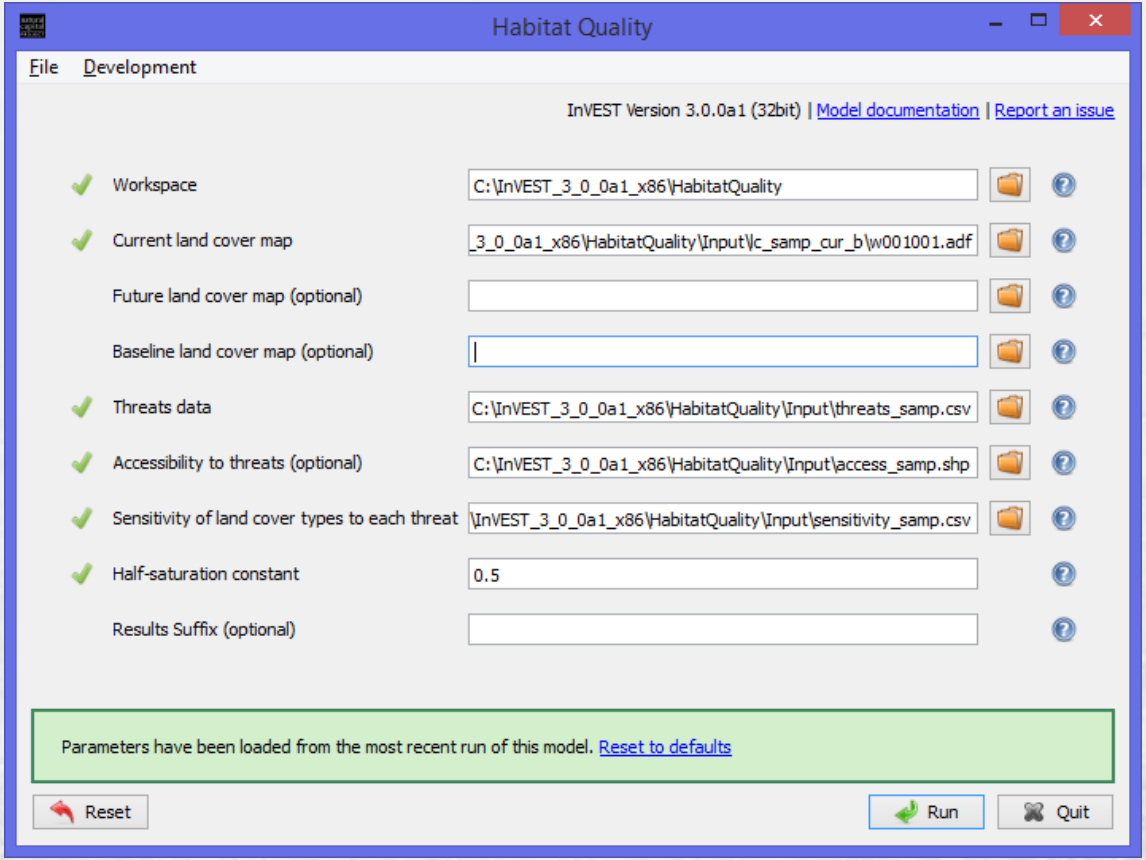


WORKSPACE

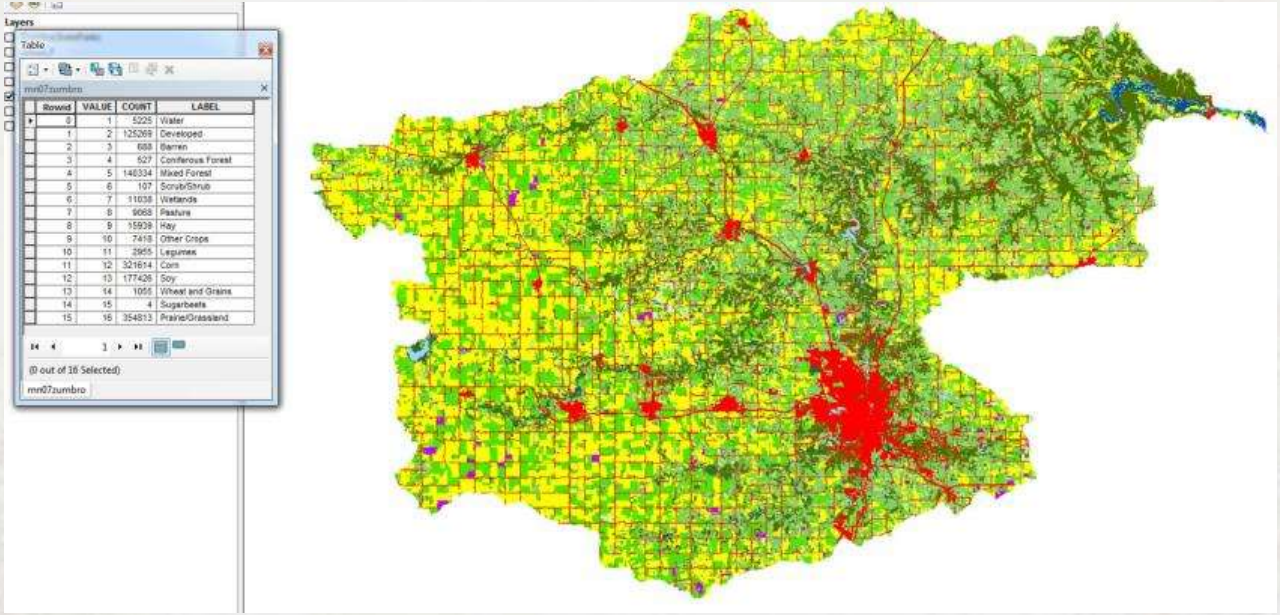
- The threat rasters are not an input into the User Interface, instead:
- The Workspace chosen should contain a folder, “input”, that holds all the threat rasters



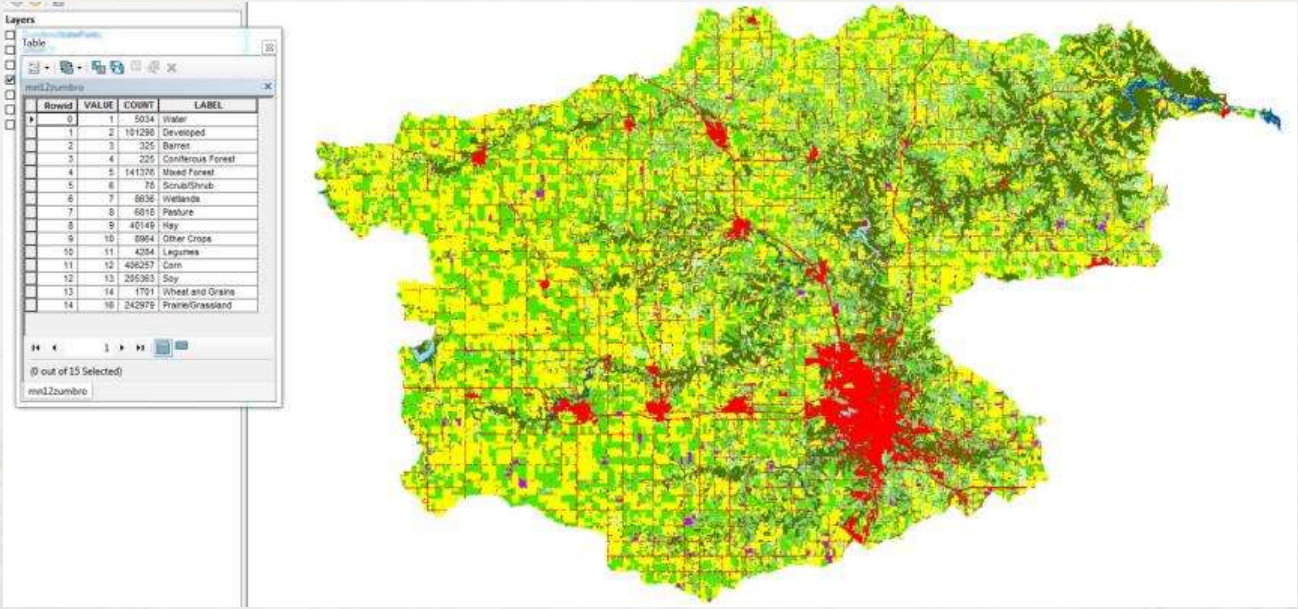
USER INTERFACE



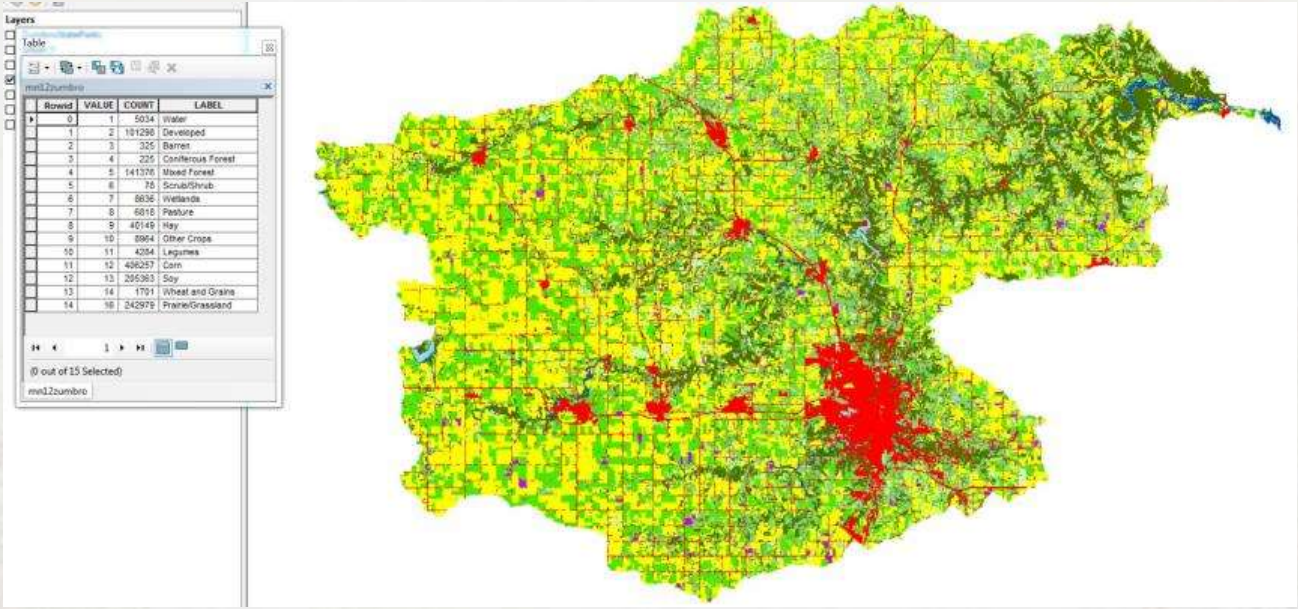
CURRENT LULC MAP (RASTER)



FUTURE LULC MAP (RASTER)



BASELINE LULC MAP (RASTER)



Baseline is used for rarity calculations

THREAT DATA (TABLE)

Table

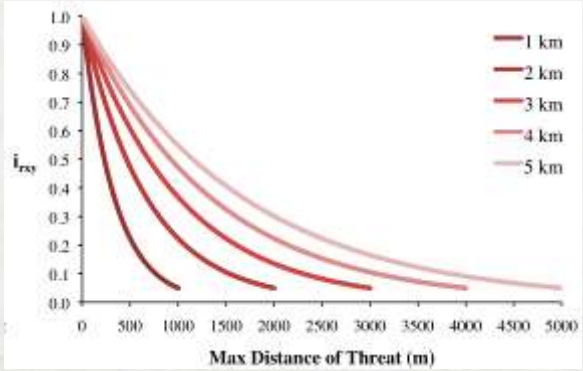
threats.csv

OID	THREAT	MAX_DIST	WEIGHT
0	AG	4	0.8
1	URBAN	5	1

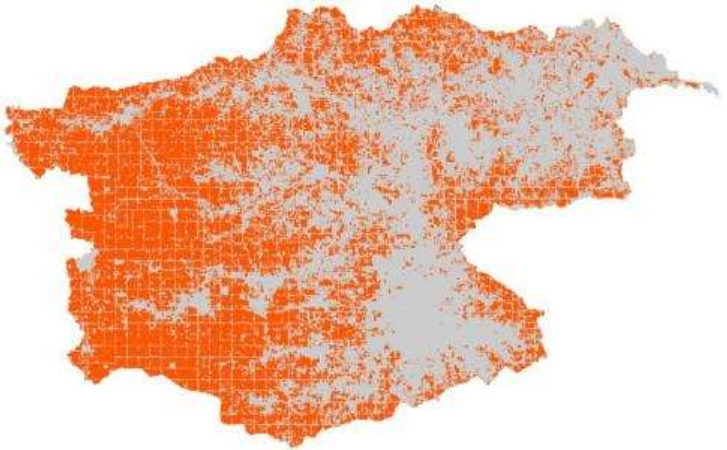
1

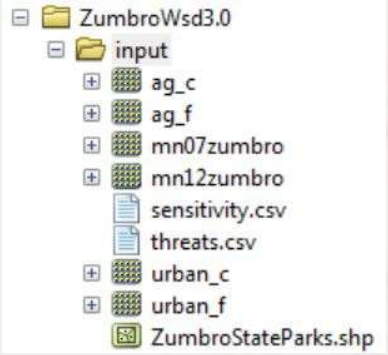
(0 out of 2 Selected)

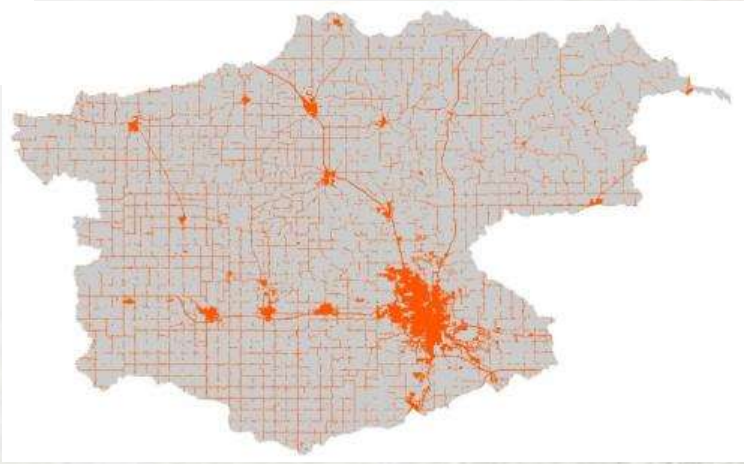
threats.csv



SOURCES OF THREAT (RASTER)

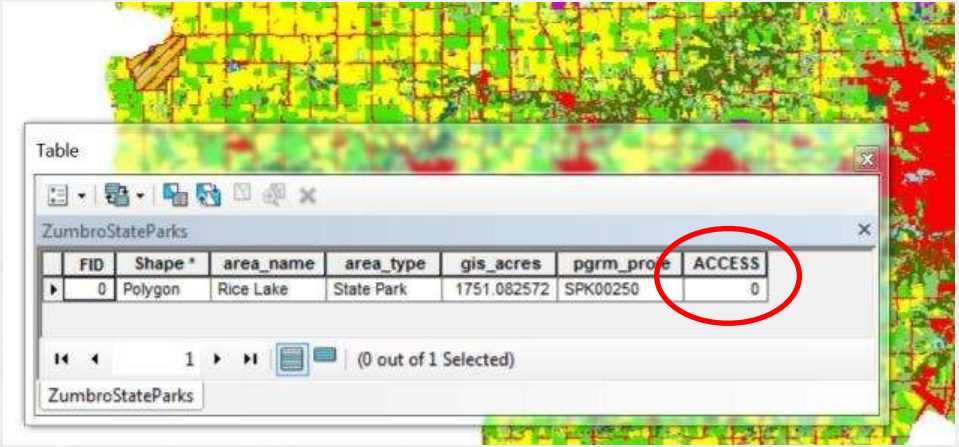






Note: This data must be in the input folder. You do not manually enter it into the model.

THREAT ACCESSIBILITY (POLYGON)



HABITAT AND SENSITIVITY (TABLE)

- Each row represents a unique LULC value from the LULC raster
- That Land Cover type is assigned a Habitat score
  - 0 = Non habitat
  - 1 = highest habitat suitability
- Each Threat is assigned a value for how sensitive that Habitat is to the Threat

Table

sensitivity

OID	OID_	LULC	NAME	HABITAT	L_AG	L_URBAN
0	0	0	Background	0	0	0
1	1	1	Water	0	0	0
2	2	2	Developed	0	0	0
3	3	3	Barren	0	0	0
4	4	4	Coniferous Forest	0	0	0
5	5	5	Mixed Forest	0	0	0
6	6	6	Scrub/Shrub	0	0	0
7	7	7	Wetlands	0	0	0
8	8	8	Pasture	1	0.8	0.9
9	9	9	Hay	0.75	0	0.7
10	10	10	Other Crops	0.25	0	0.6
11	11	11	Legumes	0.25	0	0.5
12	12	12	Corn	0.25	0	0.4
13	13	13	Soy	0.25	0	0.4
14	14	14	Wheat and Grains	0.5	0	0.6
15	15	15	Sugarbeets	0.25	0	0.6
16	16	16	Prairie/Grassland	1	1	1
17	17	17	Switchgrass	0.75	0.4	0.7

1 (0 out of 18 Selected)

sensitivity

HALF SATURATION FUNCTION

Habitat quality

Habitat suitability

Degradation

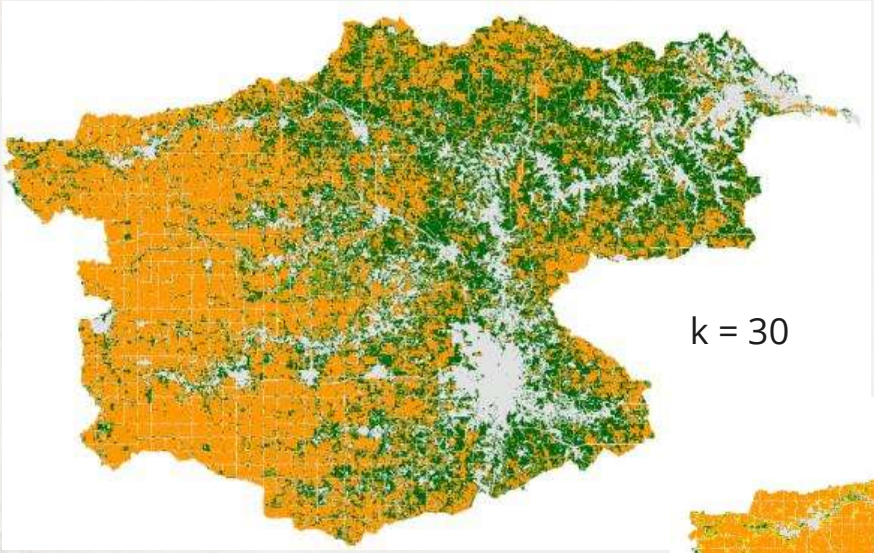
$$Q_{xj} = H_j \left(1 - \left(\frac{D_{xj}^z}{D_{xj}^z + k^z}\right)\right)$$

Parcel

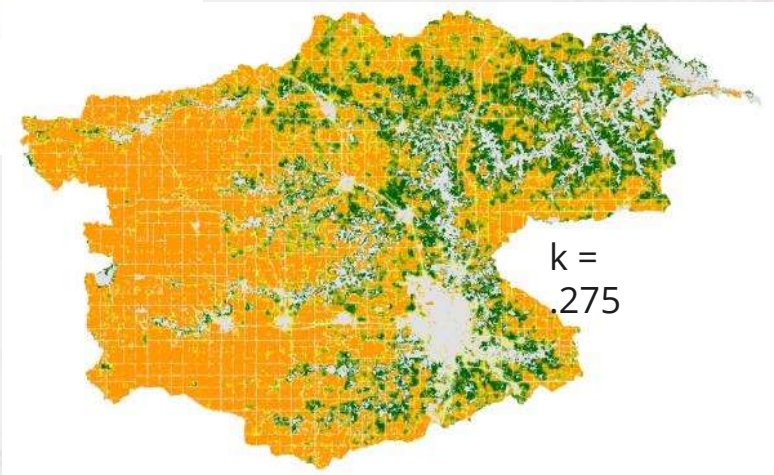
LULC

Half Saturation Constant

HALF SATURATION CONSTANT

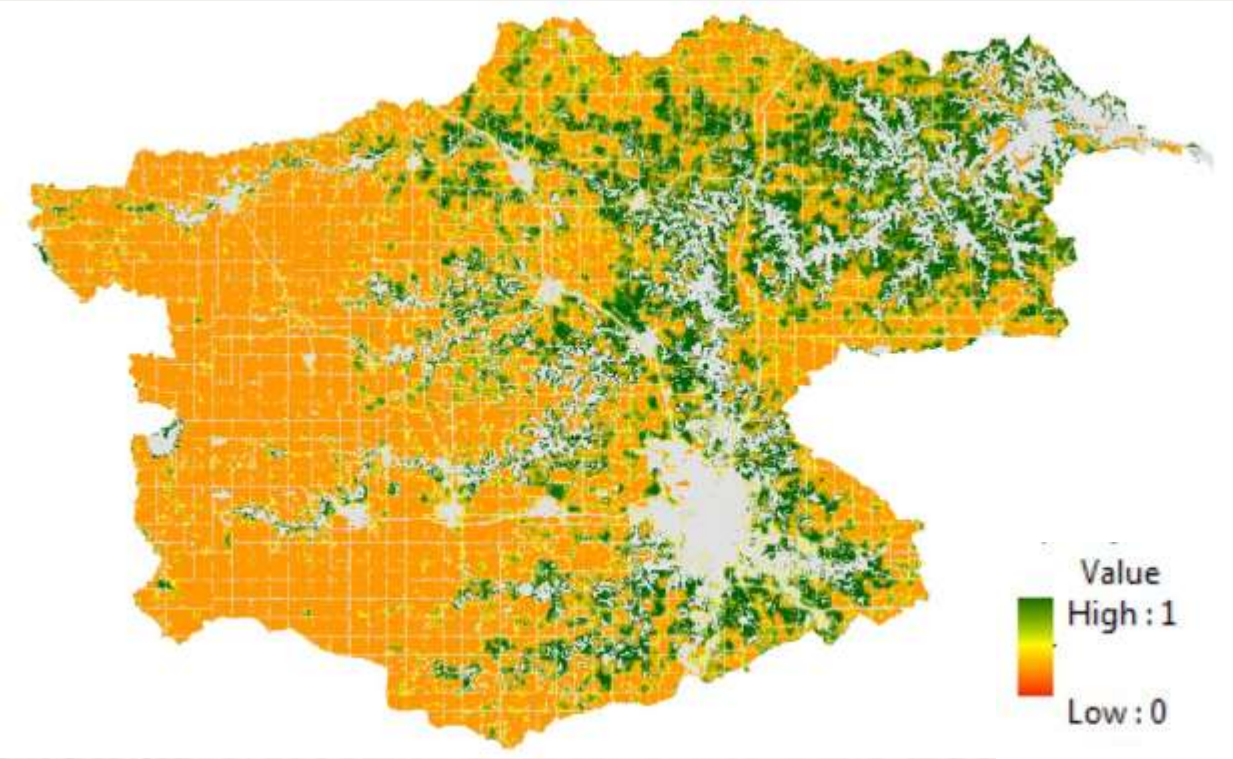


k = 30

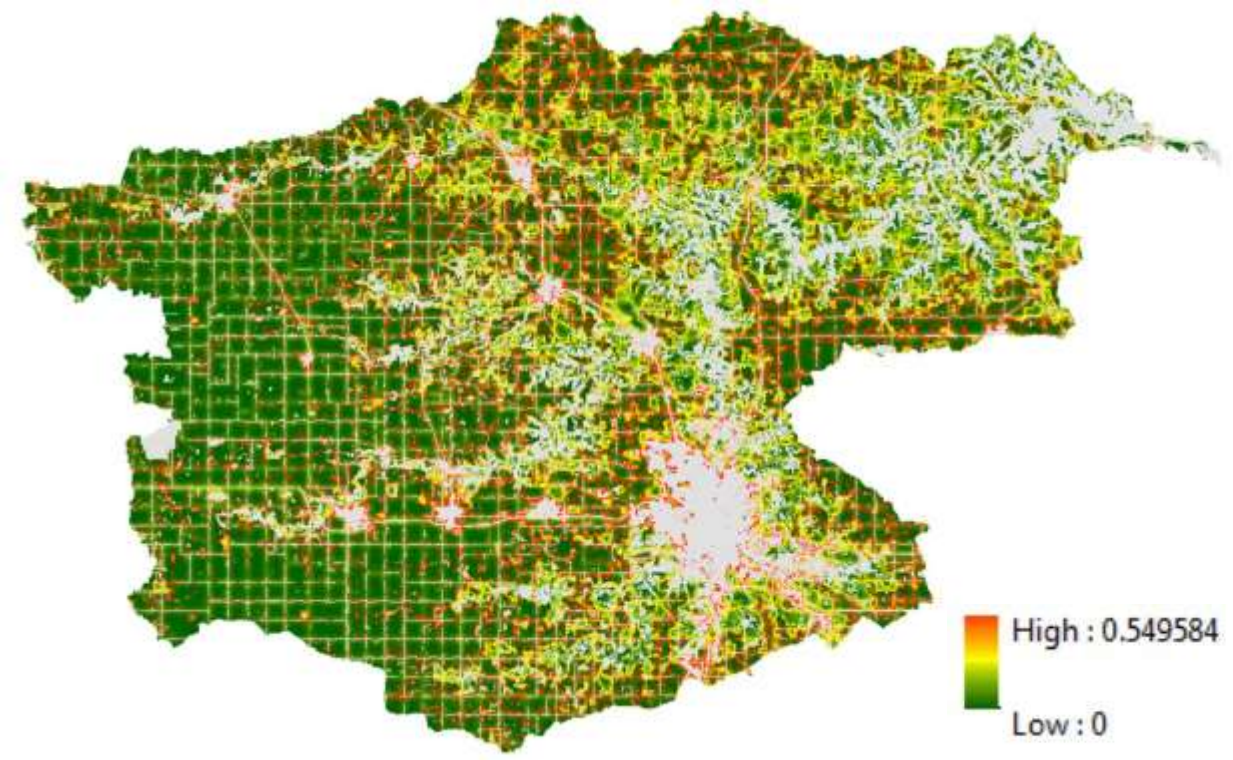


k = .275

OUTPUT: HABITAT QUALITY MAP



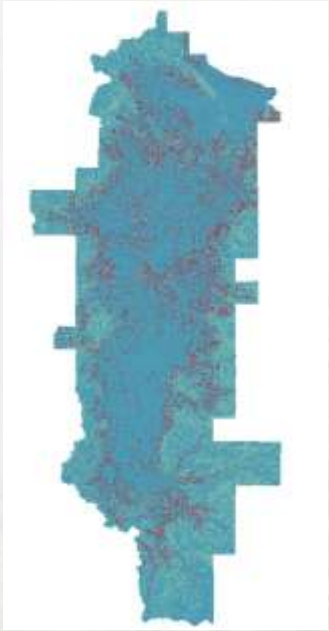
OUTPUT: DEGRADATION MAP



HABITAT RARITY

- Looks at ratio between Current or Future and Baseline extents of each LULC type
- Derive an index by subtracting from 1 that represents the rarity of that LULC class

$$R_j = 1 - \frac{N_j}{N_{baseline}}$$

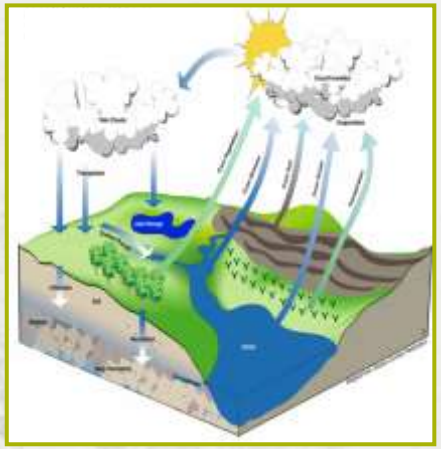


QUESTIONS?

ANNUAL WATER YIELD

Perrine Hamel

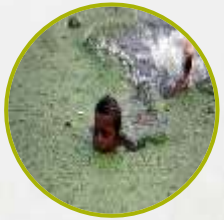
MODEL OVERVIEW



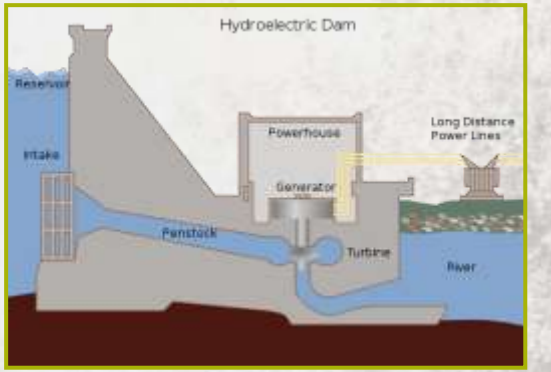
Hydropower

Drinking water

Irrigation



Pollution dilution



Supply: Water yield

Service: Water scarcity

Value: Hydropower production....

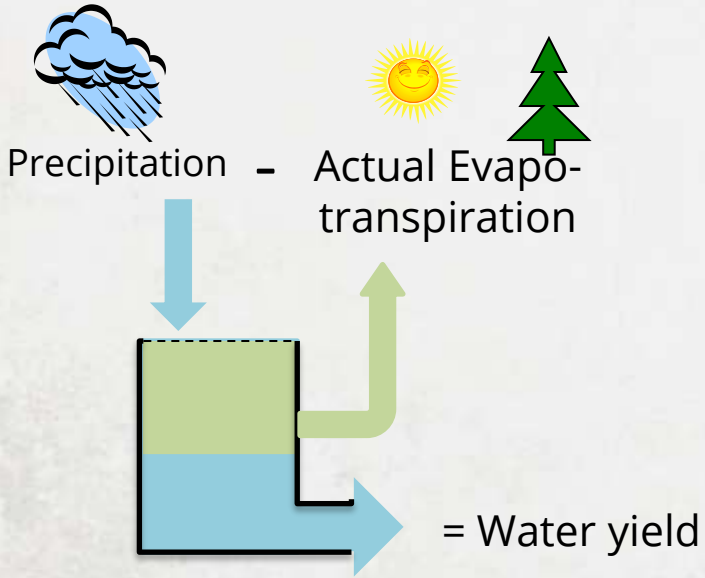
AIMS
QUESTIONS THE MODEL HELPS ANSWER

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

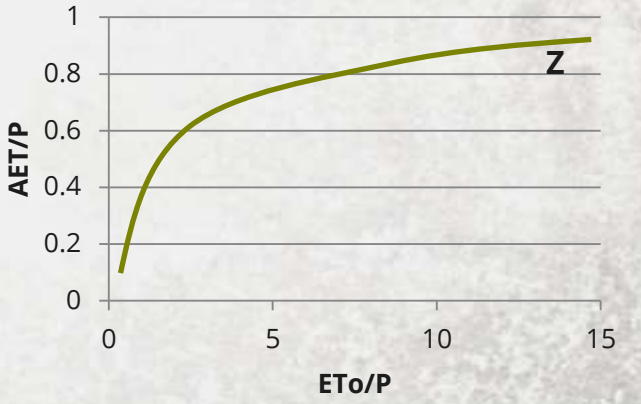
SUPPLY

Annual water yield

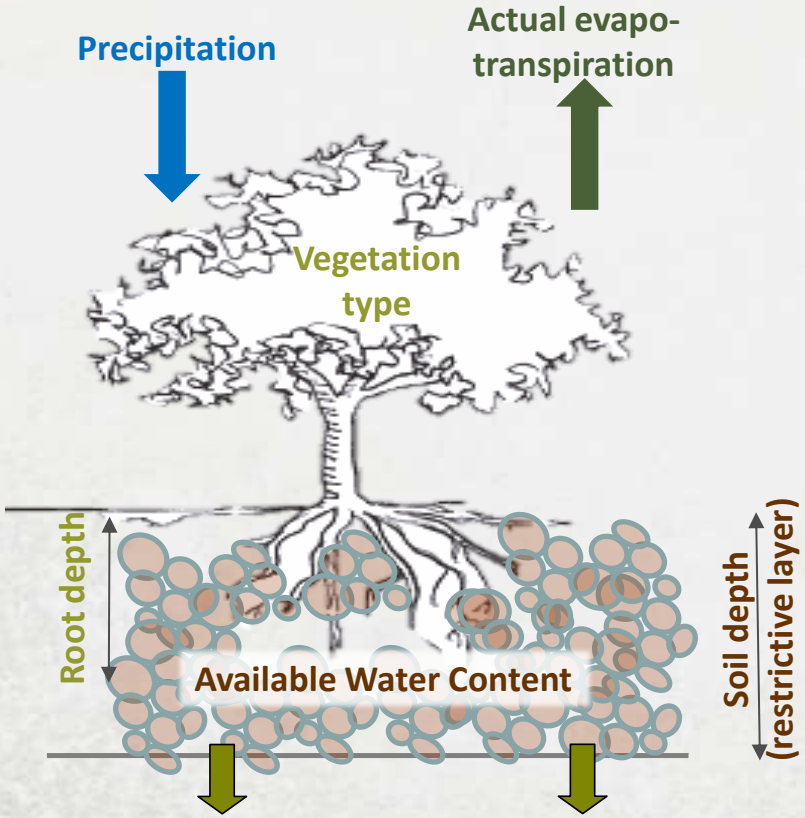
SUPPLY: ANNUAL WATER YIELD
BASIC PRINCIPLES



- Precipitation: rain only
- Evapotranspiration: energy demand (wind/sun)
- Budyko curve theory: water/energy budget



SUPPLY: ANNUAL WATER YIELD
BASIC PRINCIPLES



- **On EACH CELL:**

Potential evapotranspiration: "energy demand"

Actual evapotranspiration: water actually evapotranspired!

- **TOTAL YIELD:**

SUM OF CELLS

SUPPLY: ANNUAL WATER YIELD
WHAT HAPPENS WITH NON-VEGETATED LULC?

Theory developed for natural vegetation (forests, grassland)

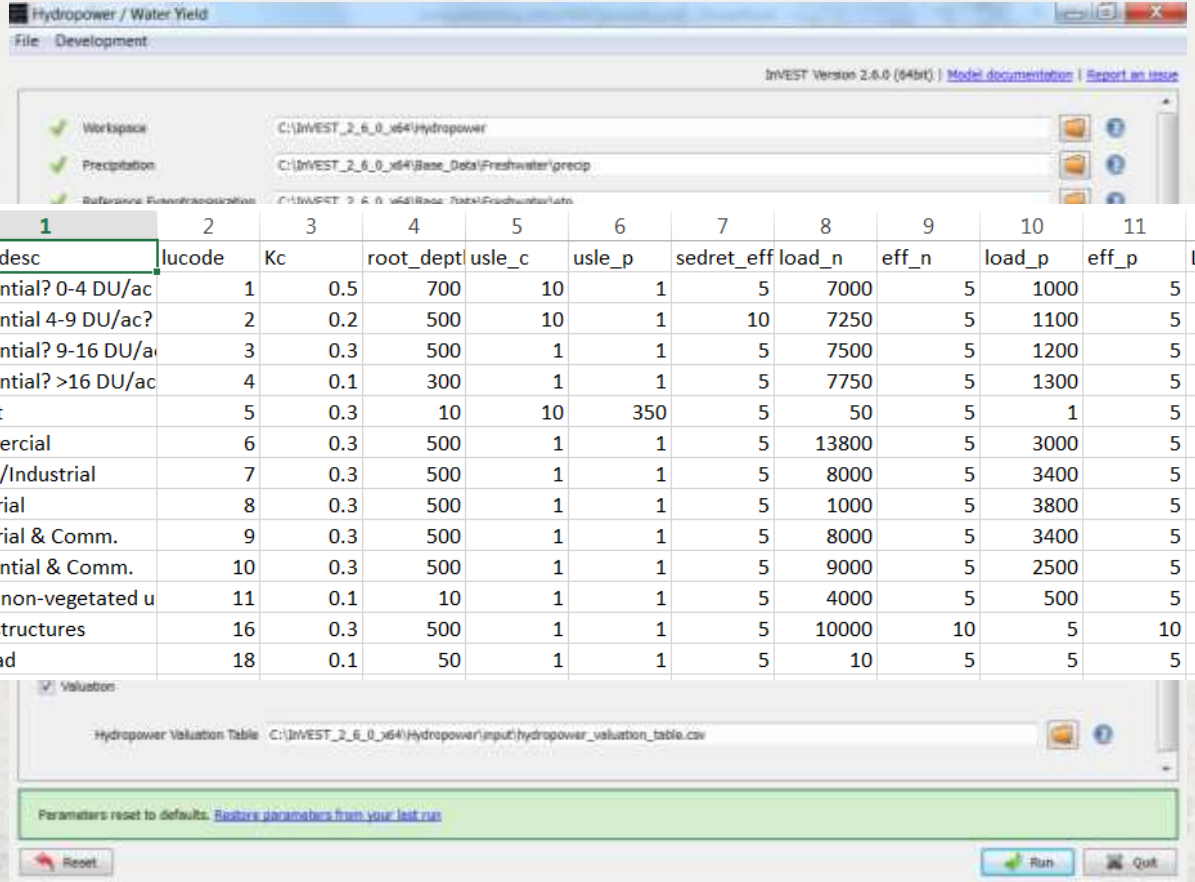
- Urban land use?
- Open water?
- Wetlands?

Possibility to use a **different equation**: $AET = K_c \times ET_0$

Actual evapotranspiration

Reference evapotranspiration

ANNUAL WATER YIELD



	1	2	3	4	5	6	7	8	9	10	11	12
1	LULC_desc	lucode	Kc	root_dept	usle_c	usle_p	sedret_eff	load_n	eff_n	load_p	eff_p	LULC_veg
2	Residential? 0-4 DU/ac	1	0.5	700	10	1	5	7000	5	1000	5	0
3	Residential 4-9 DU/ac?	2	0.2	500	10	1	10	7250	5	1100	5	0
4	Residential? 9-16 DU/a	3	0.3	500	1	1	5	7500	5	1200	5	0
5	Residential? >16 DU/ac	4	0.1	300	1	1	5	7750	5	1300	5	0
6	Vacant	5	0.3	10	10	350	5	50	5	1	5	0
7	Commercial	6	0.3	500	1	1	5	13800	5	3000	5	0
8	Comm/Industrial	7	0.3	500	1	1	5	8000	5	3400	5	0
9	Industrial	8	0.3	500	1	1	5	1000	5	3800	5	0
10	Industrial & Comm.	9	0.3	500	1	1	5	8000	5	3400	5	0
11	Residential & Comm.	10	0.3	500	1	1	5	9000	5	2500	5	0
12	Urban non-vegetated u	11	0.1	10	1	1	5	4000	5	500	5	0
13	Rural structures	16	0.3	500	1	1	5	10000	10	5	10	0
14	Railroad	18	0.1	50	1	1	5	10	5	5	5	0

SERVICE AND VALUE

Water scarcity and Hydropower production

SERVICE
WATER SCARCITY

Simple water balance:

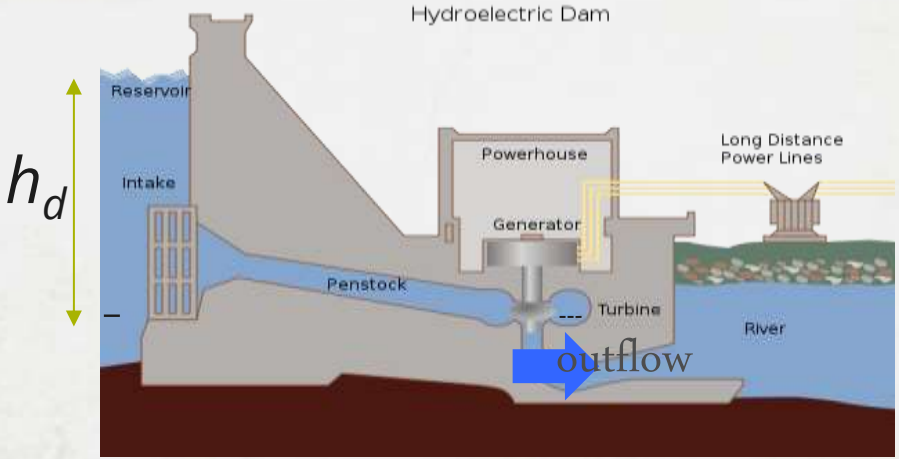
$$V_{in} = WY - d$$

Volume in reservoir

Water yield

Demand: upstream the point of interest (reservoir)

VALUE
HYDROPOWER PRODUCTION



head efficiency % Annual volume

Energy $\varepsilon_d = 0.00272 \times h_d \times \beta \times \gamma \times V_{in}$

SUMMARY

Inputs, outputs, assumptions

ANNUAL WATER YIELD
MODEL INPUTS

Climate
Precipitation; Reference evapotranspiration;
Z coefficient

Soils
Soil depth;
Available Water content

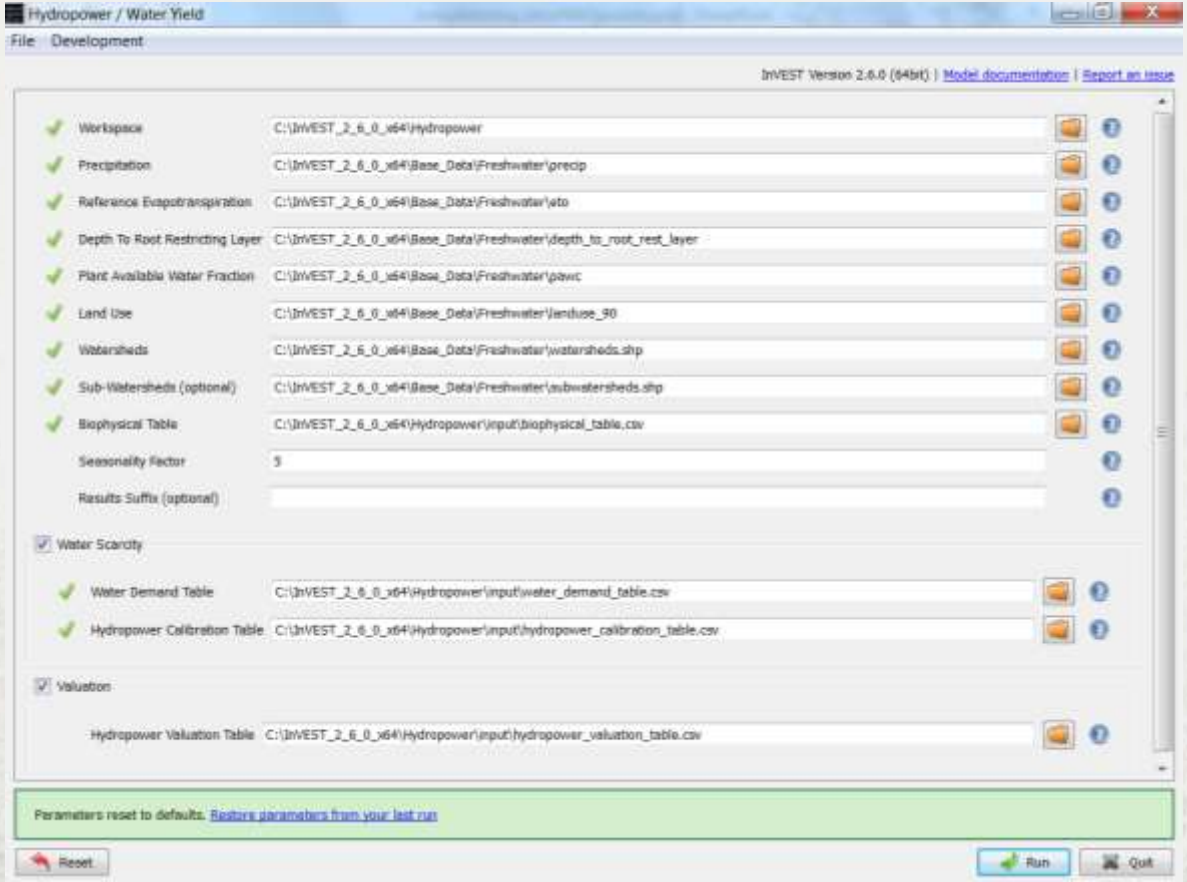
Land Use/ Land Cover (LULC)
Raster;
Root depth;
Crop coefficient

Watersheds
Upstream of point of interest (e.g. reservoir)

Water demand
Irrigation, drinking water

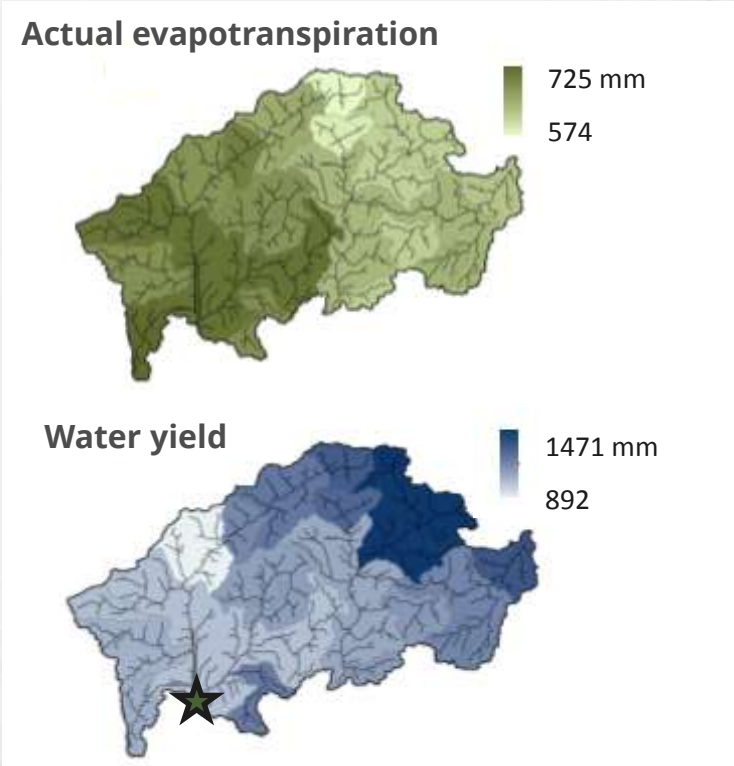
Hydropower valuation
Plant data, economic data

ANNUAL WATER YIELD



ANNUAL WATER YIELD
MODEL OUTPUTS

- Water yield (mm and m^3)
- Actual evapotranspiration (mm)
- Water supply (mm and m^3)
- Energy/value for hydropower



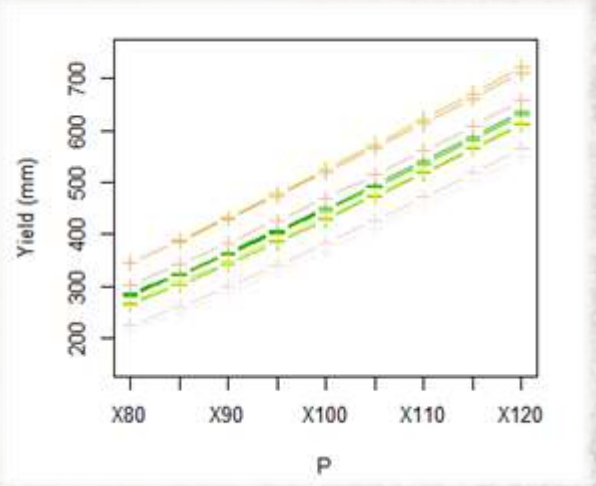
MAIN ASSUMPTIONS

SUPPLY

- **Long term** annual water balance
- No distinction between **surface** and **subsurface** flow
- Use **local data** (sensitivity to climate inputs)

SERVICE AND VALUATION

- **Source of water demand** is in the catchment
- No account of **seasonality**
- Simple relationship between yield and power



IMPROVING MODEL INTERPRETATION

- Critical **selection of model inputs**: check sources, literature, etc.
- Enhanced possibilities for **uncertainty analyses** (batch runs)
  - Confidence intervals
  - Calibration
- Possibility to "**customize**" the model (use of alternative equation)
- Improved guidance on **Z coefficient** (proportional to number of events)

Q&A