natural capital PROJECT

INTRO TO InVEST MODELS

TNC Eastern Division Training

April 29 – 30, 2014

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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

SEASONAL WATER YIELD
HYDROPOWER, IRRIGATION

NUTRIENT
WATER PURIFICATION

SEDIMENT
WATER PURIFICATION

FLOOD MITIGATION

AGRICULTURE

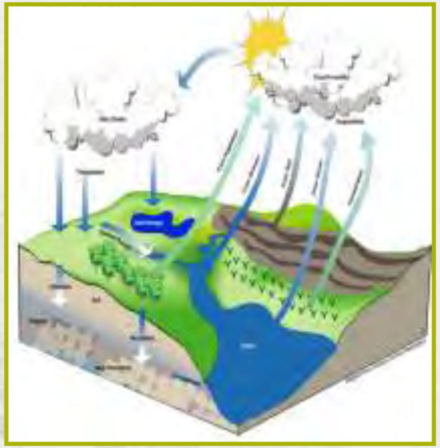
RESOURCES
QUESTIONS? ISSUES WITH THE MODELS?

- 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!

InVEST
integrated valuation of environmental services and tradeoffs

ANNUAL WATER YIELD

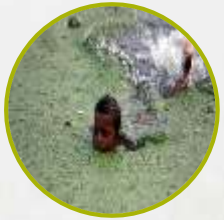
MODEL OVERVIEW



Hydropower

Drinking water

Irrigation



Pollution dilution

Supply: Water yield

Service: Water scarcity

Value: Hydropower production….

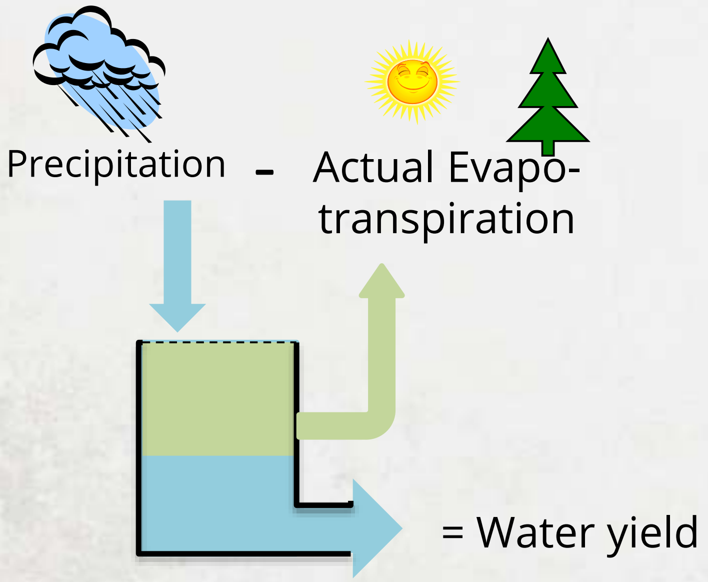
AIMS
QUESTIONS THE MODEL HELPS ANSWER

- 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?

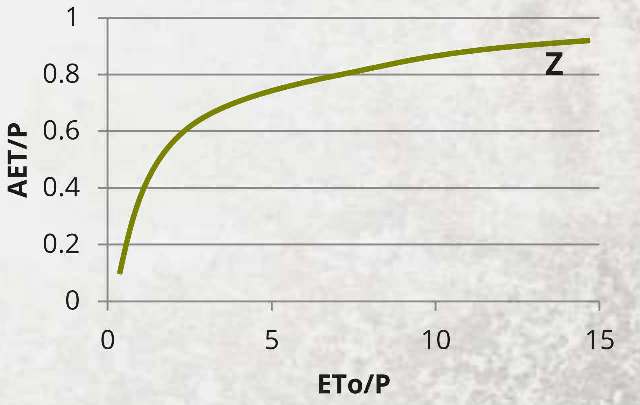
SUPPLY

Annual water yield

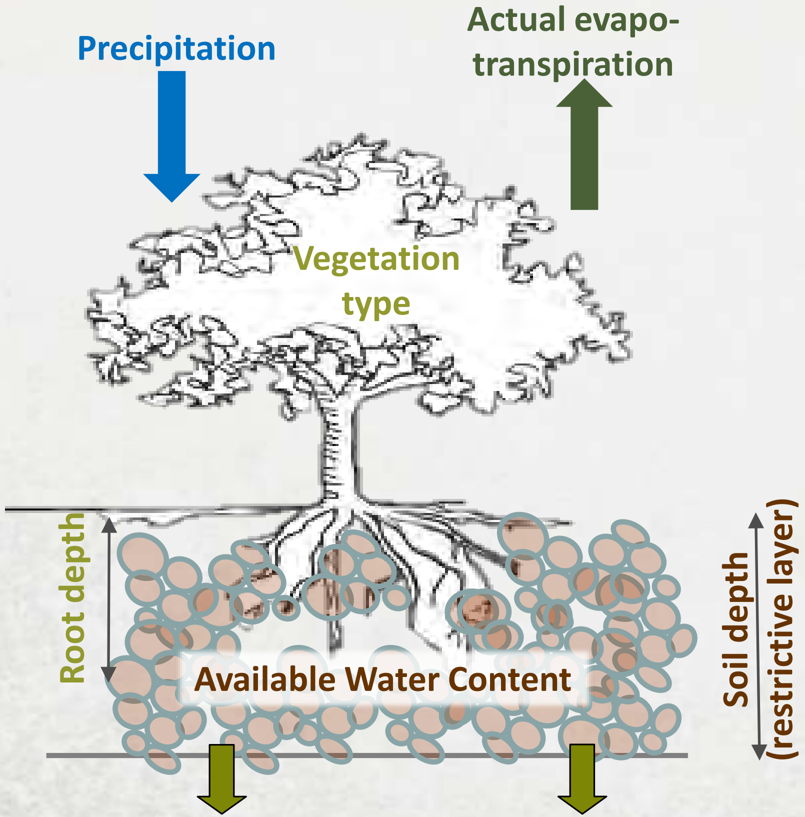
SUPPLY: ANNUAL WATER YIELD
BASIC PRINCIPLES



- 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)

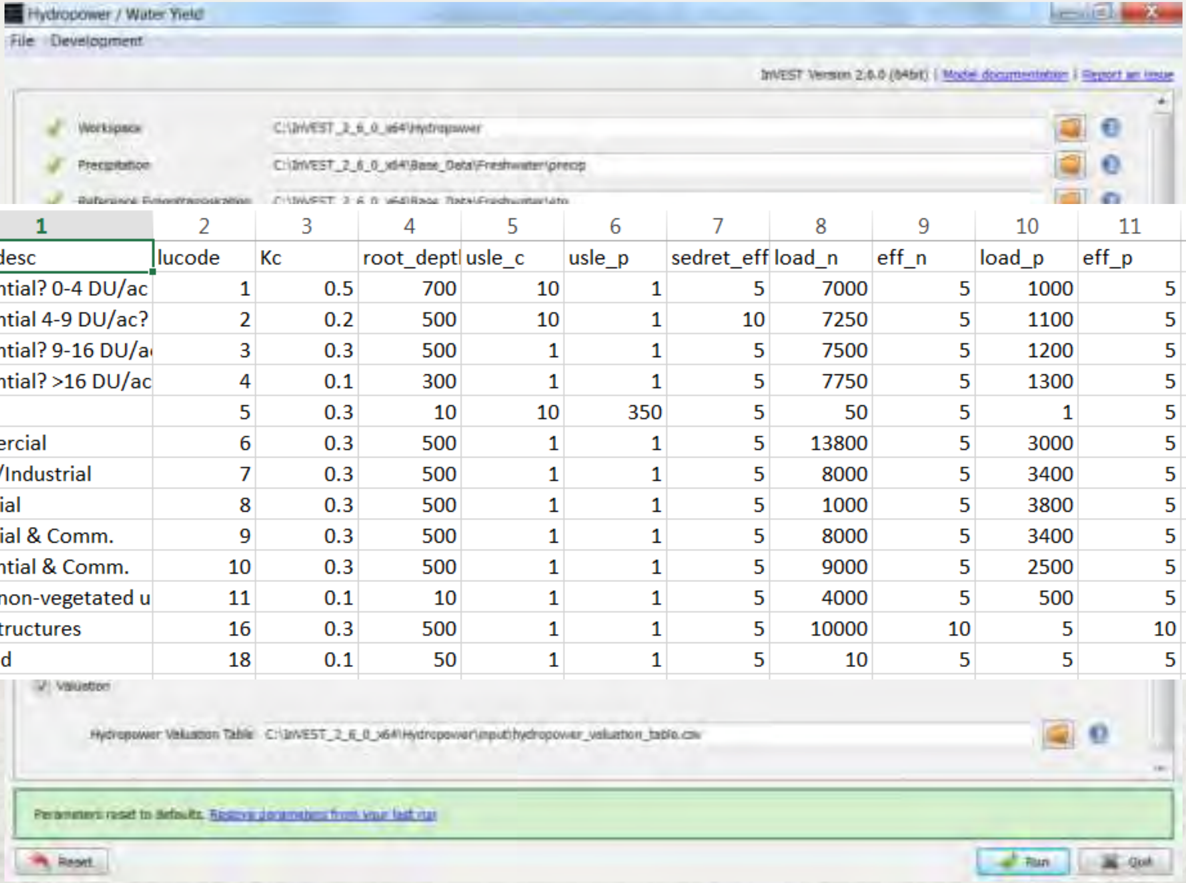
- Urban land use?
- Open water?
- Wetlands?

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:

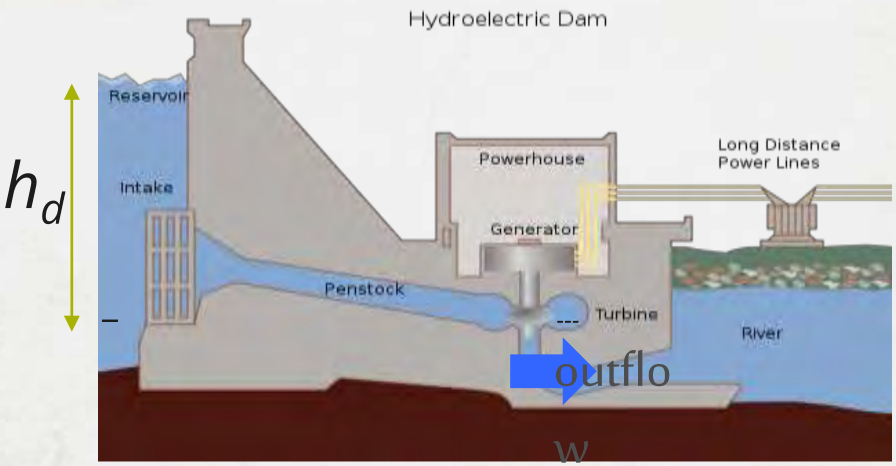
$$V_{in} = WY - d$$

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

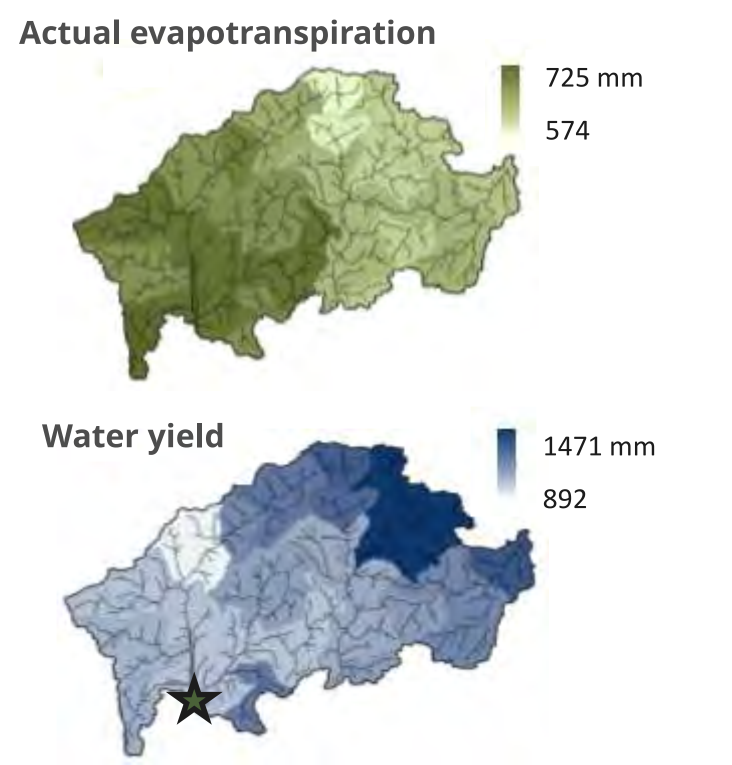
Watersheds
Upstream of point of interest (e.g. reservoir)

Water demand
Irrigation, drinking water

Hydropower valuation
Plant data, economic data

ANNUAL WATER YIELD
MODEL OUTPUTS

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



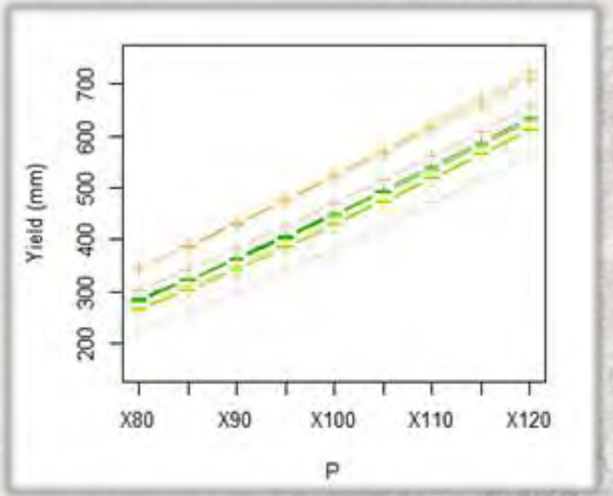
MAIN ASSUMPTIONS

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

NUTRIENT RETENTION

NUTRIENT POLLUTION

- **~ 14,000** people die daily from water pollution
- Global water treatment cost: **~$24.6 billion/year**
- Dead zone in the Gulf of Mexico: **~17,000 km²**
- Non-point sources are a major cause

Global dead zones

NASA, 2008

NUTRIENT MODEL QUESTIONS

- Where are the pollutant sources?
- Where is natural capital providing nutrient retention on the landscape?
- How much is retained?
- What is the value of this retention for avoided costs of treatment?

NUTRIENT RETENTION MODEL

- Based on runoff and export coefficients
  - Includes geomorphology and climate
  - Potential export from a parcel
  - Nitrogen and phosphorus
- Enhanced by hydrologic connectivity
  - What happens as the parcel's export moves downslope?
  - Influence of intervening landcover
- Nutrient retention valued as ecosystem service

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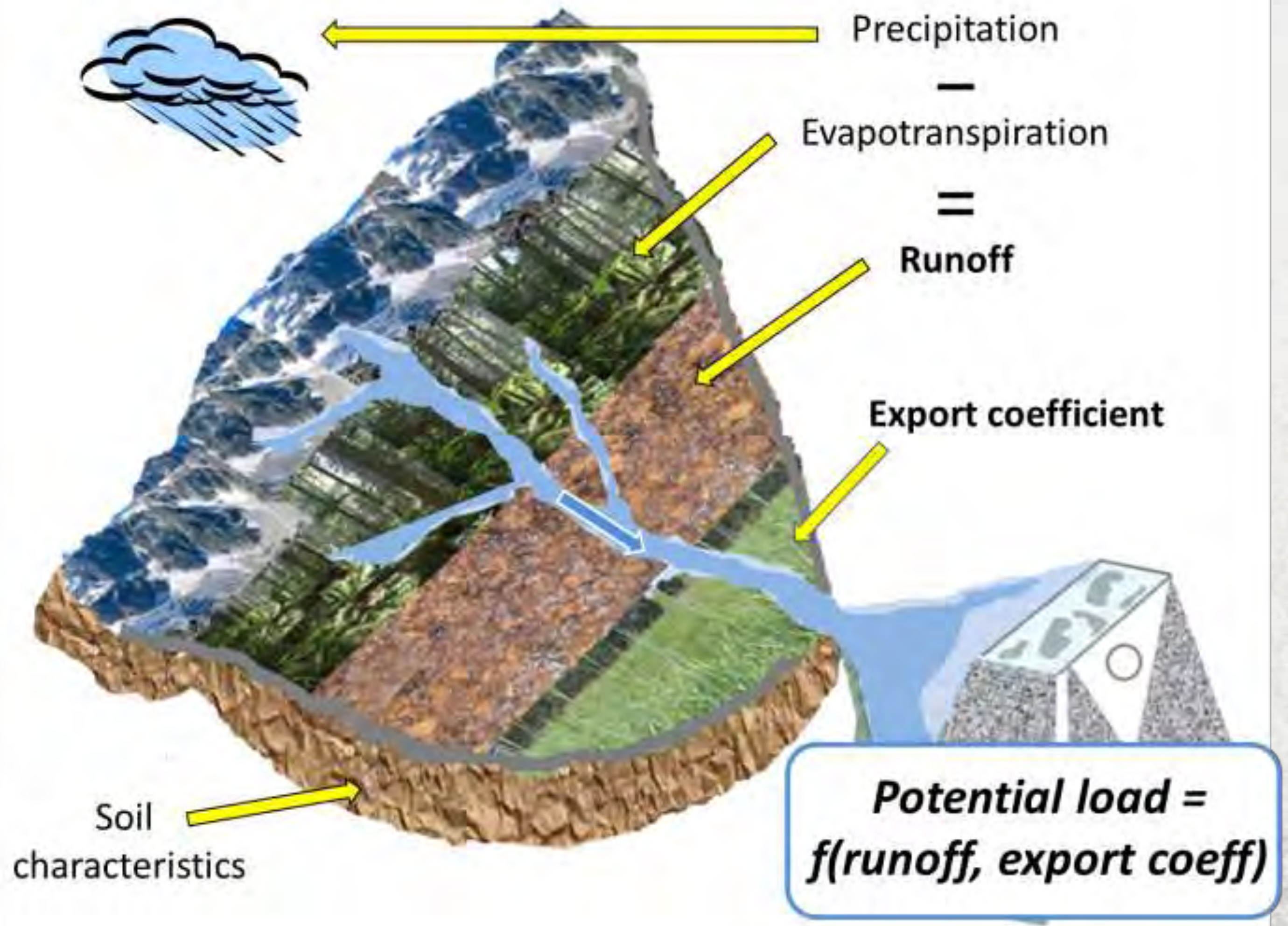
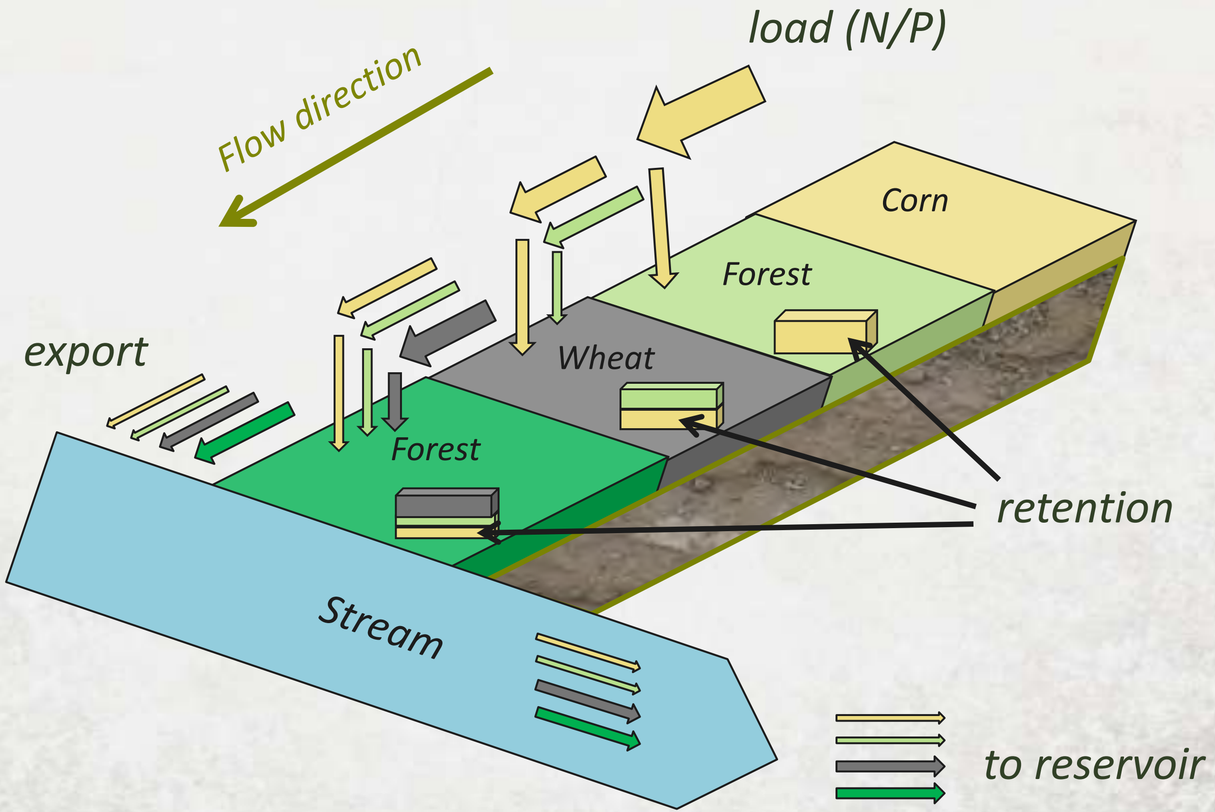


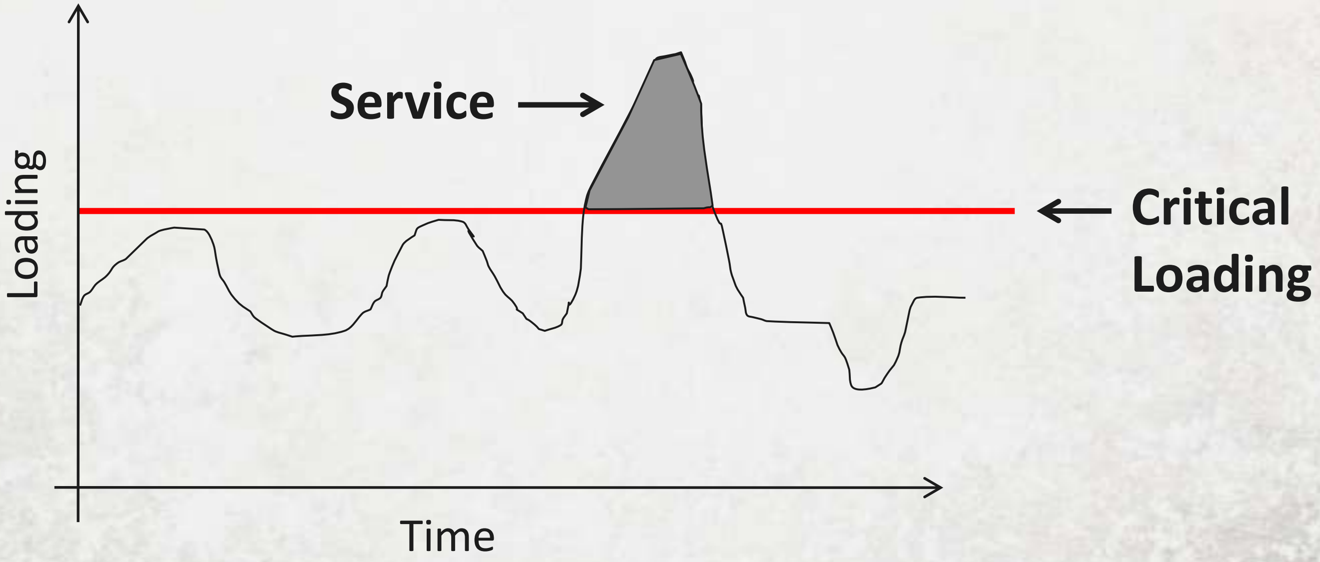
MODEL OVERVIEW

natural capital PROJECT



VALUATION MODEL

Based on *avoided treatment costs*



MODEL INPUTS

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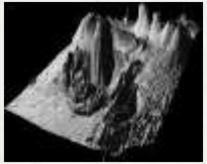
Climate

Precipitation, Potential evapotranspiration, Zhang

Soils

Soil depth,
Available water content



Topography

Digital elevation model

Watersheds

Catchments flowing into points of interest

Land use/Land cover

Export coefficients, retention capacity, root depth, etk

$$

Economic

Critical loading, treatment cost, time, discount rate

MODEL COEFFICIENTS

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	1	2	3	4	5	6	7	8	9	10	11	12
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MODEL OUTPUTS

Nutrient Exported

Kg/year

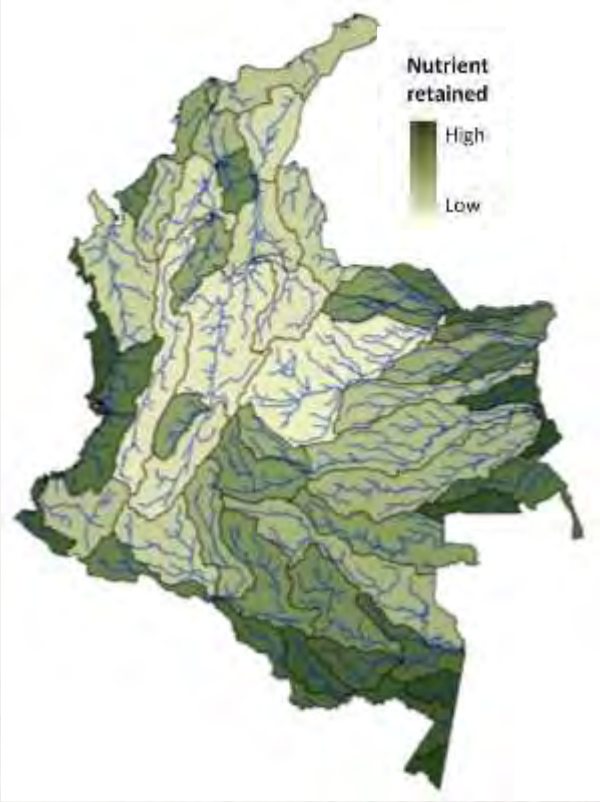
Nutrient Retained

Kg/year

Used in valuation

Value of Nutrient Removal for Water Quality

Currency over time period



BIOPHYSICAL RESULTS

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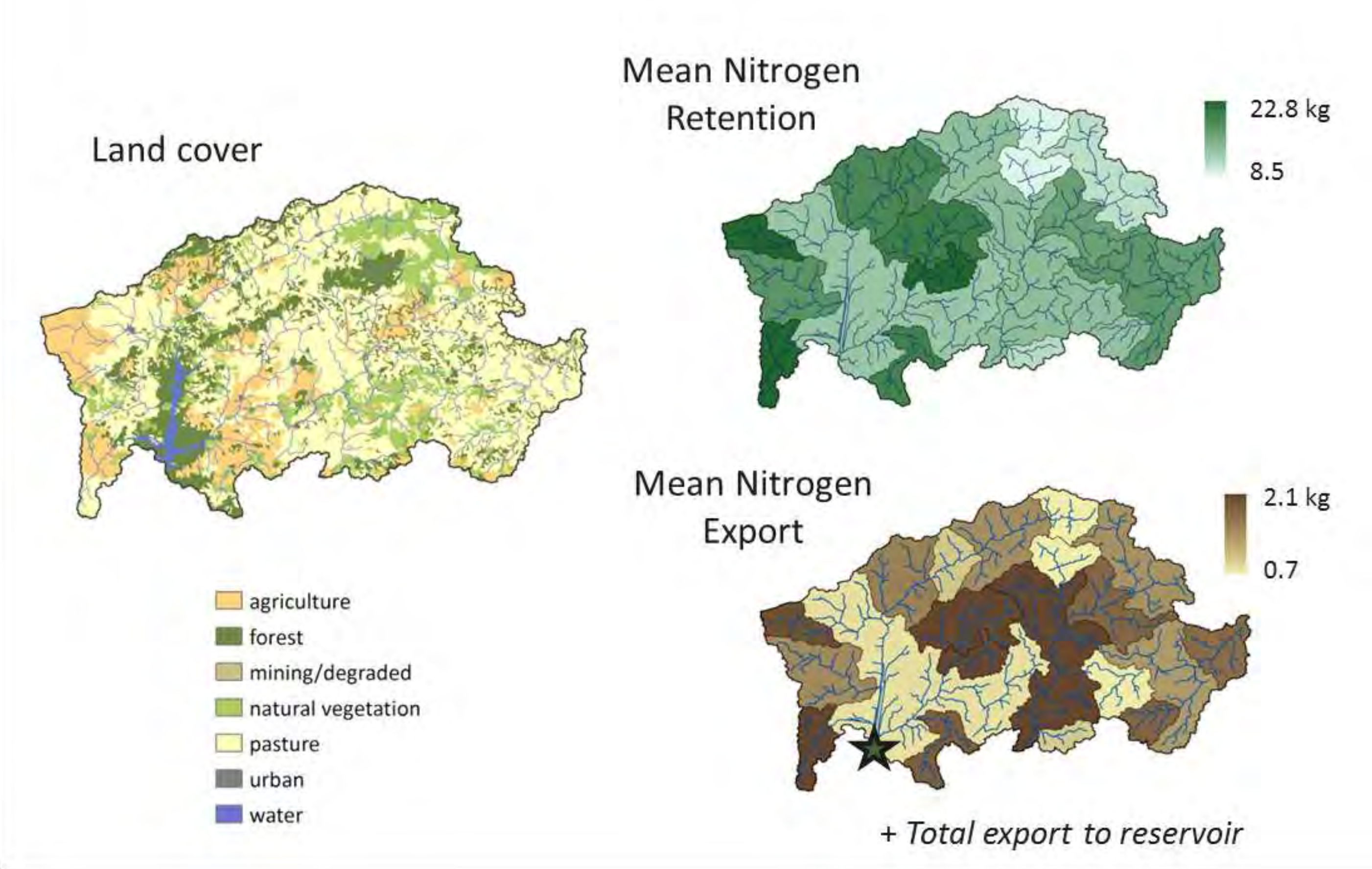

MODEL LIMITATIONS

- 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

Q&A

SEDIMENT RETENTION

AIMS
QUESTIONS THE MODEL HELPS ANSWER

- Where are the sediment sources?
- Where is sediment retained?
- How much is retained?
- What is the value of this retention?

MODEL OVERVIEW

- 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

MODEL OVERVIEW

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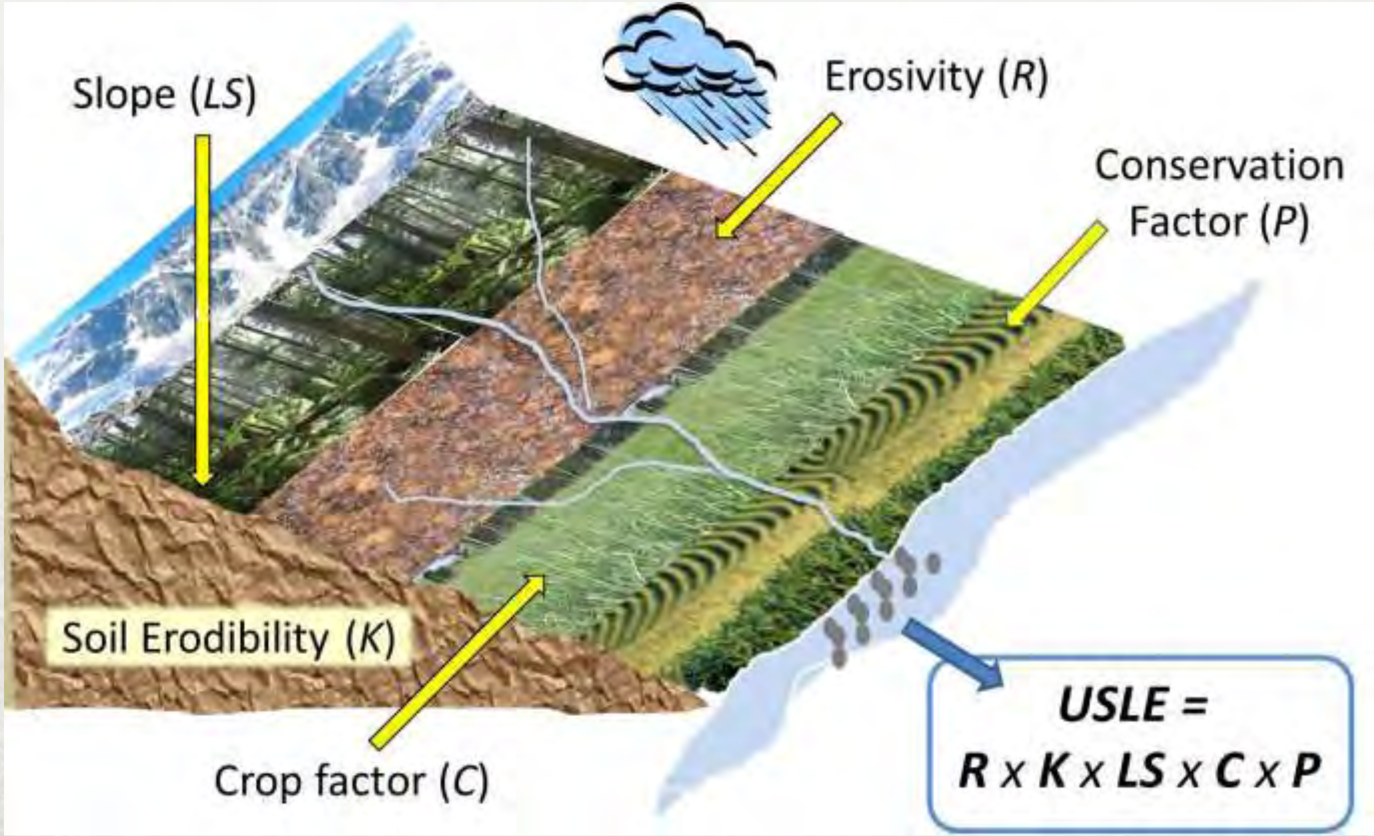
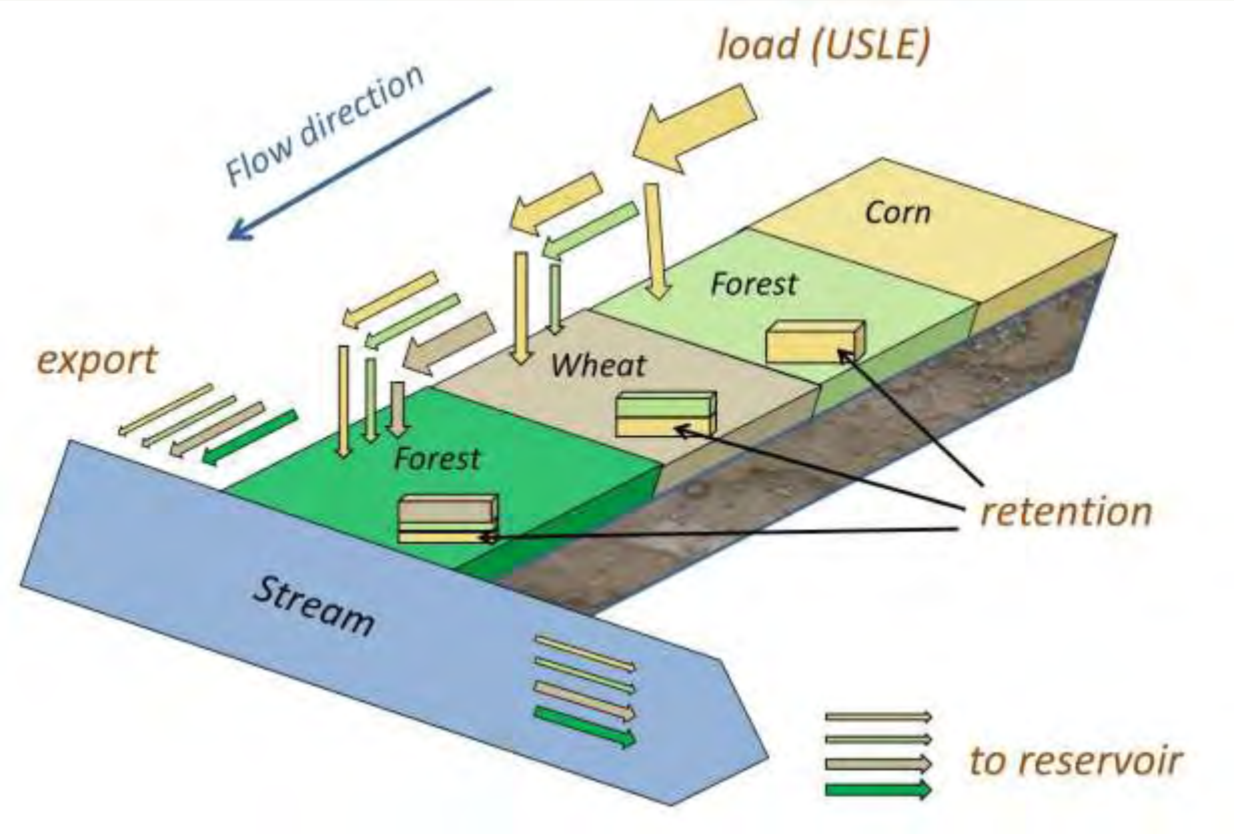
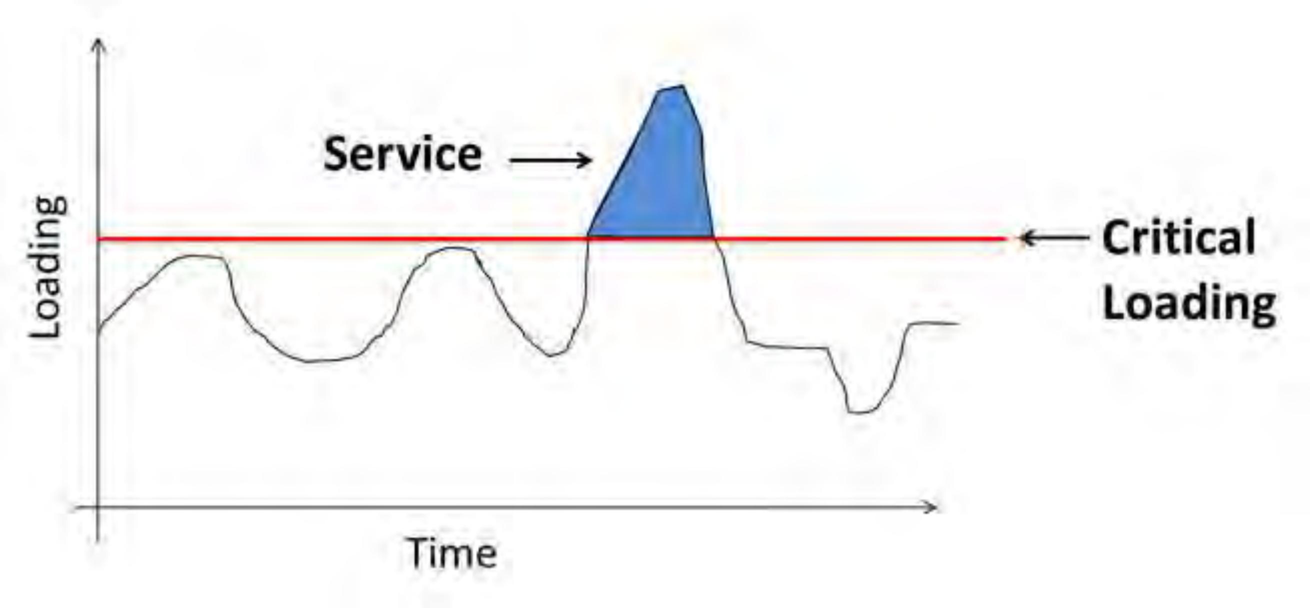


MODEL OVERVIEW



VALUATION

- Based on avoided treatment costs
- Can value for dredging and/or water quality



BIOPHYSICAL INPUTS

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

Topography
Digital elevation model, slope threshold

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

BIOPHYSICAL OUTPUTS

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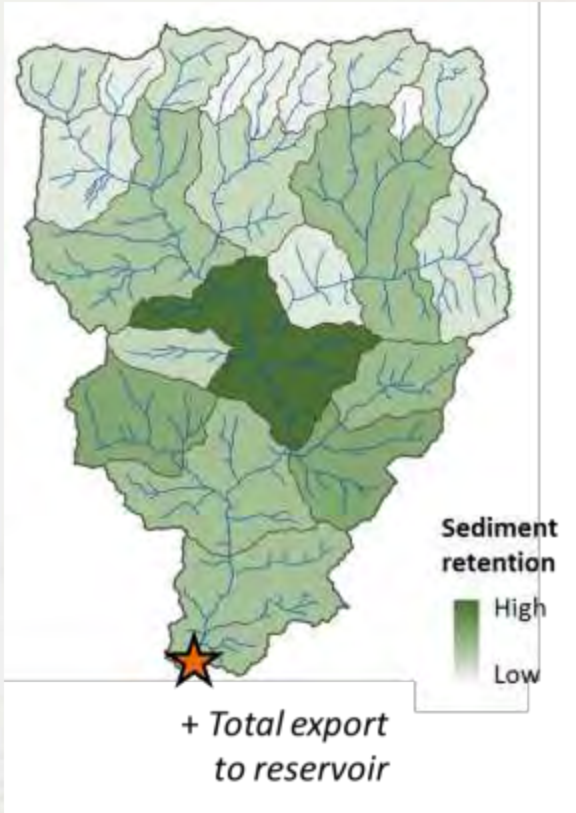
Potential Soil loss
Calculated from USLE
Per sub-watershed

Sediment Retained
Per watershed and sub-watershed
Used in valuation

Sediment Exported
Per watershed and sub-watershed



VALUATION

Input

Sediment Retained
From biophysical analysis

Economic data
Reservoir dredging costs
Or water quality filtering costs

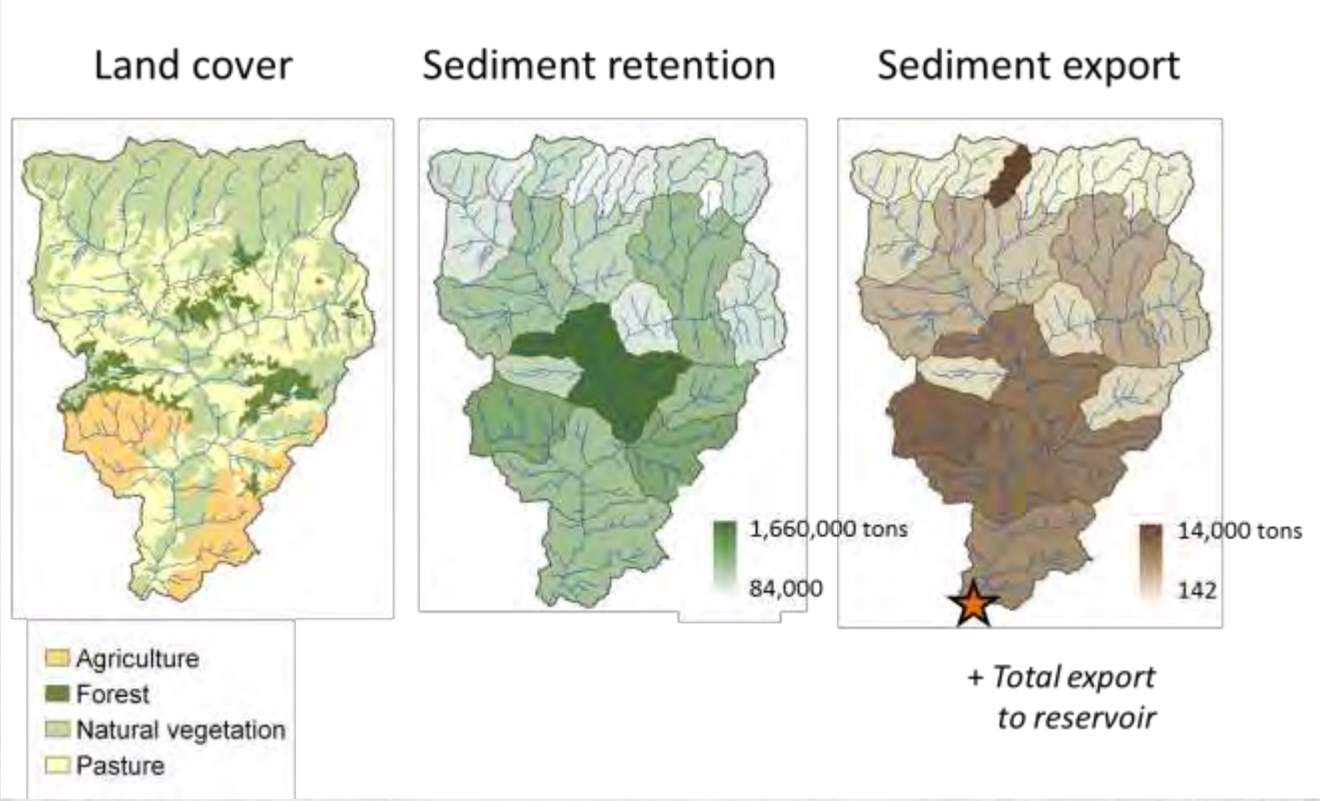
Watershed Areas
Catchments flowing into reservoirs

Output

Value of Sediment Removal for Dredging

Value of Sediment Removal for Water Quality

INTERPRETING RESULTS



LIMITATIONS/ASSUMPTIONS

- 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

FUTURE STEPS

- Sediment delivery ratio
- Gully and bank erosion
- Dam retention
- In-stream flow and retention

Q&A

CARBON STORAGE AND SEQUESTRATION

CARBON BACKGROUND

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

EXISTING MODELS

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- 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

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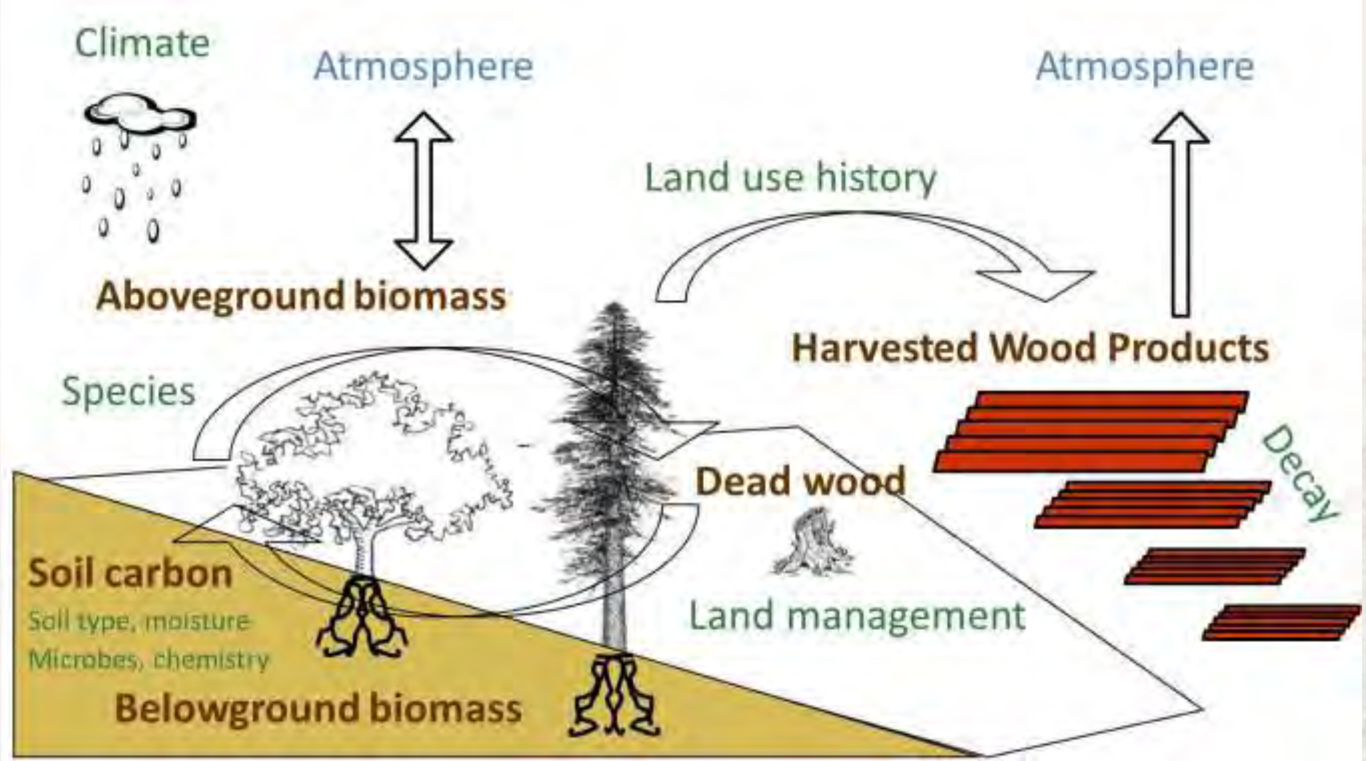
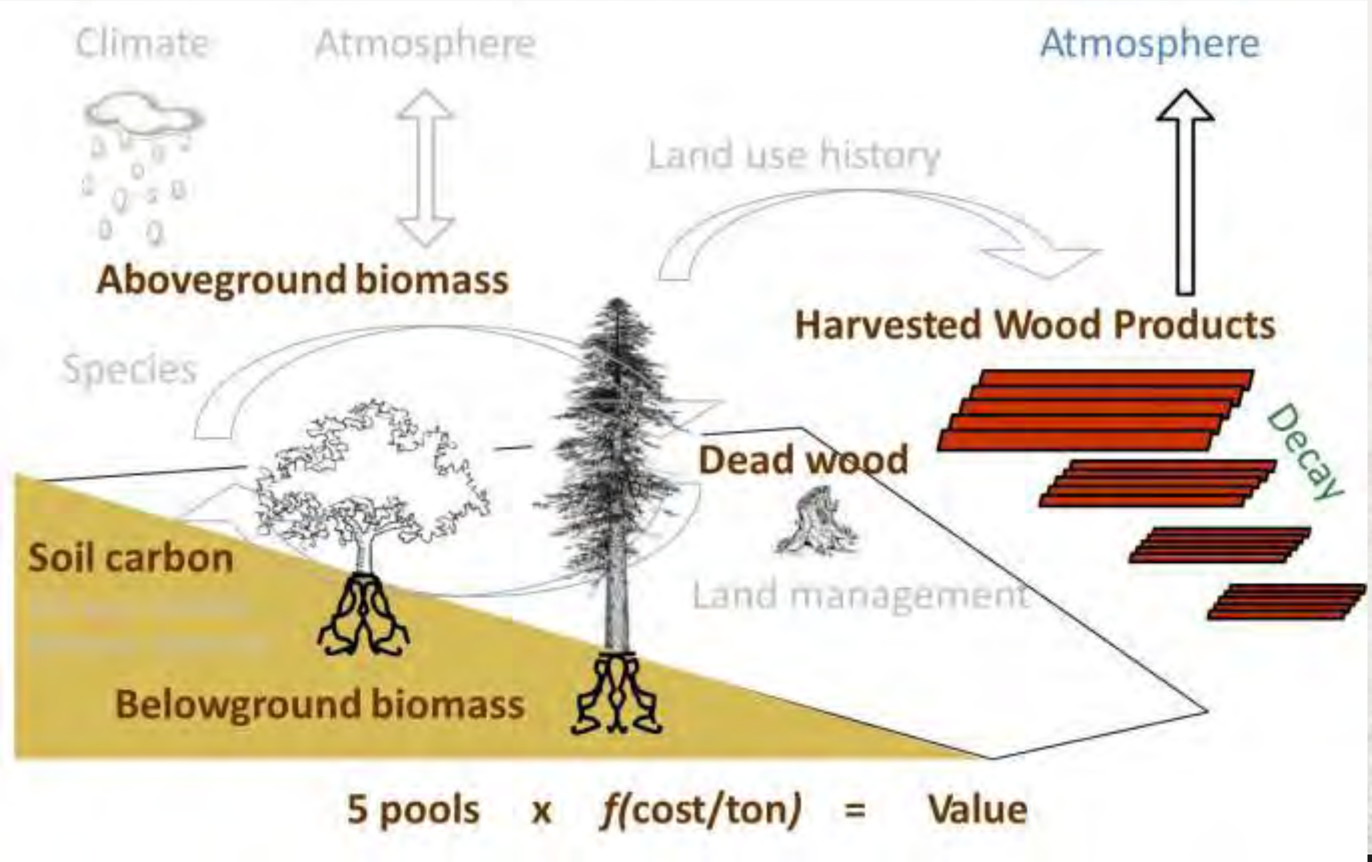
- Model estimates carbon stock as a function of land use/land cover.
- *Storage* indicates the mass of carbon in an ecosystem at any given point in time.
- *Sequestration* indicates the change in carbon storage in an ecosystem over time.
- Valuation is applied to sequestration.

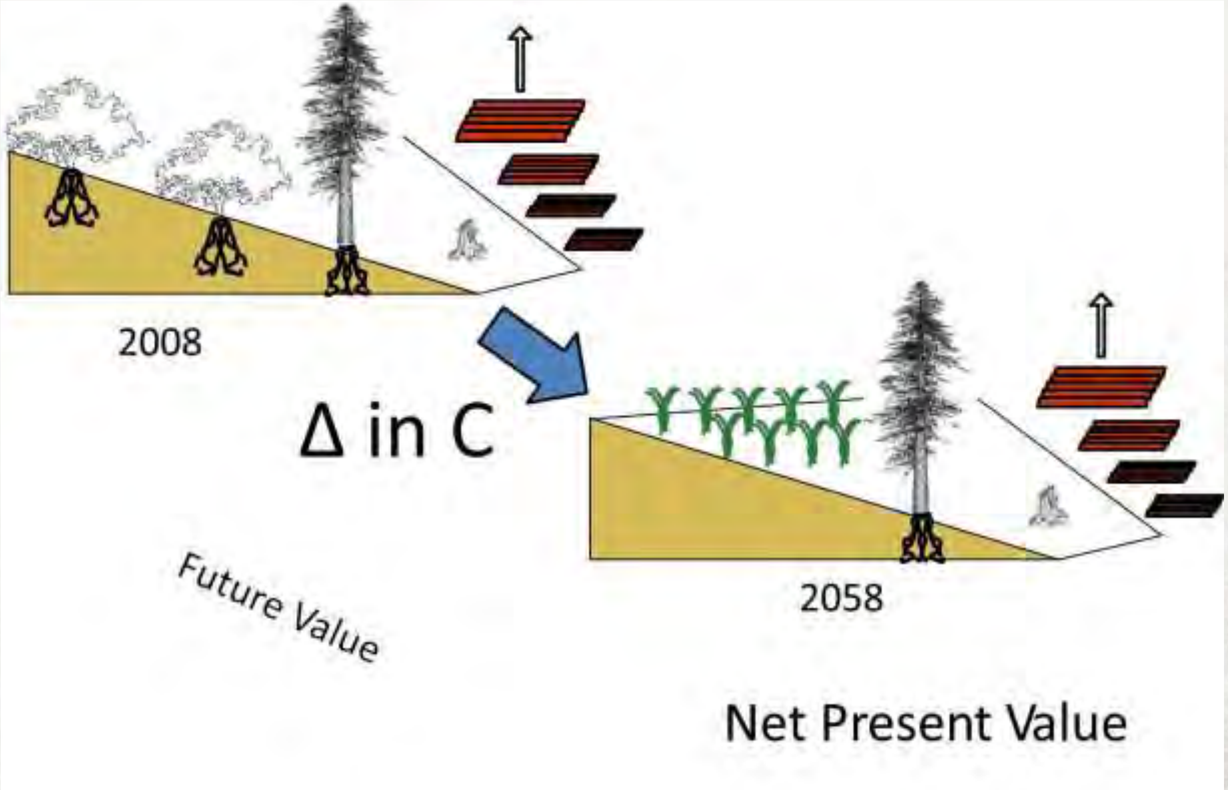
CARBON – OVERVIEW



InVEST CARBON STORAGE MODEL



SEQUESTRATION AND VALUE



APPROACH TO VALUATION

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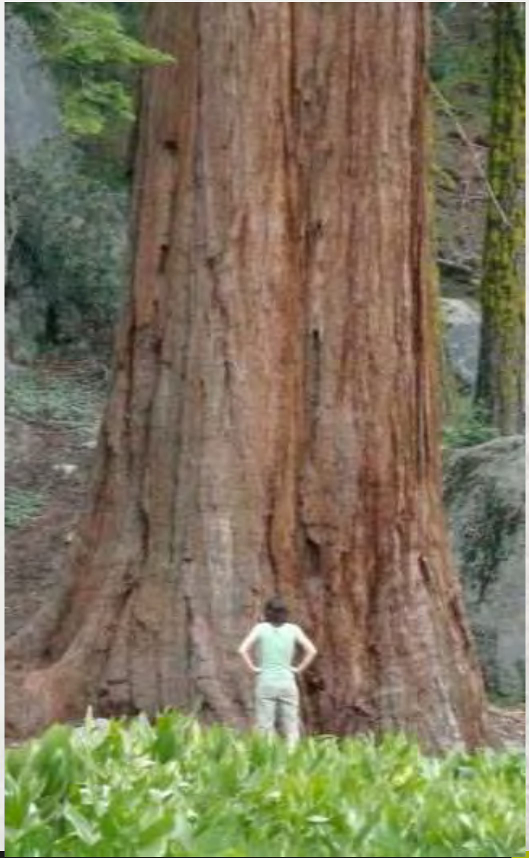
- Net Present Value is a function of:
  - Market discount rate
  - Rate of change in the social value of carbon
  - Social or market cost of carbon

- 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

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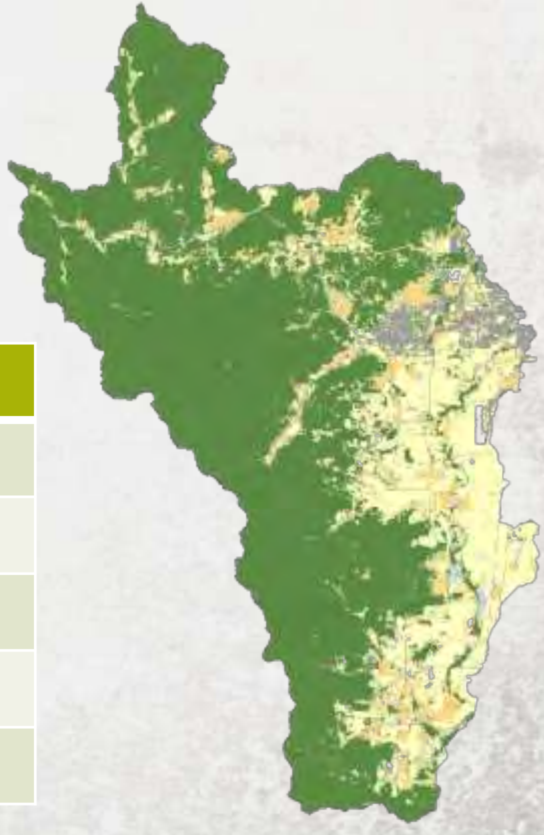
- Required data:
  - Land use/land cover (LULC map)
  - Table of carbon pools (metric tons/ha):

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

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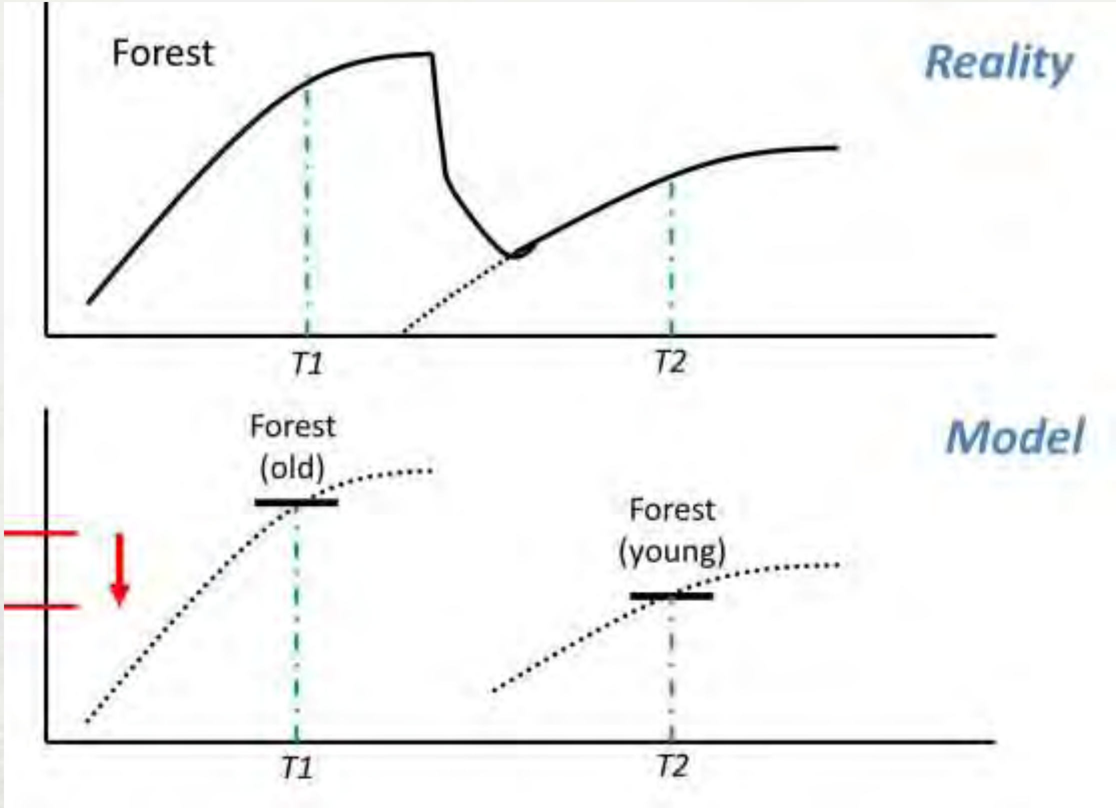
- Local plot studies
- Published analysis on similar regions
- IPCC tables

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

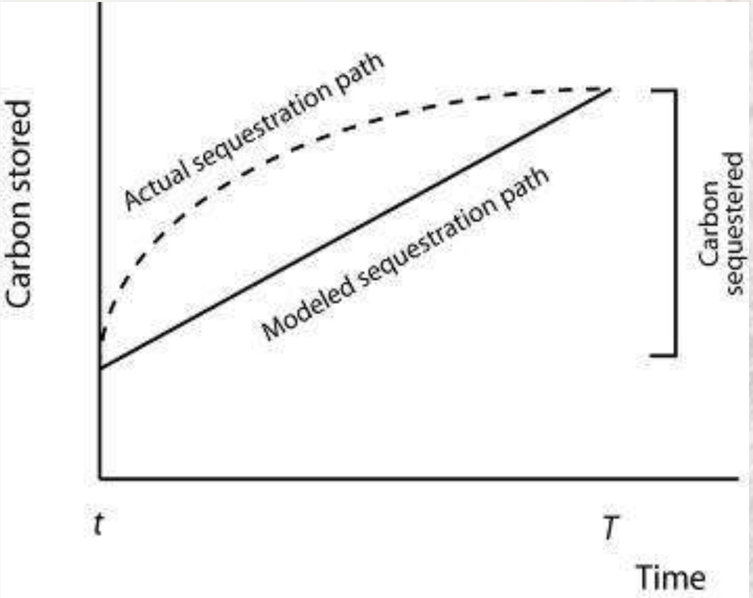


OUPUT

- 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

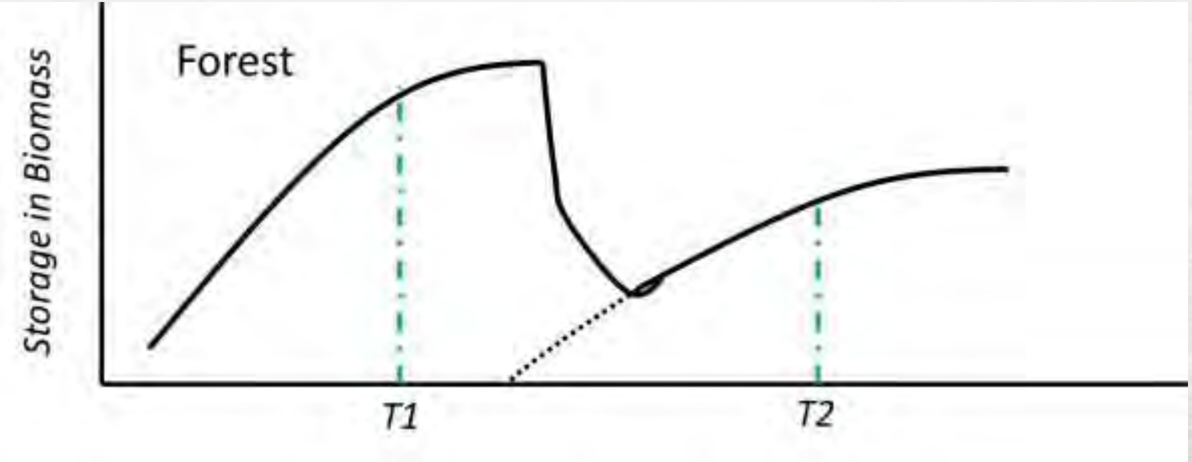
- Simplified carbon cycle
- Economic variation assumes a linear trend in sequestration over time
- Output is only as detailed and reliable as land use classes and carbon pool data
- Carbon sequestration does not occur in an area unless LULC changes over time or wood is harvested



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



Q&A