Presentation given the TransLinks workshop:

Modeling and Managing Watersheds

September 13-16, 2011

Kigali, Rwanda
Umubano Hotel, Boulevard de l'umuganda

This workshop was hosted by the Wildlife Conservation Society, the United States Forest Service (USFS) and the United States Agency for International Development (USAID)

This workshop was generously supported by the American people through the United States Department of Agriculture (USDA) Forest Service and the United States Agency for International Development (USAID), under the terms of the TransLinks Cooperative Agreement No.EPP-A-00-06-00014-00 to the Wildlife Conservation Society (WCS). TransLinks is a partnership of WCS, The Earth Institute, Enterprise Works/VITA, Forest Trends and the Land Tenure Center. The contents are the responsibility of the authors and do not necessarily reflect the views of USAID or the United States government.

Modeling Ecosystem Services (Water Quantity and Quality):

-Overview of WaSSI-CB and InVEST

Ge Sun, Steve McNulty, Erika Cohen and Matt Wingard

Eastern Forest Environmental Threat Assessment Center
Southern Research Station
USDA Forest Service, Raleigh NC

Sep 13, 2011; Kigali, Rwanda

Models

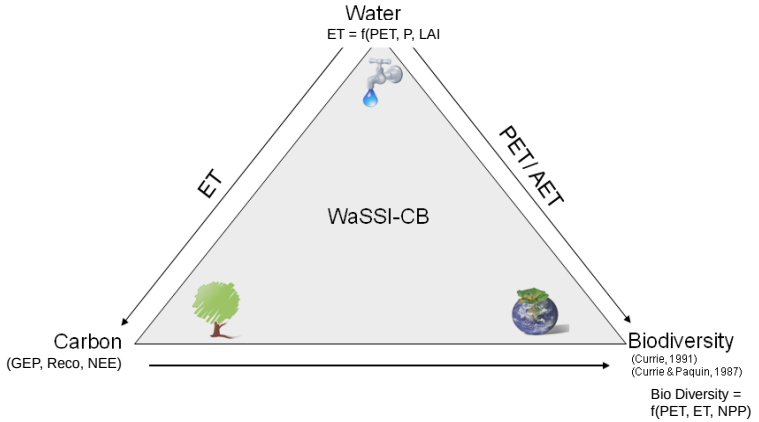
- WaSSI-CB: Water Supply Stress Index Carbon and Biodiversity
  - USDA Forest Service Southern Research Station
  - Water Quantity Modeling
- InVEST: Integrated Valuation of Ecosystem Services and Tradeoffs
  - Partners: Stanford University's Woods Institute for the Environment, University of Minnesota's Institute of the Environment, The Nature Conservancy, and World Wildlife Fund
  - Water Quality Modeling

Why WaSSI-CB?

- Clean and stable water, carbon sequestration are major forest ecosystem services;
- Ecosystem services are threatened by climate change, human influences (i.e. population growth and land use practices), water shortages, air pollution;
- Quantify water and carbon for designing Ecosystem Service Payment Schemes;

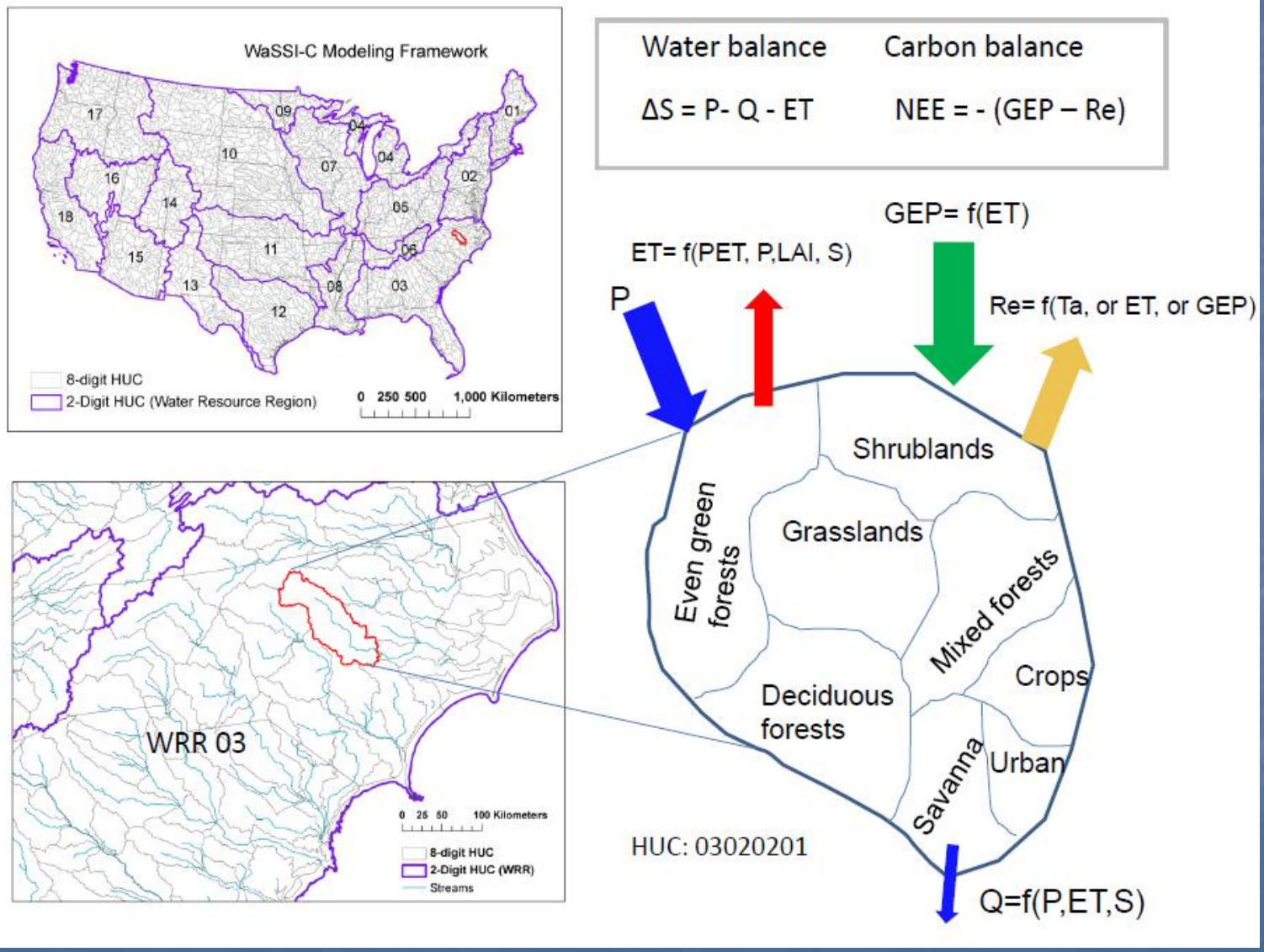
WaSSI-CB

- Design
  - Empirical and process models
  - Time step: monthly
  - Modeling Unit: Variable
    - US: 8 digit hydrologic unit code (HUC) (~3300 km^2)
    - Brazil: 1.4 x 1.4 degree grid (~150 x 150 km^2)
    - Mexico: 0.5 x 0.5 degree grid (~50 x 50 km^2)
  - Modeling Extent: Variable
    - Local, regional, or national

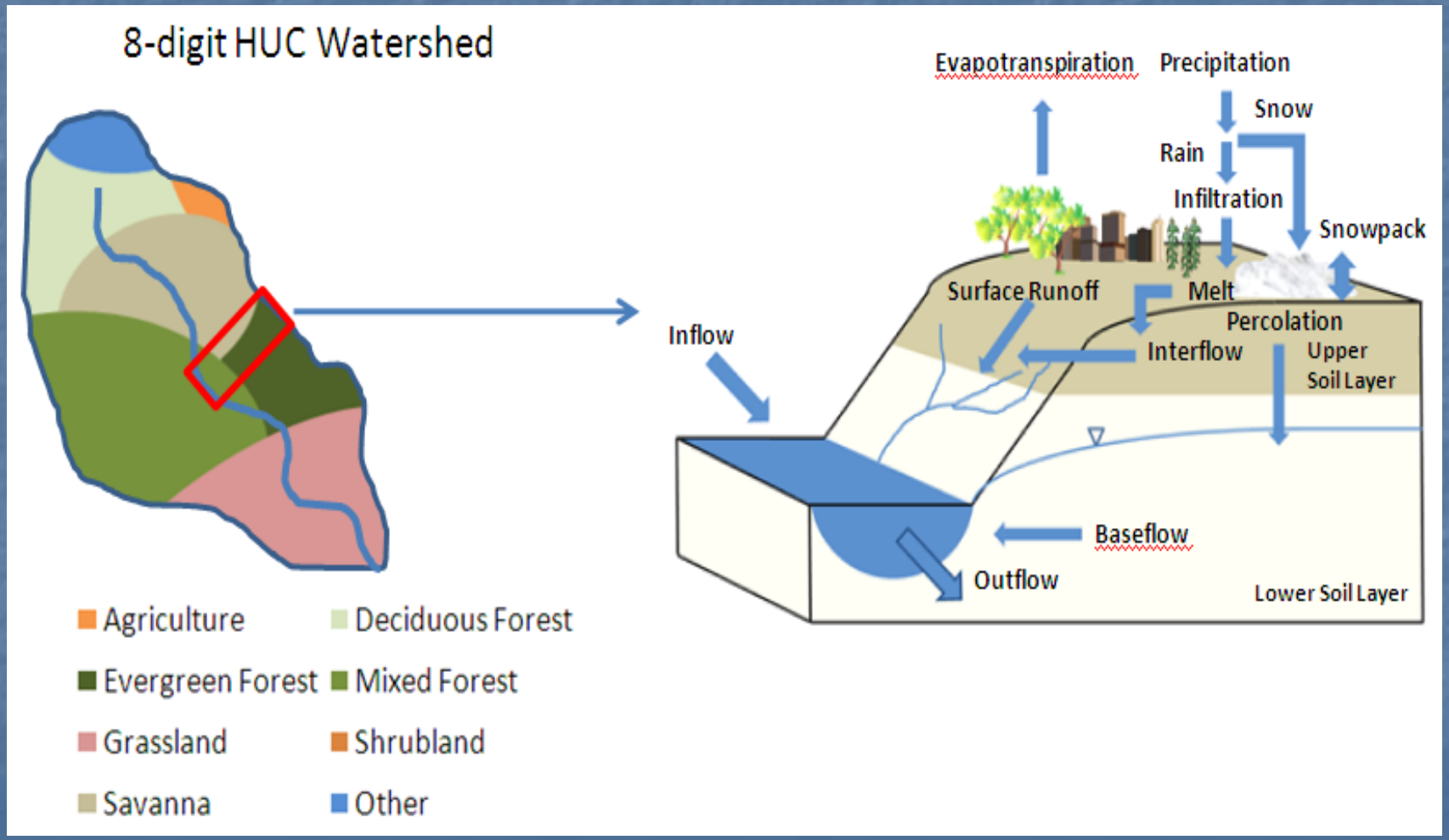


WaSSI-CB Modeling Framework

Models: WaSSI-CB



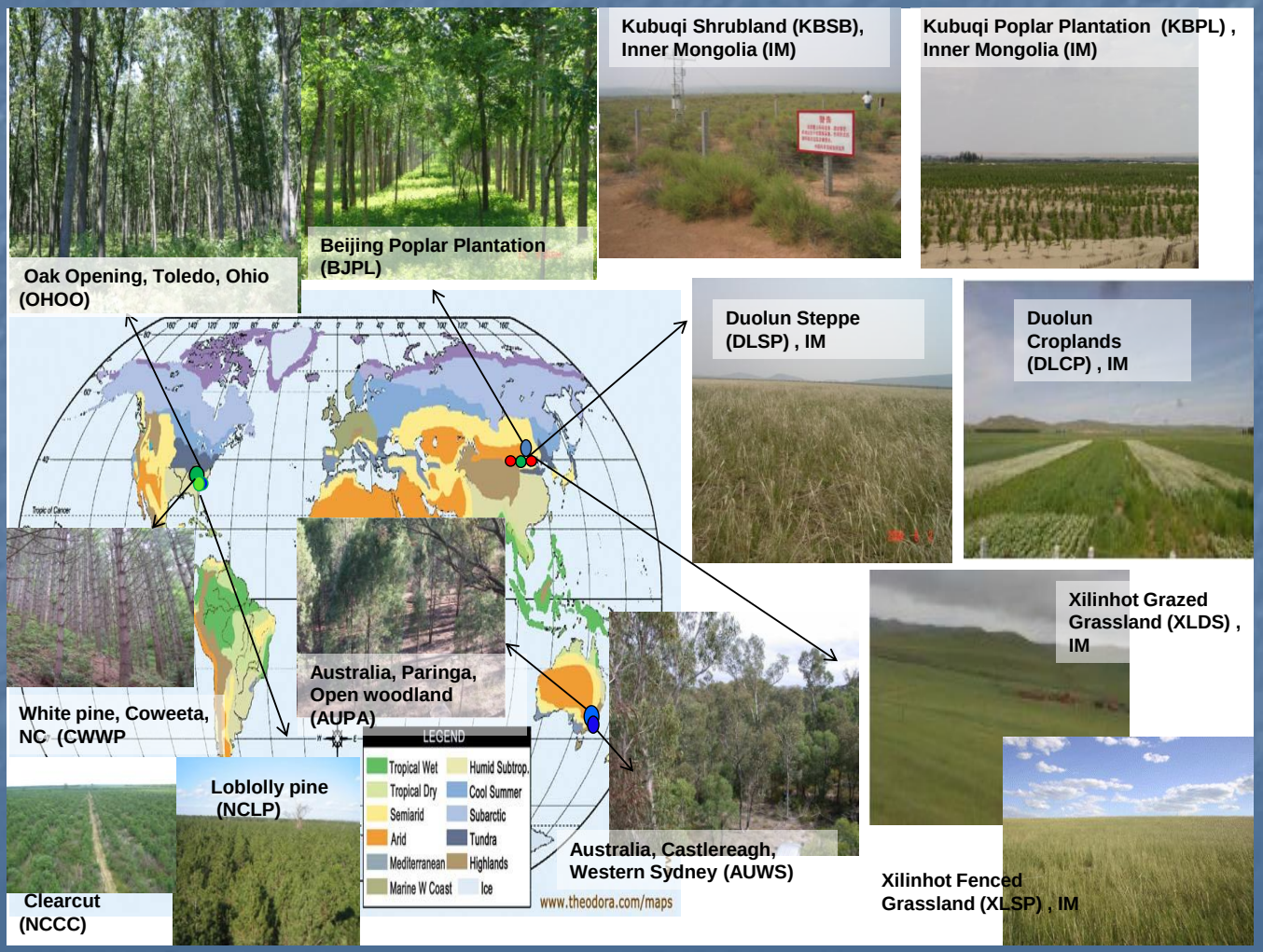
Models: Water Balance



Models: WaSSI-CB

- What it does:
  - Calculates monthly potential and actual evapotranspiration
  - Calculates monthly runoff
  - Calculates monthly water supply, demand, and stress (if input data is available)
- Science behind the model:
  - A general evapotranspiration model
  - Monthly water balance by landcover type
    - Water yield = P – ET - ΔS

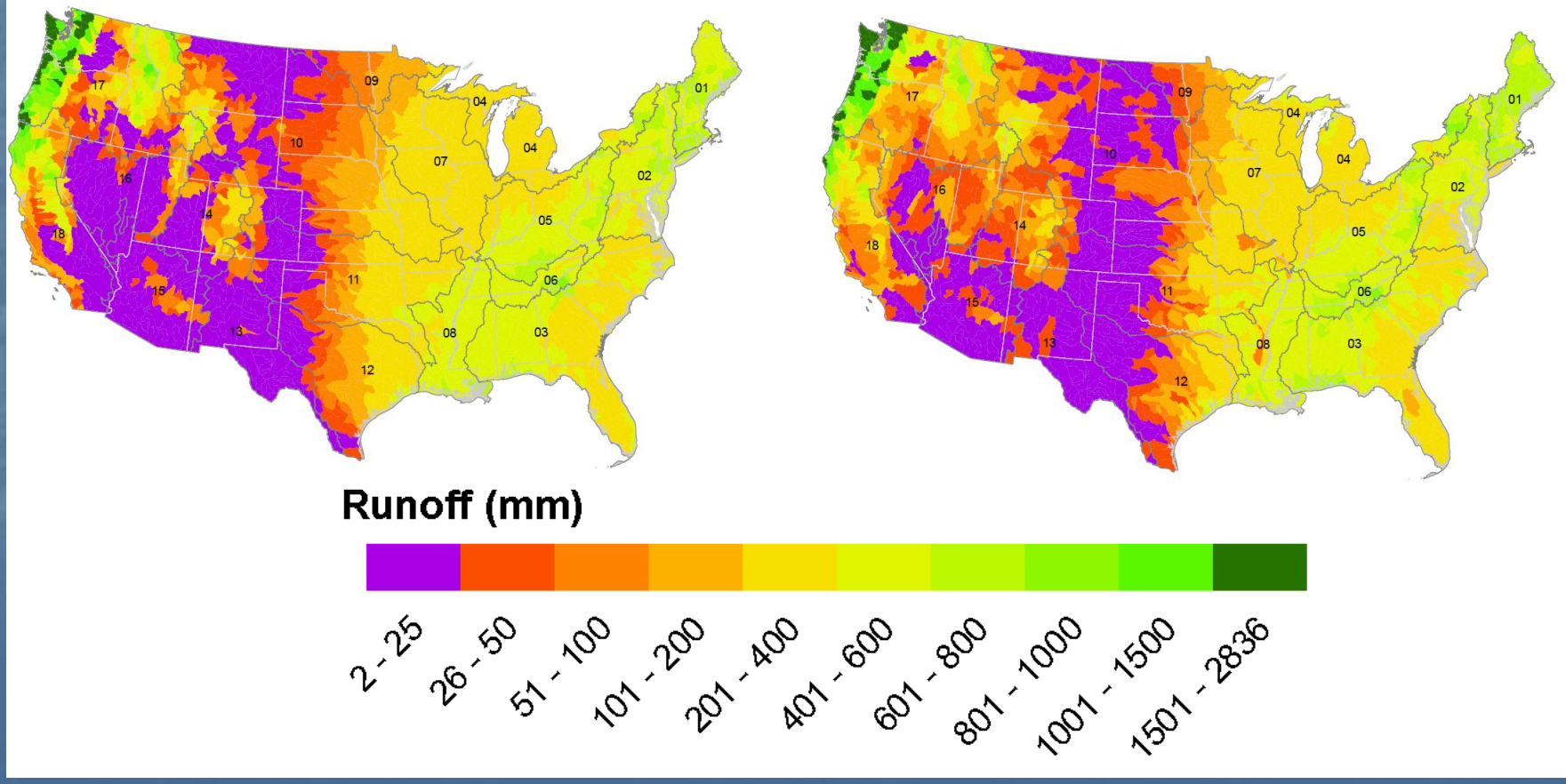
Science behind the model



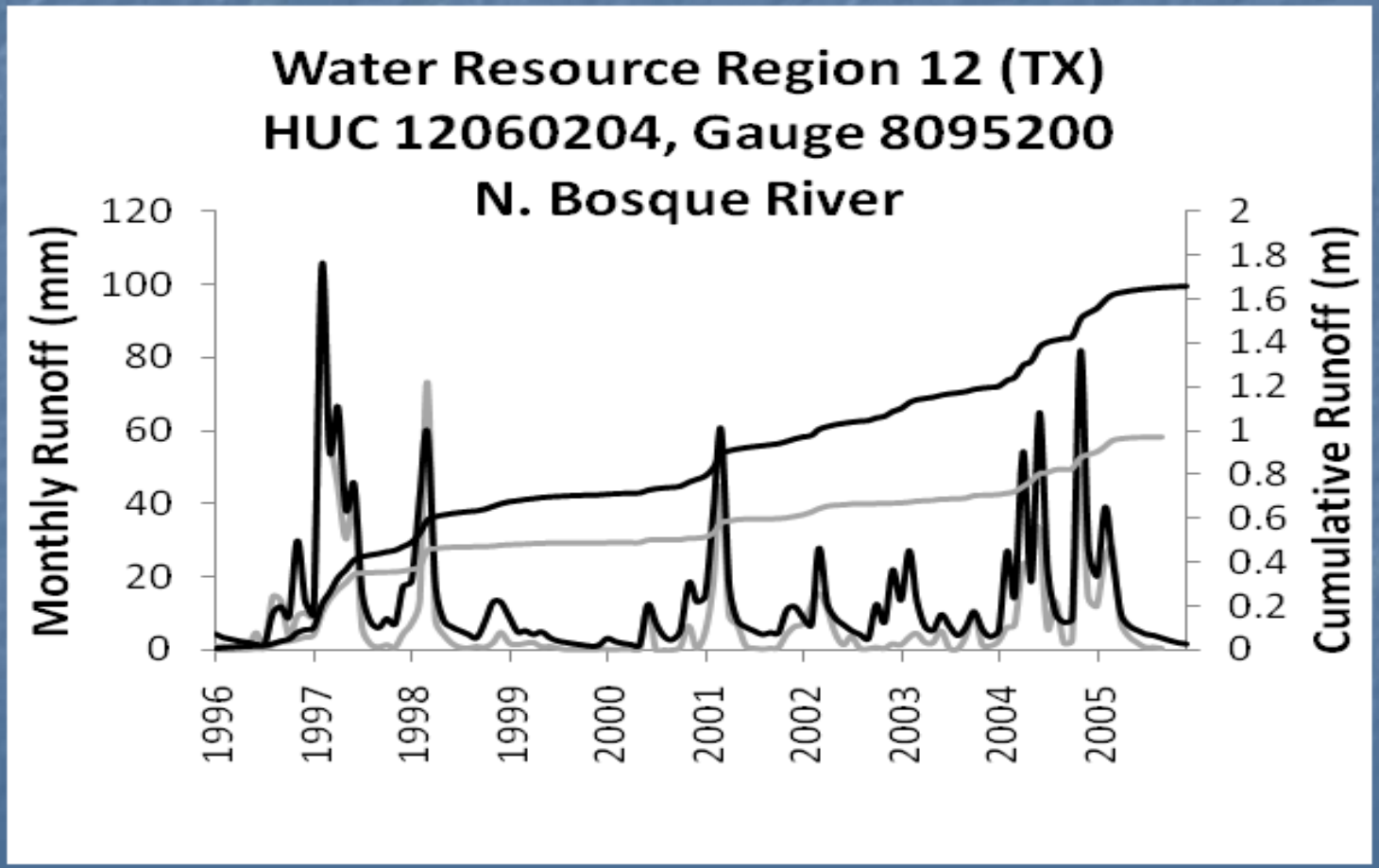
1960-2007 Average Annual Runoff Prism Historic Climate

Predicted

Measured



Example Output: Monthly Streamflow



What does the Model Offer?

(examples from the US and Africa)

Data Requirements for WaSSI-CB

Climate Data Used for Applications in Africa

- Historic: CRU TS3.1
  - Climate Research Unit (CRU) Time-Series (TS) Dataset
  - The University of East Anglia
    - Version 3.1
    - Spatial Resolution: 0.5 x 0.5 Degree ~ 50 km^2
    - Temporal Resolution: 1901-2009
    - Time Step: Monthly
    - Variables: Minimum Temperature, Maximum Temperature, and Precipitation
    - Based on monthly mean temperature

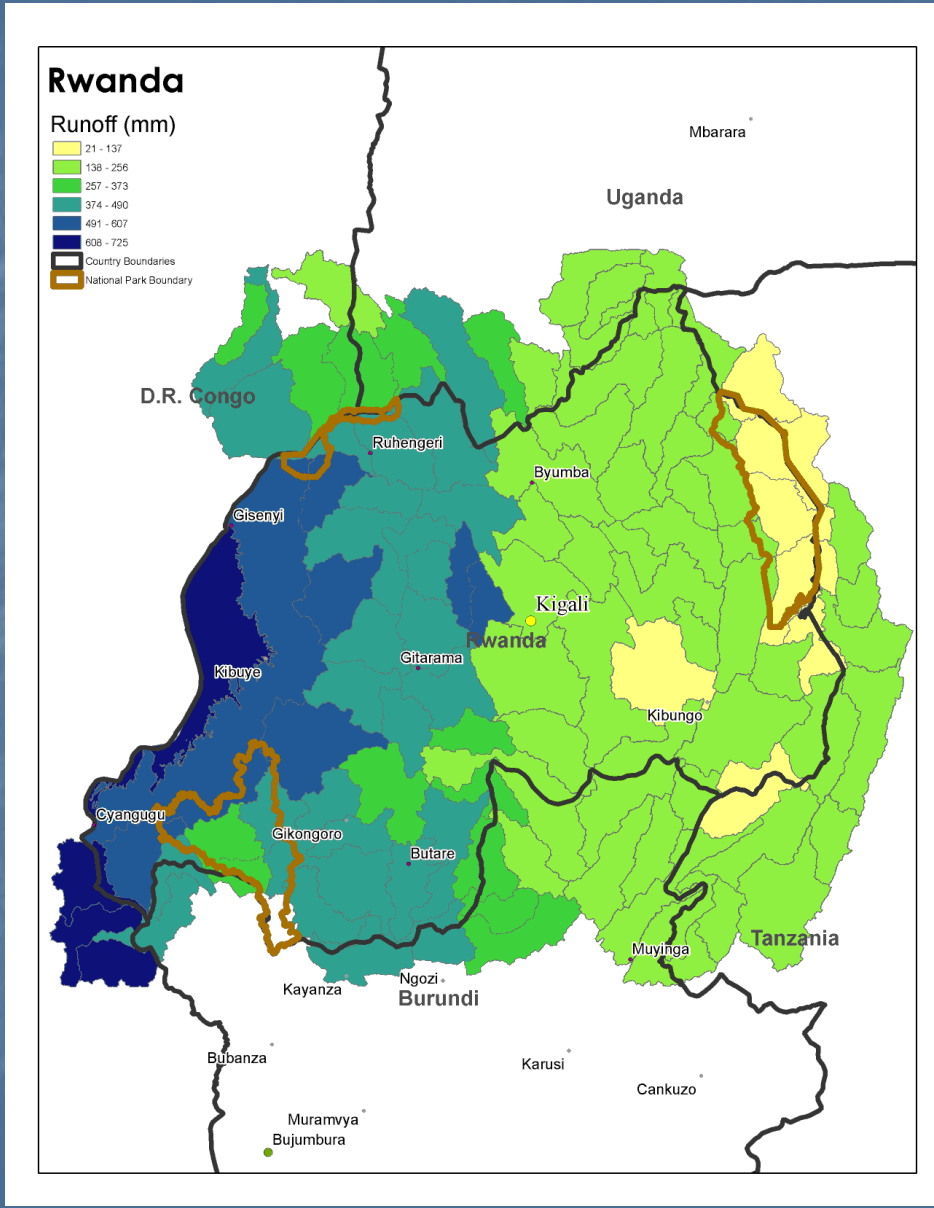
Land Cover

- Globcover
  - European Space Agency (ESA), MERIS instrument
- Spatial Resolution
  - 300*300 m^2
- Temporal Resolution
  - 2009 composite
    - Jan. 1 2009 – Dec. 2009
- Land Cover Classes
  - Global Legend: 22 classes
  - UN Land Cover Classification System

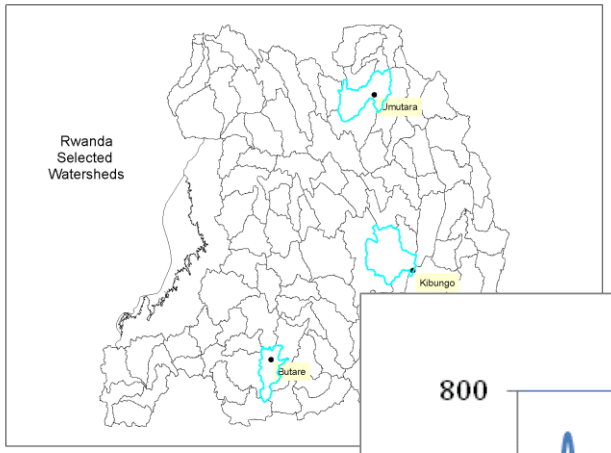
Leaf Area Index (LAI)

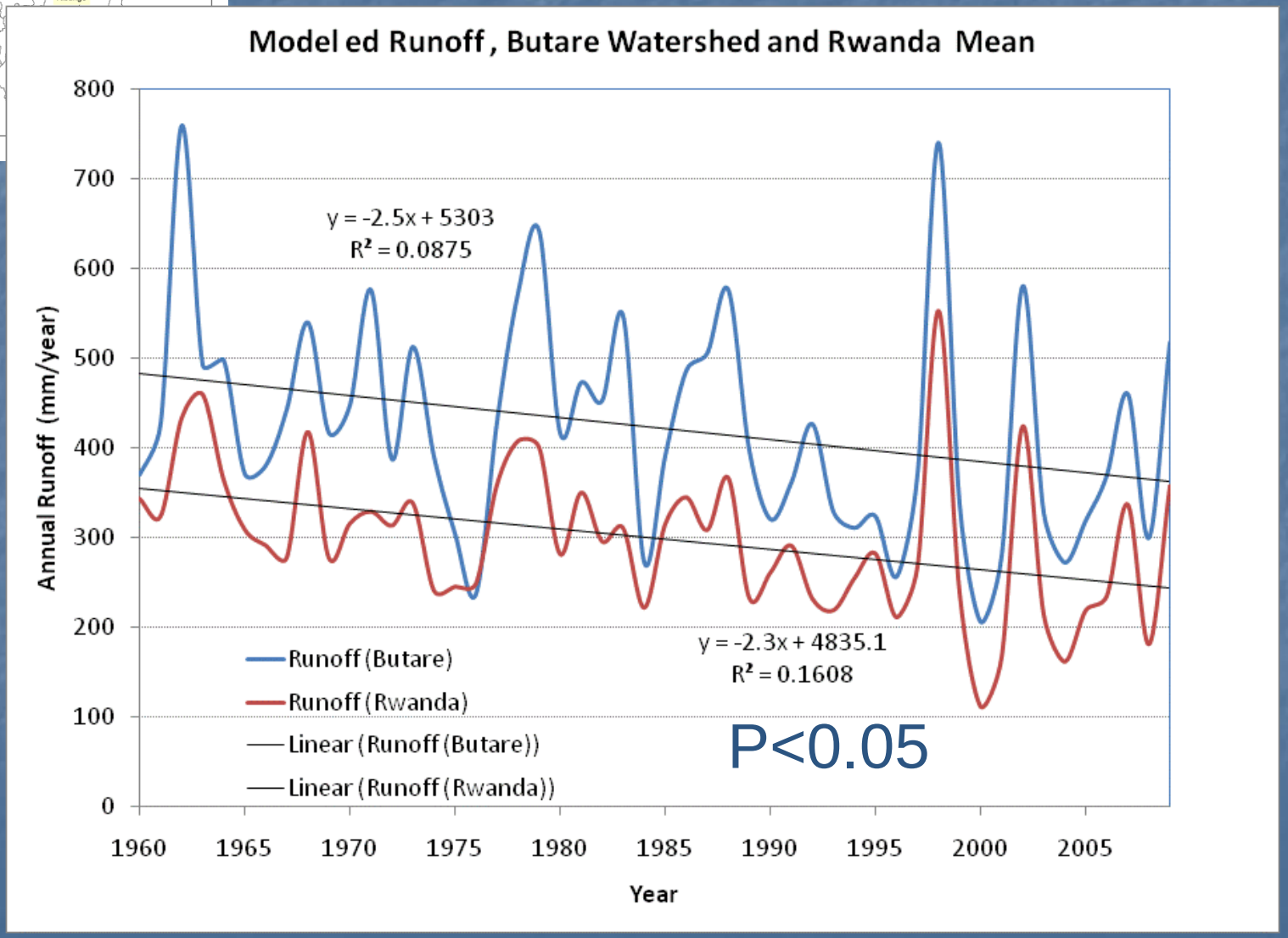
- Leaf Area Index data (Zhao et al.,2005)
  - Numerical Terradynamic Simulation Group (NTSG) at the University of Montana Missoula
    - Source: MODIS Imagery, MOD15(FPAR/LAI)
    - Spatial Resolution: 1 km^2
    - Temporal Resolution: 2000-2006
    - Time Step: Monthly

Runoff Maps


Rwanda
Runoff (mm)
21 - 137
138 - 256
257 - 373
374 - 490
491 - 607
608 - 725
Country Boundaries
National Park Boundary
Mbarara
Uganda
D.R. Congo
Ruhengeri
Byumba
Gisenyi
Kigali
Rwanda
Gitarama
Kibuye
Kibungo
Cyangugu
Gikongoro
Butare
Tanzania
Muyinga
Ngozi
Kayanza
Burundi
Bubanza
Karusi
Cankuzo
Muramvya
Bujumbura

Runoff Time Series (1960-2009)





What is InVEST?

Integradted Valuation of Ecosystem Services and Tradeoffs

Why InVEST?

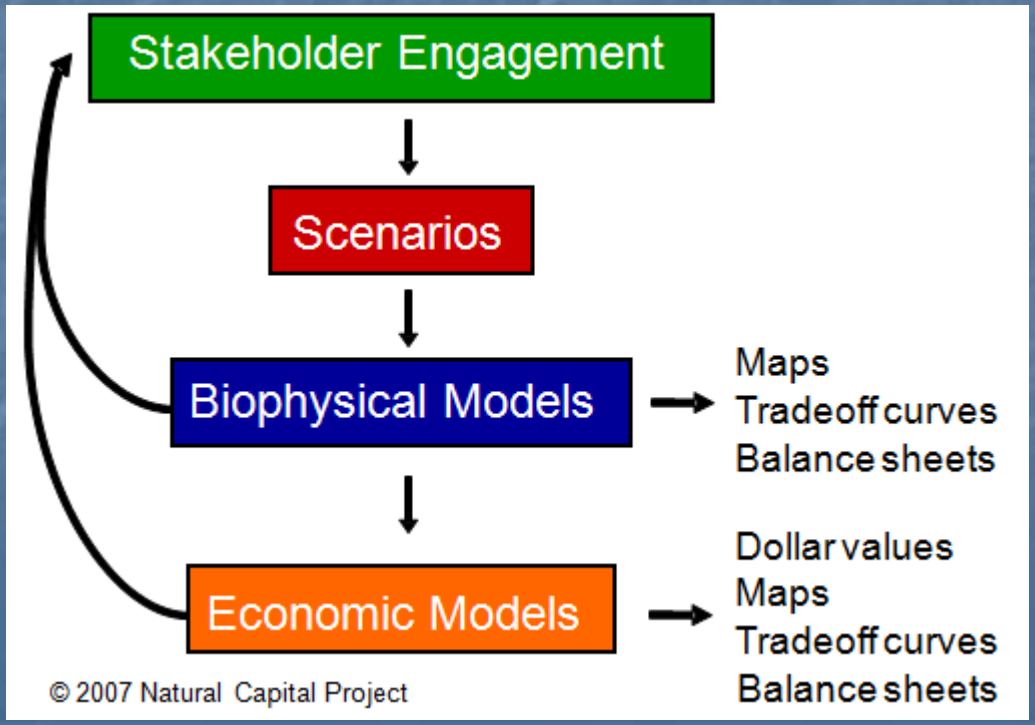
"Help corporations to decide how and where to invest natural capital to sustain nature's benefits to society"

Model Development

- Partners:
  - Stanford University's Woods Institute for the Environment,
  - University of Minnesota's Institute of the Environment
  - The Nature Conservancy
  - World Wildlife Fund
- Widely used globally (USA, Tanzania, Colombia and Ecuador, China) in decision making and higher education

InVEST

- Process and Results
  - Biophysical Models
    - Quantifies the amount of the ecosystem service (i.e. amount of sediment loss in tons)
  - Economic Models
    - Estimates the value for that ecosystem service (i.e. dollar cost of removing the sediment)



InVest

- Design
  - Tiered approach
- Toolbox
  - ESRI ArcGIS ArcToolBox environment
  - 11 models
  - More in development

TIER 1 Models	TIER 2 Models	TIER 3 Models
Simplest models; ignore certain real processes	Incorporate more real processes	Most complex; dynamic, process-based models
Least data required	More data required	Most data required
Annual average time step, no temporal dynamics	Daily to monthly time step, some temporal dynamics	Daily to monthly time step, temporal dynamics with feedbacks and thresholds
Appropriate spatial extent ranges from sub-watershed to global	Appropriate spatial extent ranges from parcel to global	Appropriate spatial extent ranges from parcel to global
Low precision estimates best for identifying areas of high & low ecosystem service production	More precise estimates of ecosystem service delivery	More precise estimates of ecosystem service delivery
No ecosystem service interactions	Some ecosystem service interactions	Sophisticated ecosystem service interactions with feedbacks and thresholds
Produce either absolute values or relative indices	Produce absolute values	Produce absolute values

Tallis et al., 2010

InVest 2.0

- Software Requirement
  - ARCGIS 9.3 (service pack 1 or 2)
  - ArcInfo level license
  - Spatial Analyst extension installed & activated
  - Python 2.5 or higher
  - Tool runs as scripts in ArcToolbox

InVEST 2.0 Models

- Wave Energy Model
- Coastal Vulnerability Model
- Marine Fish Aquaculture
- Aesthetic Quality
- Biodiversity: Habitat Quality & Rarity
- Carbon Storage and Sequestration
- Reservoir Hydropower Production
- Water Purification: Nutrient Retention
- Sediment Retention Model
- Managed Timber Production Model
- Crop Pollination

InVEST Sediment Model

- What it does:
  - "Calculates the average annual soil loss from subwatershed
  - Determines how much soil will arrive at a certain point
  - Estimates the ability of each parcel to retain sediment
  - Assess the cost of removing accumulated sediment on an annual basis"

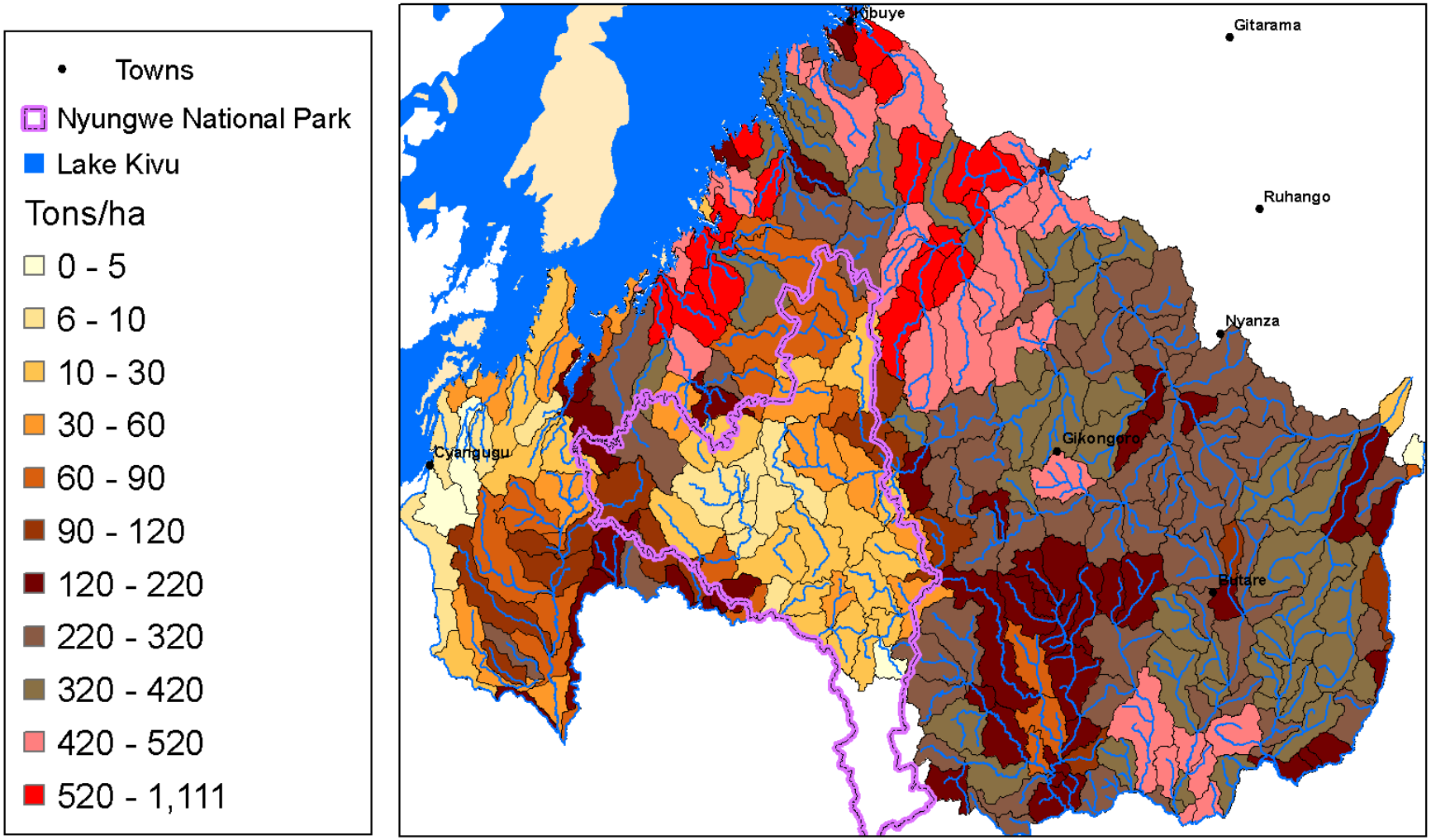
Tallis et al., 2010

InVest 2.0

- Sediment Retention Model
  - How it does it:
    - Universal Soil Loss Equation
    - Sediment Retention
    - Sediment Services
      - Avoided Sedimentation of Reservoirs
      - Water Quality
    - Sediment Valuation

Example Products from InVEST

Universal Soil Loss Equation Mean Potential Soil Loss by Watershed: Baseline



Summary

- WaSSI-CB for Water Quantity (dynamic) and InVEST for sediment production (annual longterm mean);
- Maps to show priority 'hot spots" ;
- Both models are relatively easy to learn;
- Both models are designed to require minimum data to run.