Modeling impacts of anthropogenic activities and climate change on water resources in data-rich and data-poor regions

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HydroPredict, Vienna, September 2012

Special Session 3: Choosing Models for Resilient Water Resources Management Water Partnership Program (WPP)/TWIWA-The World Bank



# Managing water in a changing world: What does the future hold?

Increasing population

#### Climate change



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Land conversion



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# WaSSI application case studies

#### Conterminous U.S.

"Data Rich" region

Evaluate the impacts of impervious cover, water withdrawals, and future climate change on river flows

#### Rwanda

"Data Poor" region

Evaluate landuse and climate change impacts on water quantity and sedimentation





# WaSSI model structure

## Monthly Watershed Water Balance

Water Withdrawal and Return

Flow Routing

## Water Supply Stress & Instream flows



# Watershed water balance



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#### **Evapotranspiration**

ET=f(PET, PPT, LAI) Sun et al., Ecohydrology,2011

### Soil moisture and runoff

Sacramento Soil Moisture Accounting Model NOAA, National Weather Service

### Water withdrawal and return

Estimated water use in the U.S. by sector, adjusted for population *U.S. Geological Survey, 2009* 

## **Streamflow**

Q<sub>out</sub> = Q<sub>in</sub> + Q<sub>gen</sub> – WU Caldwell et al., HESS, 2012



# Case Study: United States

## WaSSI applications

- Lockaby, G., Nagy, C., Vose, J. M et al., 2011. Water and Forests, in Wear D. N. and Greis J. G. (eds.) The Southern Forest Futures Project: Technical Report.
- Averyt, K., Fisher, J., Huber-Lee, A., et al., 2011. Freshwater use by U.S. power plants: Electricity's thirst for a precious resource, A report of the Energy and Water in a Warming World initiative, Cambridge, MA, Union of Concerned Scientists.
- Marion, D., Sun, G., Caldwell, P. et al., 2012. Managing Forest Water Quantity and Quality Under Climate Change in the Southern U.S., in Vose, J. (ed.) Climate Change Adaptation and Mitigation Management Options, (In press).
- Sun, G., Caldwell, P.V., Georgakakos, A.P., et al., 2012. Impacts of Climate Change and Variability on Water Resources in the Southeastern US, in: Southeastern Regional Technical Report to the National Climate Change Assessment, Water Resources, (in review).



# Inputs- United States

Database	Source	Resolution
Watershed boundaries	USGS Watershed Boundary Dataset	8-digit Hydrologic Unit Code
Soil properties	State Soil Geographic (STATSGO) Dataset	1 X 1 km
Land cover and impervious area	2006 National Land Cover Dataset	30 X 30 m
Leaf area index	2000-2006 Moderate Resolution Imaging Spectroradiometer (MODIS)	1 X 1 km
Mean elevation	USGS National Elevation Dataset	30 X 30 m
Climate (temp, precip)	PRISM, or CMIP <sub>3</sub> IPCC AR <sub>4</sub> projections	4 X 4 km 12 X 12 km
Watershed connectivity	USGS National Hydrography Dataset	1:100,000
Water withdrawals, return flows	2005 USGS Water Use Estimates	County
Population and impervious projections	USEPA Integrated Climate and Land Use Scenarios	County



## U.S. model testing Caldwell et al., HESS, 2012



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# Impacts on historical stream flow

Caldwell et al., HESS, 2012



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# Impacts on stream flow by 2041-2060

Caldwell et al., HESS, 2012



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# Case study: Rwanda





# Nyungwe Forest

- Essential water source
  - ~30% in Nile River Basin
  - ~70% in Congo River Basin
- National Park Buffer Zone created in 1984 to:
  - Protect the forest
  - Produce wood products
  - Provide employment opportunities for local people
  - Numerous management issues have led to loss of forest and soil erosion





# Nyungwe Watershed Modeling Project

- Objective: Simulate landcover and climate change impact on water quantity and sedimentation in Nyunwge and surrounding area
- Partners: US Forest Service, Wildlife Conservation Society, and US AID
- Tools
  - WaSSI- Water quantity
  - InVEST- sedimentation
- Scenarios
  - Current landcover and climate (1989-2009)
  - 20% forest conversion to agriculture
  - 2021-2040 climate, multi-model ensemble A2 emission scenario in (PPT +1.4%, TEMP +1.0°C)





# Inputs- Rwanda

Database	Source	Resolution
Watershed boundaries, mean elevation	Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) GDEM2	30 X 30 m
Soil properties	Harmonized World Soils Database Version 1.2	1 X 1 km
Land Cover	2009 European Space Agency (ESA) Globcover	300 X 300 m
Leaf Area Index	2000-2006 Moderate Resolution Imaging Spectroradiometer (MODIS)	1 X 1 km
Climate (historical)	University of East Anglia Climatic Research Unit (CRU) Monthly Time Series Data, V. 3.1	o.5 X o.5 degree
Climate (future)	Wildlife Conservation Society Albertine Rift Climate Change Assessment: Multi-model Mean Downscaled IPCC AR4 Data	o.5 X o.5 degree



# Rwanda model testing











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## InVEST Results: Predicted mean sediment exported by watershed



20% forest conversion





# Take away points

- Water is a priority for the U.S. Forest Service!
- WaSSI is a modeling tool under development to separate and quantify impacts of humans and climate change on water resources
- WaSSI can be easily adapted to different regions, scales, and data availability
- The goal of WaSSI is to:
  - Help answer the "So what?" questions of climate predictions
  - Identify priority watersheds for conservation and management
  - Cost effectively test planned management scenarios





## www.forestthreats.org/research/tools/WaSSI



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# Thank you!

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# A legacy of Forest Service management for ecosystem services

- Organic Act of 1897
  - "No national forest shall be established, except to improve and protect the forest within the boundaries, or for the purpose of <u>securing favorable</u> <u>conditions of water flows</u>..."
- Weeks Law of 1911
  - "...examine, locate, and purchase such forested, cutover, or denuded lands within the watersheds of navigable streams as in his judgment may be necessary to the <u>regulation of the flow of navigable streams or for the</u> <u>production of timber</u>."
- Sustained Yield Forest Management Act of 1944
  - "...in order to secure the benefits of forests in <u>maintenance of water supply,</u> regulation of stream flow, prevention of soil erosion, amelioration of <u>climate, and preservation of wildlife</u>."
- National Forest Management Act of 1976
  - Protection of "<u>multiple use and sustained yield of the products and services</u> <u>obtained</u>" and "the coordination of outdoor recreation, range, timber, watershed, wildlife and fish, and wilderness."



## Local scale: Blue River, Colorado Caldwell et al., HESS, 2012



