Significance of Uncertainty in Evapotranspiration Estimates on Water Balance Modeling in SWAT

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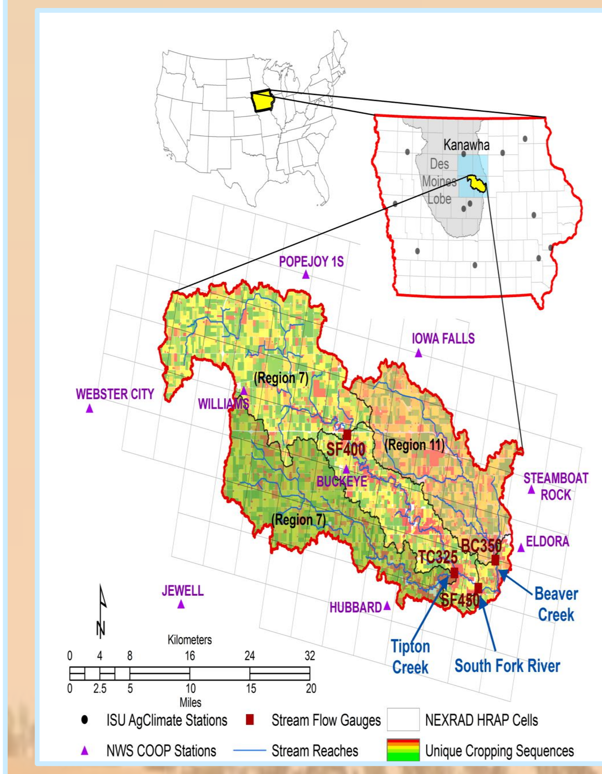
Introduction

In water quality models, such as SWAT, accurate forcing of Potential ET (PET) is crucial for producing reasonable predictions of water budget components, sediment and other pollutant loads from larger river basins. Methods and data, needed to compute PET, vary in space and time such as air temperature, vapor pressure, wind speed, and solar radiation. In SWAT, PET is required as an input and is either computed internally by the weather generator using available weather data by a choice of three different methods: i) Priestley-Taylor; ii) Penman-Monteith; and iii) Hargreaves methods, or calculated by an external source and provided to SWAT as an input. The actual ET (AET) is then calculated in SWAT based on available water, crop and soil moisture conditions. Most often, the modelers rely on the models to simply match AET annual means, provided by the literature values, when calibrating the models due to sparse data. For this study, we used three methods to calibrate AET parameters: i) basin-wide/annual (using literature values); ii) subbasin/monthly (using Atmosphere-Land Exchange Inverse (ALEXI) model output); and iii) HRU/daily (using the NDVI/crop coefficient method from two *in situ* towers in corn and soybean fields).

South Fork of the Iowa River



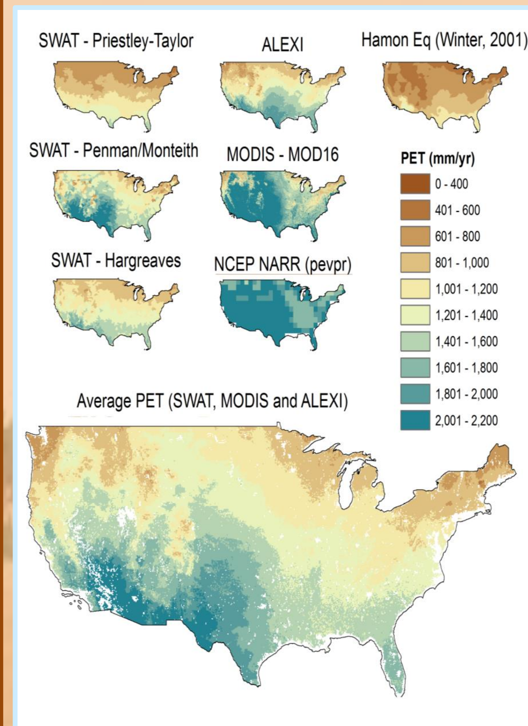
Conservation Effects Assessment Project (CEAP)

- One of 15 CEAP Watersheds.
- Watershed area = 788 km²
- 84% cropland with 99% planted to corn + soybean.
- Hydric soils with many potholes and extensive tile drainage.

Data

Yearly / Basin:

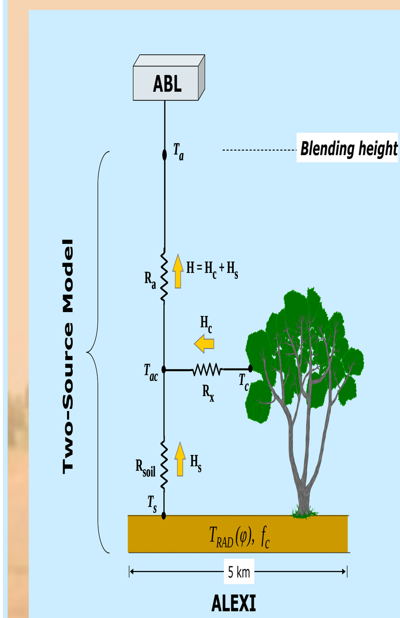
Typical SWAT calibration uses annual average from one source of Potential ET only depending on overall water budget.

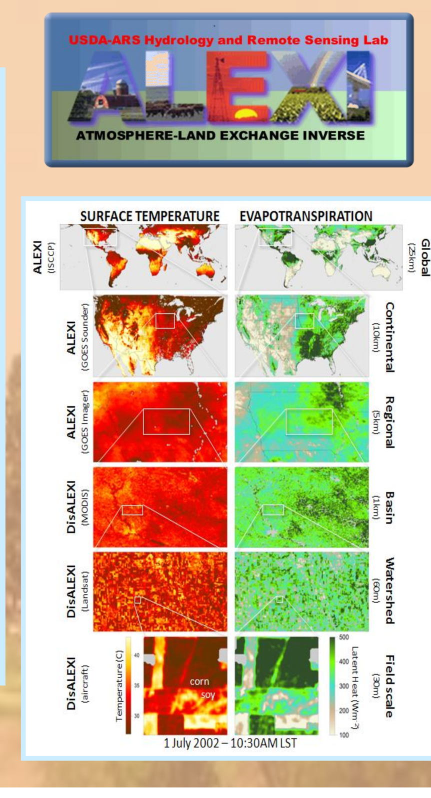


Results depend on selecting PET source and matching to limited literature AET values. This is only sufficient for annual calibration.

Monthly / Subbasin:

The Atmosphere-Land Exchange Inverse (ALEXI) model (Anderson et al., 2007a,b) was designed to minimize the need for ancillary meteorological data while maintaining a physically realistic representation of land-atmosphere exchange over a range in vegetation cover conditions using remotely sensed data.





A two-source model (soil + vegetation) energy balance model is applied in a time differential mode, coupled with an atmospheric boundary layer (ABL) model to internally simulate land-atmosphere feedback on near-surface air temperature and surface fluxes. This reduces sensitivity to LST retrieval errors.

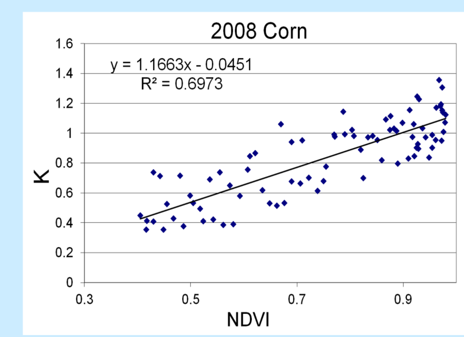
Daily / HRU:

Micrometeorology

NDVI/ Crop Coefficient

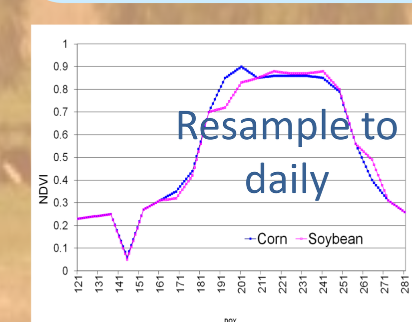
$$K_c = \frac{ET_c}{ET_o}$$

$$K = a \cdot NDVI + b$$



$$ET_c = K_c \cdot ET_o$$
$$= (a \cdot NDVI + b) ET_o$$

Micrometeorological and Surface Flux measurements were collected in adjacent Corn and Soybean fields during the growing season. Measurements included: Humidity, Air Temperature, Wind Speed/Direction, Turbulent Energy (H & λE) and CO2 Fluxes, Four Component Radiation Budget (Rn, K↓, etc.) Daily means were also calculated.



8-Day MODIS NDVI

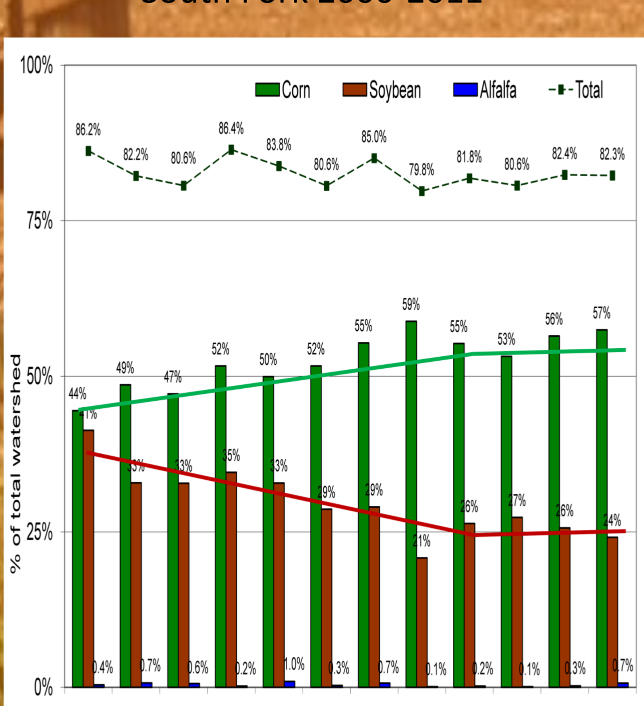
$$ET_c = (a \cdot NDVI + b) ET_o$$

Daily Actual ET Estimate

Background

Corn Production Increased to Meet Biofuels Goals

Corn and Soybean Production in the South Fork 2000-2011



SWAT

SWAT Model Scenarios: Calibrated from Beeson et al, 2011; actual crop sequence 2000-2010 from CDL, tillage, fertilizer, NEXRAD/rain gauge data and seven PET sources.

SWAT2009:

Proven to be an effective tool for evaluating the impacts of landuse changes on water quality, allows water resource assessment, and has been used to solve nonpoint source pollution problems across the globe (Arnold et al., 1998; Arnold and Fohrer, 2005).

SWAT's Major Components:

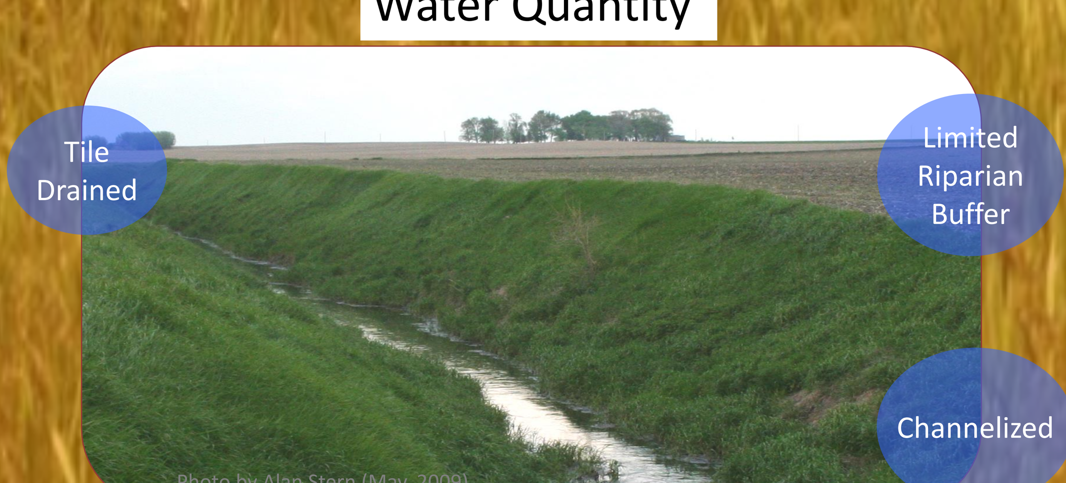
- Hydrology (water balance)
- Weather (actual/simulated)
- Sediment
- Nutrients (Nitrogen & Phosphorus)
- Management Scenarios
- Crop Growth
- Pesticides
- Groundwater
- Lateral Flow
- Bacteria

Arnold, J. G., and N. Fohrer. 2005. SWAT2000: Current capabilities and research opportunities in applied watershed modeling. Hydrol. Process. 19(3): 563-572.
Arnold, J. G., R. Srinivasan, R. S. Muttiah, and J. R. Williams. 1998. Large-area hydrologic modeling and assessment: Part I. Model development. J. American Water Resour. Assoc. 34(1): 73-89.
Beeson, P.C., P.C. Doraiswamy, A.M. Sadeghi, M. Di Luzio, M.D. Tomer, J.G. Arnold, and C.S.T. Daughtry. 2011. Treatments of precipitation inputs to SWAT models. Trans. ASABE 54:2011–2020.

Objectives:

- Develop Decision Support System
  - →Address water quality concerns while meeting the landowner's objectives
- Optimize Yield/Protect Water Quality
  - → Residue management, crop rotation, and other practices needed on a site-specific
- Improve Spatial /temporal response
  - → Incorporate most-current/highest-quality data from remote sensing, GIS, field studies, etc.

Water Quantity

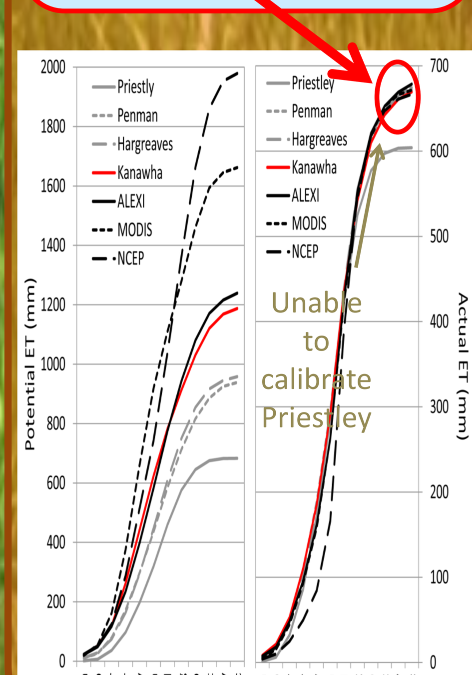


Results

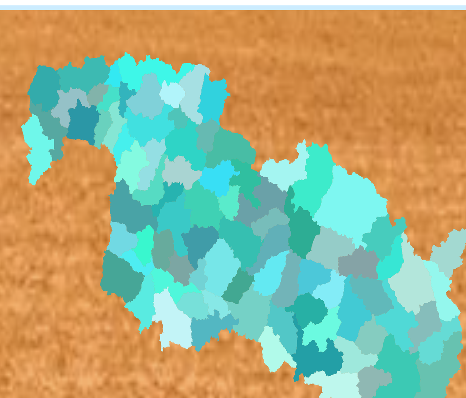
Yearly / Basin:

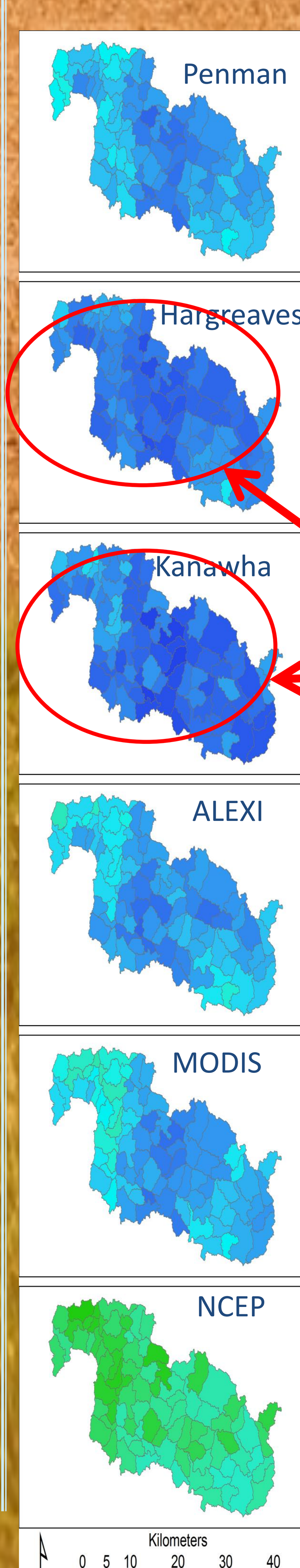
	Priestley	Penman	Hargreaves	ALEXI	Kanawha	MODIS	NCEP
PRECIP	908	908	908	908	908	908	908
PET	683	938	957	1239	1187	1661	1978
AET	604	674	671	678	669	671	667
TILE Q	194	142	145	141	145	144	143
WATER YLD	287	218	221	216	221	221	217

Calibration allows for most PET input to match literature values of annual AET



Monthly / Subbasin:





Monthly SWAT AET output vs monthly AET from ALEXI by sub-basin

Although all closely match annual values, there is monthly/sub-basin variation

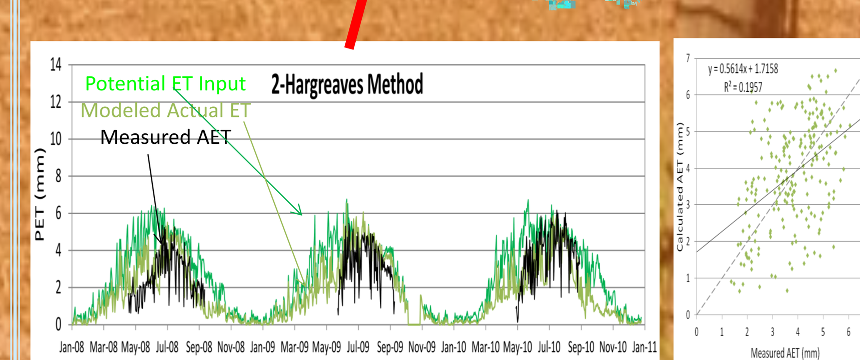
0.65 R² 0.98

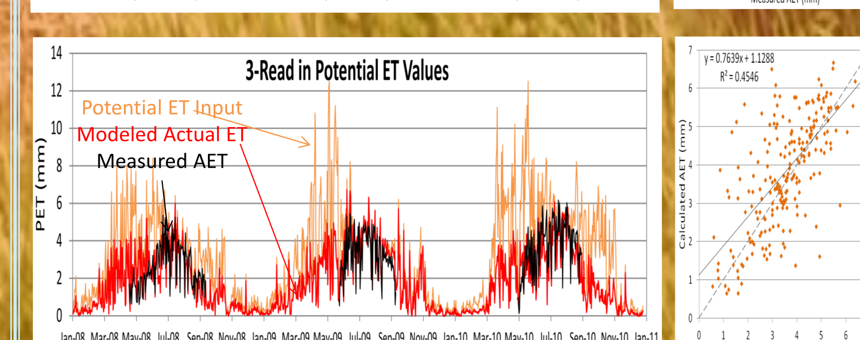
Hargreaves and Kanawha Tower typically best for AET and stream flow

Stream flow performance (NSE) at the 4 gauges

		Penman	Hargreaves	Kanawha	ALEXI	MODIS	NCEP
BC350	Cal.	0.82	0.85	0.83	0.79	0.80	0.57
	Val.	0.85	0.83	0.81	0.74	0.74	0.46
SF400	Cal.	0.77	0.83	0.80	0.81	0.79	0.59
	Val.	0.64	0.72	0.64	0.56	0.50	0.14
SF450	Cal.	0.89	0.91	0.90	0.90	0.89	0.76
	Val.	0.62	0.65	0.63	0.50	0.55	0.23
TC325	Cal.	0.71	0.77	0.70	0.72	0.72	0.50
	Val.	0.79	0.82	0.78	0.73	0.73	0.33

Daily / HRU:





- Two best monthly results vary greatly when observed on a Daily / HRU basis
- Kanawha Tower (R^2=0.455) compared to Hargreaves (R^2=0.196)

Conclusions

- Choice of evapotranspiration input to SWAT is sensitive even though annual values are correct
- In-situ and Remotely Sensed PET greatly helps calibrate SWAT AET
- Potential ET calculated independently and read-into SWAT was the best performing
- ➢Future Work: Expand remotely sensed estimation of ET for use in larger scale SWAT simulation

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