

EVALUATING LAND USE LAND COVER UNCERTAINTY USING SWAT2009_LUC TOOL

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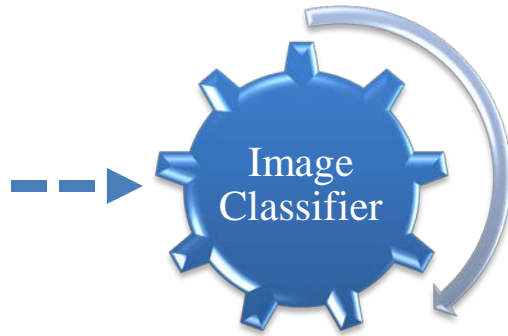
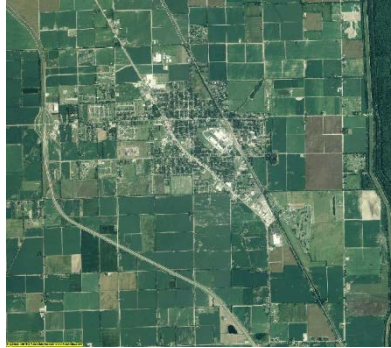
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Presented at:

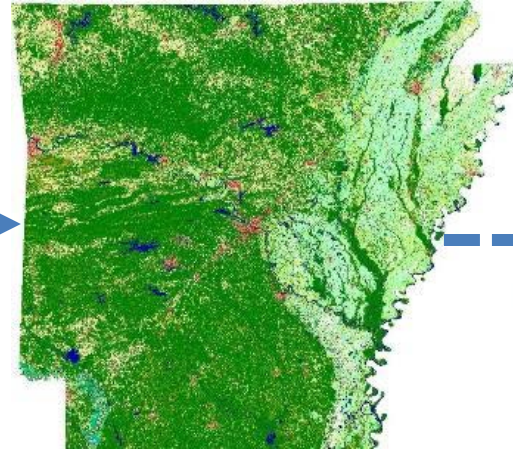
**2012 International SWAT Conference & Workshops, New Delhi, India
July 19, 2012**

LULC MAP PRODUCTION 101

Aerial multi-spectral
image



LULC



Ground
truthing

ACCURACY
ANALYSIS



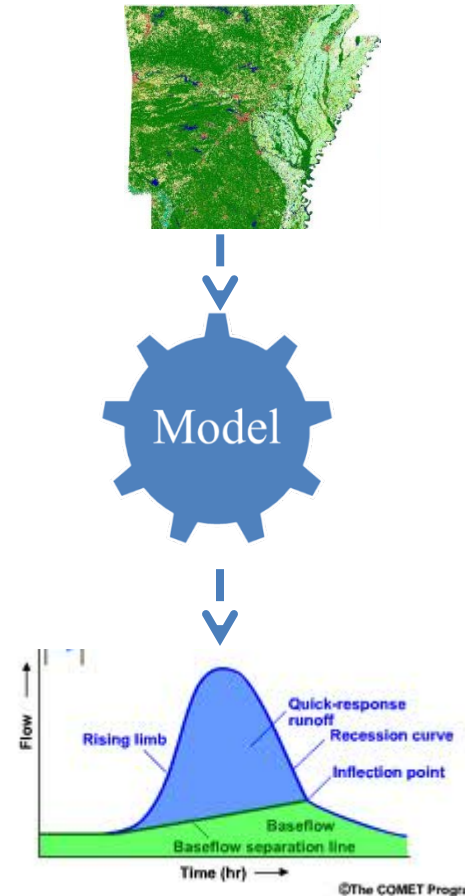
- Source of errors in LULC map: geometric, radiometric, spectral mixing,...
- Accuracy varies based on LULC category[^]
- Broad accuracy range: 75% to 95% depending on category

(*Jensen, 1996; ^Congalton, 1991) (Image sources: CAST, Landsat)

LULC ERRORS

Why do we care about LULC categorical errors?

- Input errors = Output errors
- **LULC**: important SWAT input
- Processes governing hydrologic responses are sensitive to land cover¹
- Small LULC errors can have substantial effect on watershed model output²

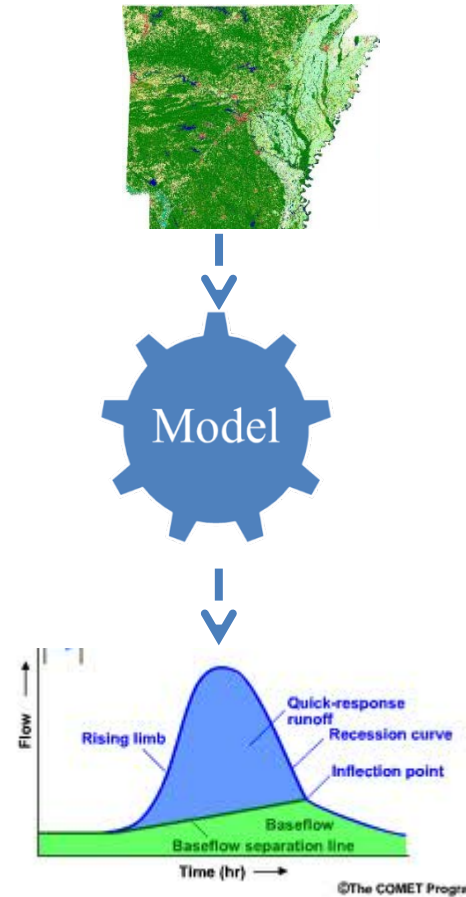


[1] Singh and Frevert, 2006; Singh and Woolheiser, 2002

[2] Stuebe and Johnston, 1990; Endreny et al., 2003; Miller et al. 2007

LULC ERRORS

- **KINEROS2**: -83% to 664% deviation in runoff volume due to LULC misclassification¹
- **HSPF**: -35% to 20% deviation in peak flows based on LULC source²
- **SWAT**: unknown??
- Even if known, can we extrapolate to all watersheds?



[1] Miller et al. (2007)
[2] Endreny et al. (2003)

LULC ERRORS

How do we handle LULC errors?

Minimize Errors¹

- ❖ Radiometric corrections
- ❖ Geometric corrections
- ❖ Improved classification techniques
- ❖ More ground samples

Propagate Errors²

- ❖ Develop LULC realizations
- ❖ Integrate in SWAT model
- ❖ Evaluate sensitivity to LULC error
- ❖ Incorporate in decision-making

FOCUS OF THIS STUDY

Propagating LULC categorical errors through the SWAT model

[1] Jensen (1996), Alfieri et al. (2007)

[2] Endreny et al. (2003), Miller et al. (2007)

TOOL DEVELOPMENT

- Error propagation results complex and specific to a watershed, land-use layer, and output
- How do we empower other modelers to conduct uncertainty analysis?
- Unify uncertainty techniques into existing modeling framework¹
- Develop automated tools that facilitate uncertainty analysis²



[1] For e.g., Harmel et al. (2010)

[2] Brown and Heuvelink (2007)

SPECIFIC OBJECTIVES

1

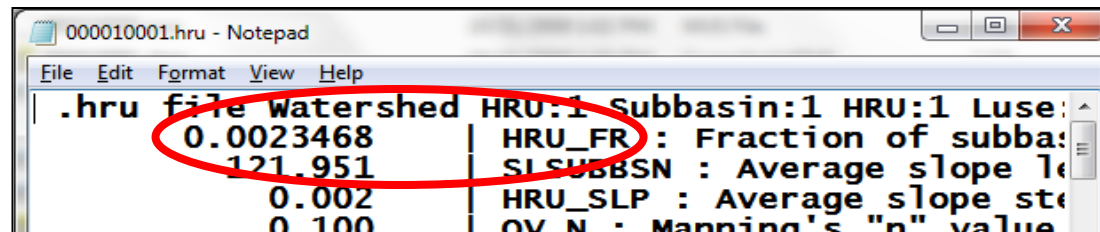
Develop an automated tool to integrate LULC realizations in the SWAT model

2

Evaluate sensitivity of SWAT output to LULC categorical errors

LUU MODULE CONCEPT

- **HRU**: unique combination of land use, soil, and slope within a subbasin
- Fractional coverage of an existing HRU is represented by HRU_FR variable in *.hru files



- LUU module operates by updating HRU_FR variable as many times as the number of temporal land use data layers require[#]

(#Pai and Saraswat, 2011)

LUU MODULE WORKING

SWAT2009
Model run 2001 - 2008

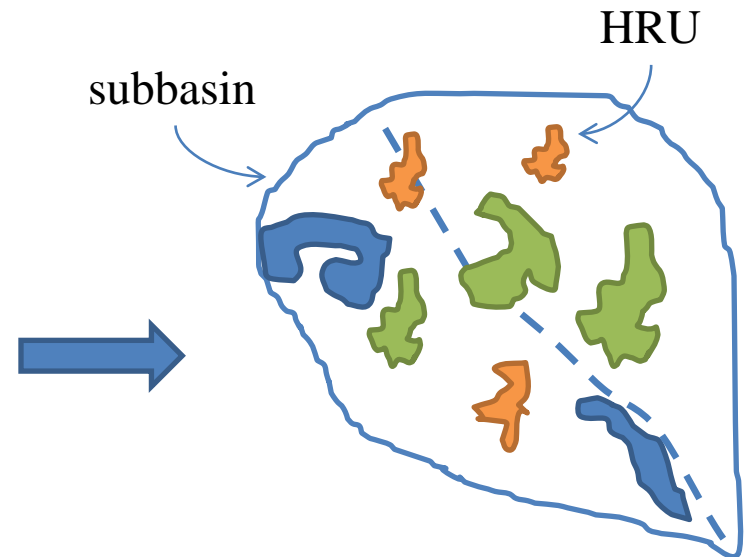


```
C:\WINDOWS\system32\cmd.exe - swat2009.exe

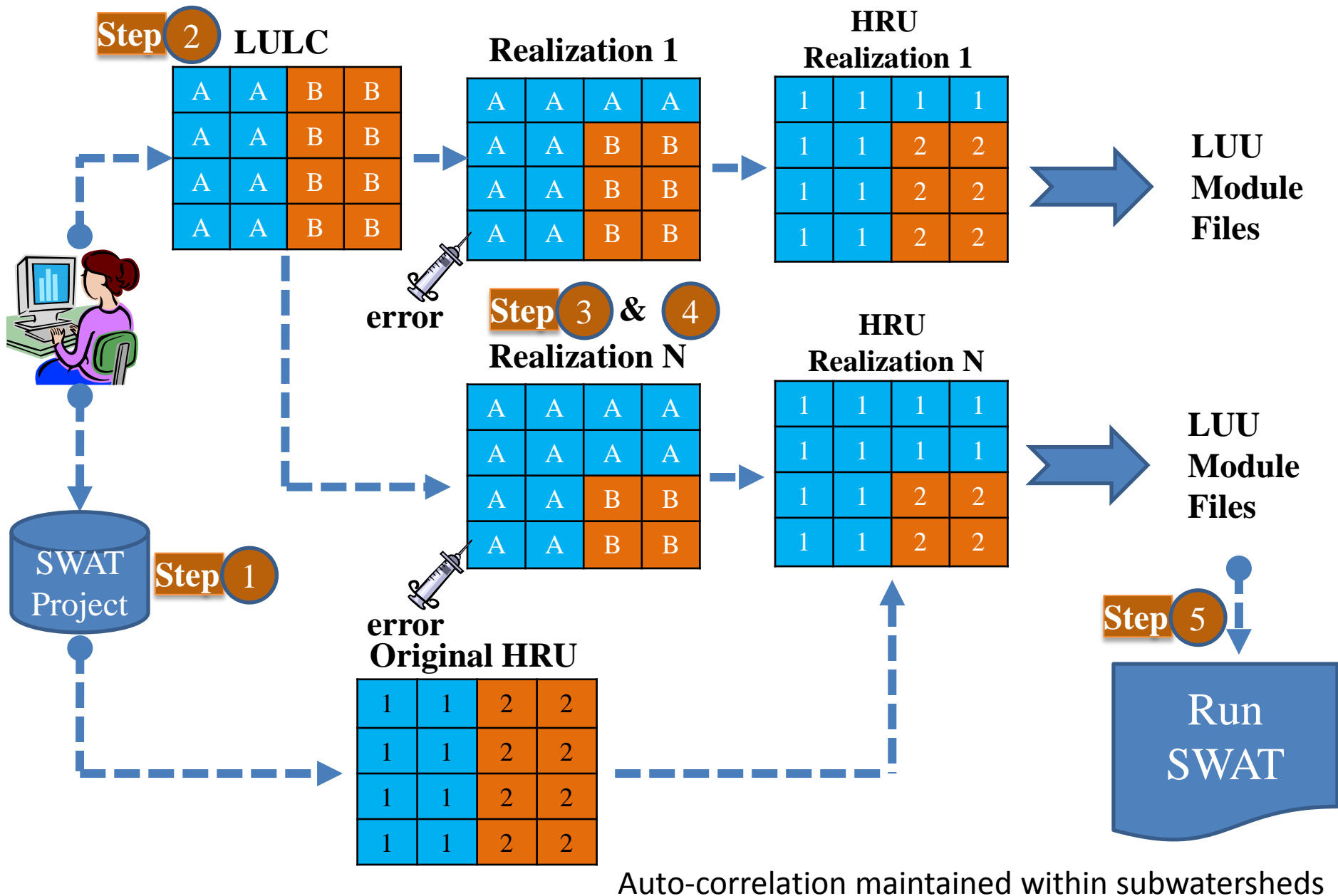
D:\Grad_Assst_Duties\SWAT_Modeling\Illinois\SWAT_Model\Scenarios\Default\TxtInOut
>swat2009.exe

      SWAT2009
      Rev. 414
      Soil & Water Assessment Tool
      PC Version
      Program reading from file.cio . . . executing

Executing year 1
Executing year 2
Executing year 3
Executing year 4
Executing year 5
Executing year 6
Executing year 7
Executing year 8
Executing year 9
Executing year 10
Executing year 11
```



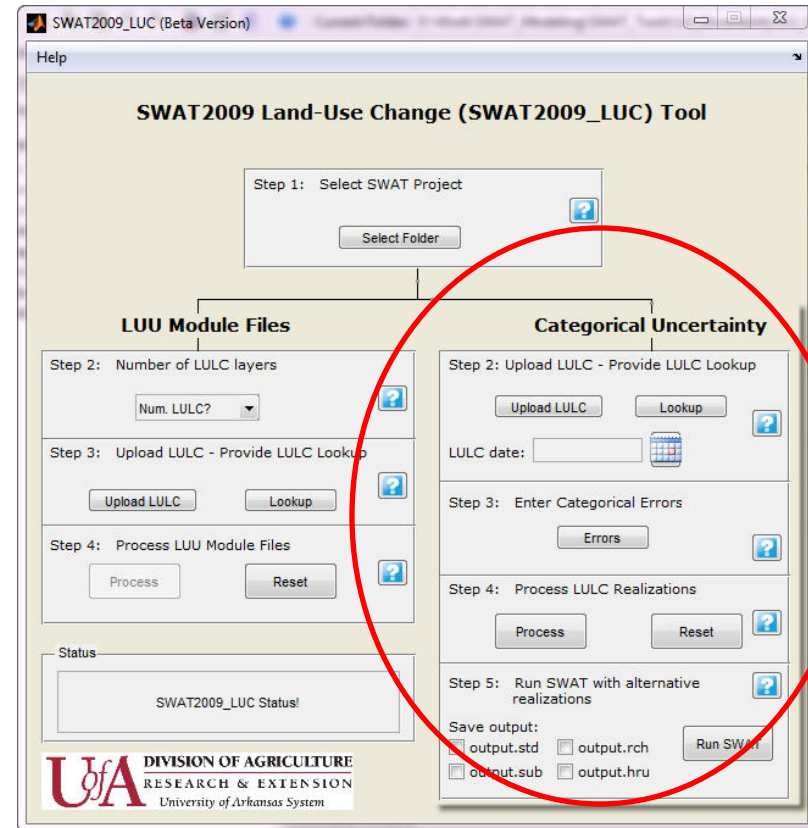
UNCERTAINTY ANALYSIS ALGORITHM



SWAT2009_LUC Tool

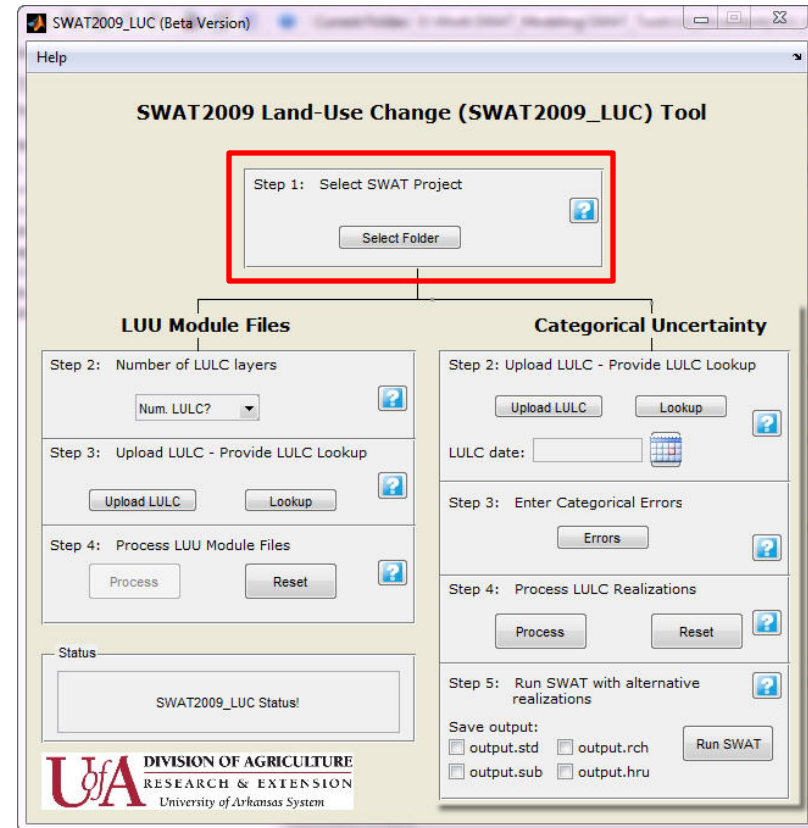
GUI developed to:

1. Interact with SWAT project
2. Ingest: LULC layer, categorical errors
3. Develops realization and LUU files
4. Runs SWAT with alternative LULC realizations



SWAT2009_LUC Tool

- **Step 1: Select SWAT Project**
- **Note:** buttons sequentially enabled
- Create sub-folders
 - SWAT2009_LUC
 - SWAT2009_LUC\Shape
 - SWAT2009_LUC\Raster
 - SWAT2009_LUC\Output
- Copy from SWAT project
 - hrus1 grid
 - hru1 shapefile



SWAT2009_LUC Tool

- **Step 2:** Upload LULC, lookup table, and starting date
- LULC map converted to Geotiff using GDAL
- Lookup table to establish LULC – HRU mapping
- Starting date used to create **lup.dat** and store in *Output* folder

SWAT2009_LUC (Beta Version)

SWAT2009 Land-Use Change (SWAT2009_LUC) Tool

Step 1: Select SWAT Project

Select Folder

LUU Module Files

Step 2: Number of LULC layers

Num. LULC?

Step 3: Upload LULC - Provide LULC Lookup

Upload LULC

Lookup

LULC date:

Step 4: Process LUU Module Files

Process

Reset

Status

SWAT2009_LUC Status!

Categorical Uncertainty

Step 2: Upload LULC - Provide LULC Lookup

Upload LULC

Lookup

LULC date:

Step 3: Enter Categorical Errors

Errors

Step 4: Process LULC Realizations

Process

Reset

Step 5: Run SWAT with alternative realizations

Save output:

☐ output.std ☐ output.rch

☐ output.sub ☐ output.hru

Run SWAT

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SWAT2009_LUC Tool

- Step 3: Enter categorical errors

Select percentage error and number of realizations for each LULC and press continue

Category	Error (%)	# Realizations
11	0	0
13	0	0
41	0	0
100	0	0
201	0	0
209	0	0
210	0	0

- Enter percentage error for each category and number of realizations that SWAT should simulate

- Error range divided uniformly by realizations

SWAT2009 Land-Use Change (SWAT2009_LUC) Tool

Step 1: Select SWAT Project

Select Folder

LUU Module Files

Step 2: Number of LULC layers

Num. LULC?

Step 3: Upload LULC - Provide LULC Lookup

Upload LULC

Lookup

LULC date:

Step 4: Process LUU Module Files

Process

Reset

Status

SWAT2009_LUC Status!

Categorical Uncertainty

Step 2: Upload LULC - Provide LULC Lookup

Upload LULC

Lookup

LULC date:

Step 3: Enter Categorical Errors

Errors

Step 4: Process LULC Realizations

Process

Reset

Step 5: Run SWAT with alternative realizations

Save output:

☐ output.std ☐ output.rch

☐ output.sub ☐ output.hru

Run SWAT

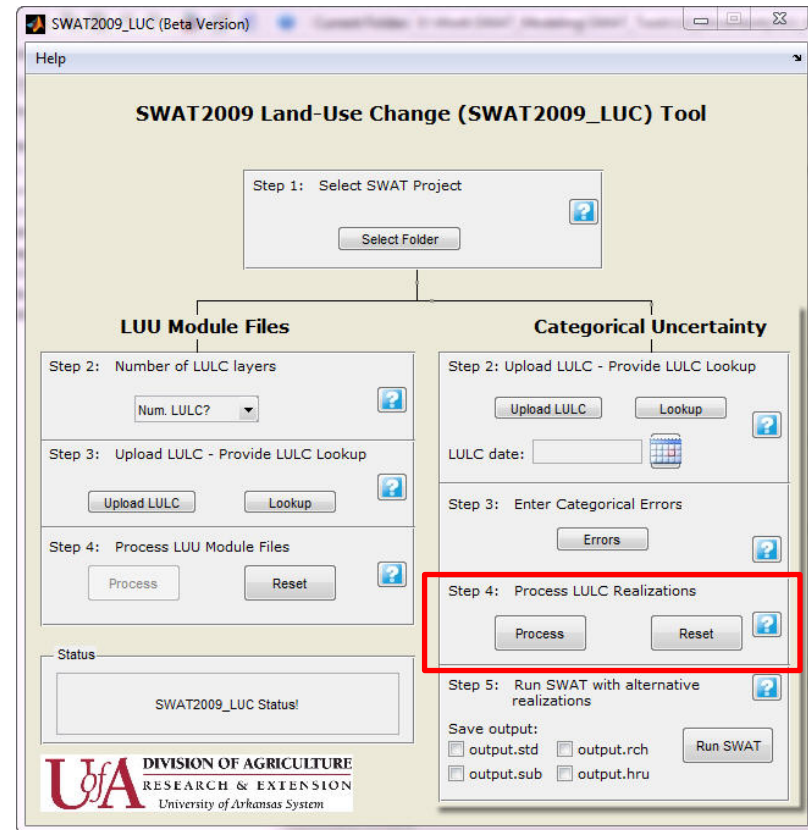
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For e.g. error $\pm 8\%$, realizations 2

-8%, and +8%

SWAT2009_LUC Tool

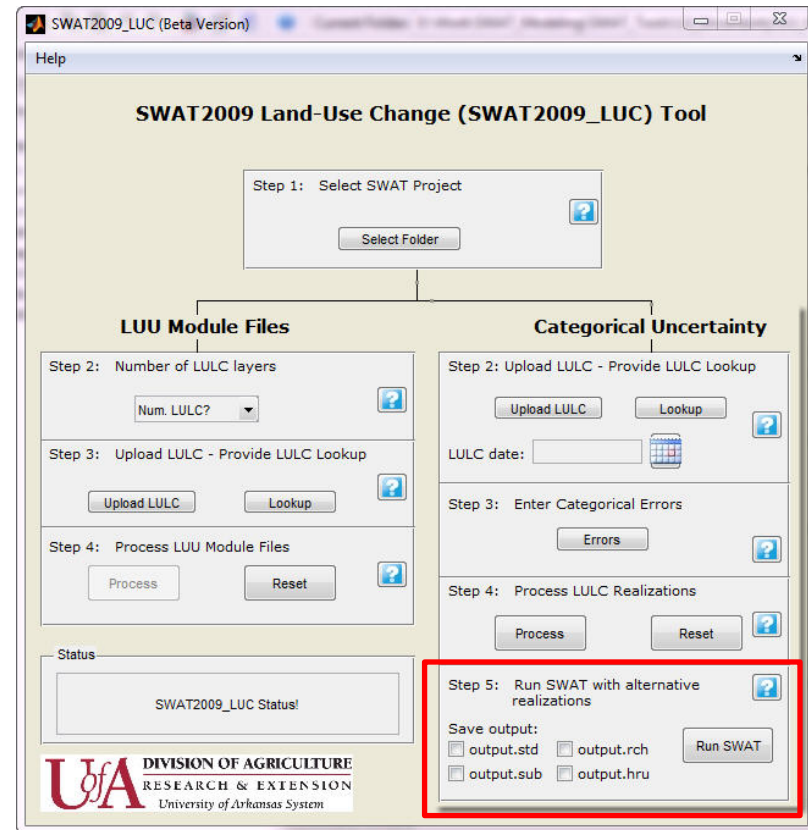
- **Step 4: Process LULC realizations**
- Tool reads HRU layer
- If HRU thresholds applied, creates a post-threshold HRU layer*
- Based on LULC realizations, creates HRU realizations
- Finally, creates LUU module files for each realization that can be consumed by SWAT



(*Pai and Saraswat, 2011)

SWAT2009_LUC Tool

- **Step 5: Run SWAT (LUU files-Output)**
- Runs SWAT model sequentially for each realization
- It is assumed that simulation period and output print settings are already setup in file.cio
- Users can choose which output files to save after simulating each realization
- Output files saved in *Output* folder



(*Pai and Saraswat, 2011)

SPECIFIC OBJECTIVES

1

Develop an automated tool to integrate LULC realization in the SWAT model

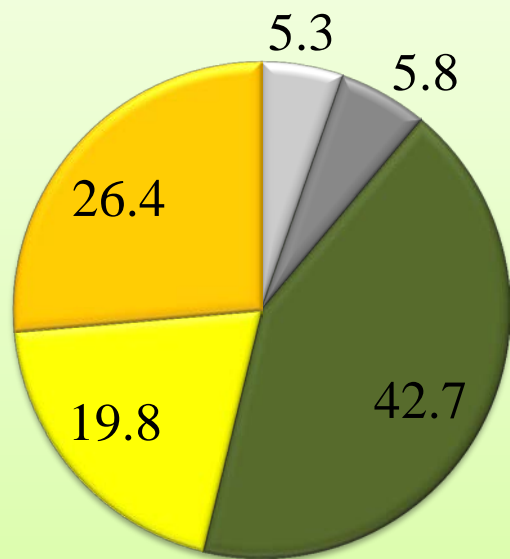


2

Evaluate sensitivity of SWAT output to LULC categorical errors

STUDY AREA

2006 LULC
Drainage: 1,963 km²



■ URLD (22%)

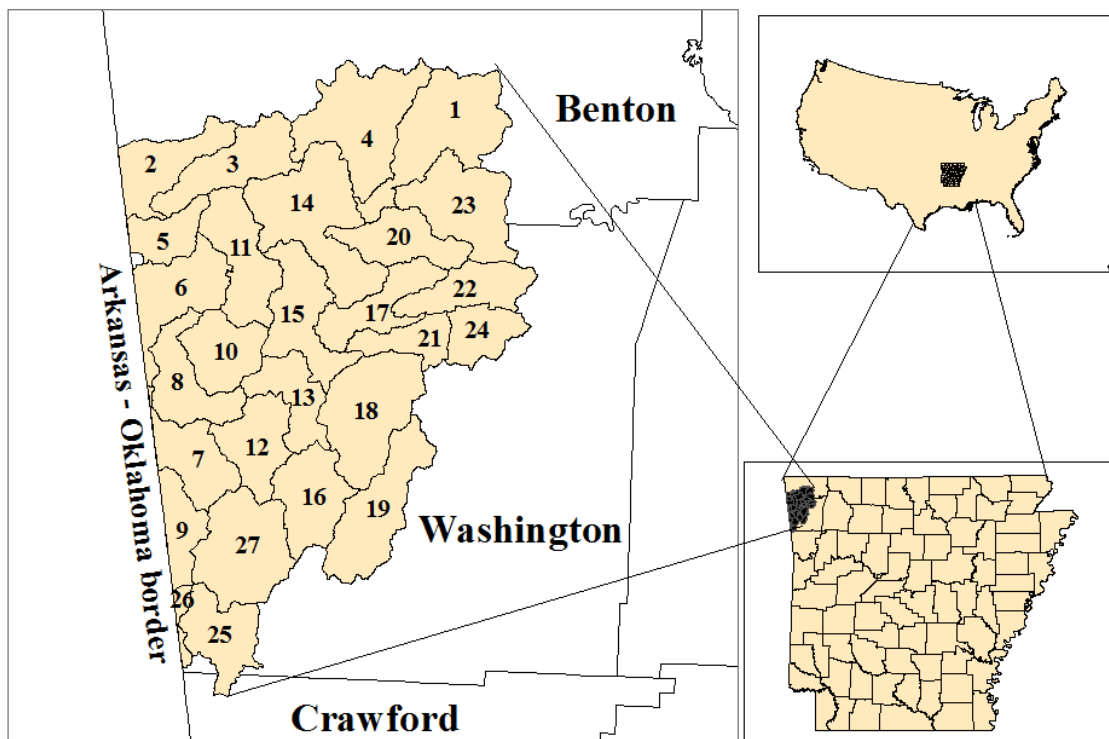
■ URHD (9%)

■ FRST (8%)

■ BERM (28%)

■ FESC (19%)

Categorical
Errors*



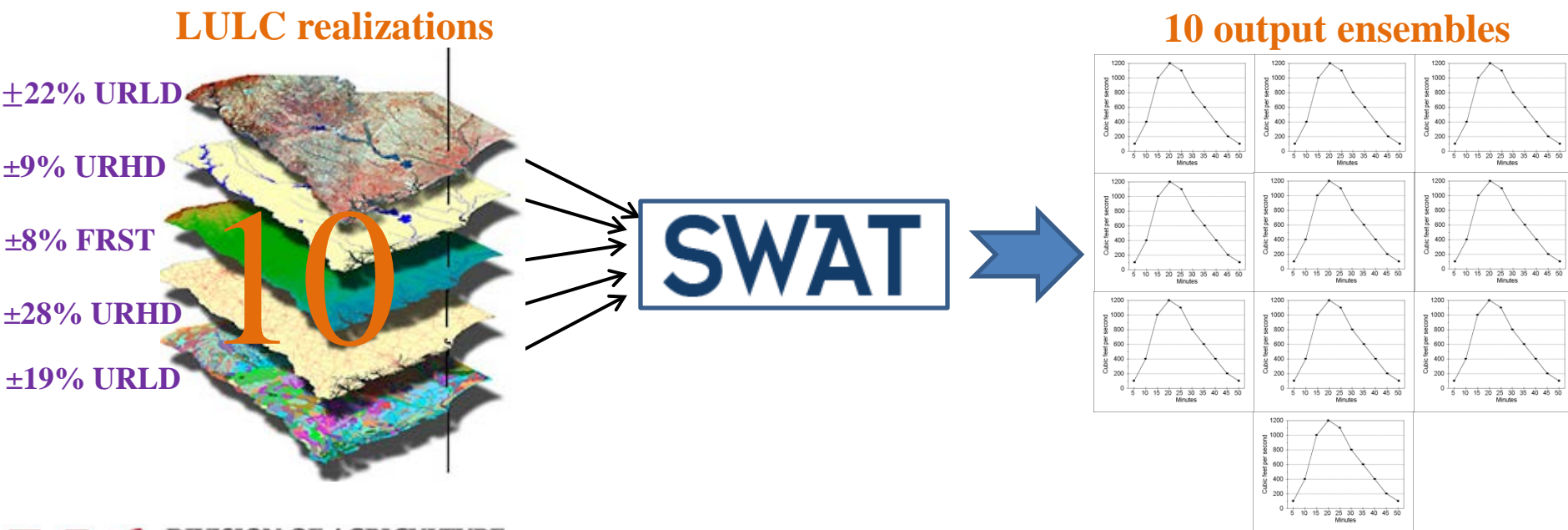
Illinois River Watershed
Arkansas, U.S.A

N
Data source: www.geostor.arkansas.gov
Map created: June, 2012

(*Gorham and Tullis, 2007)

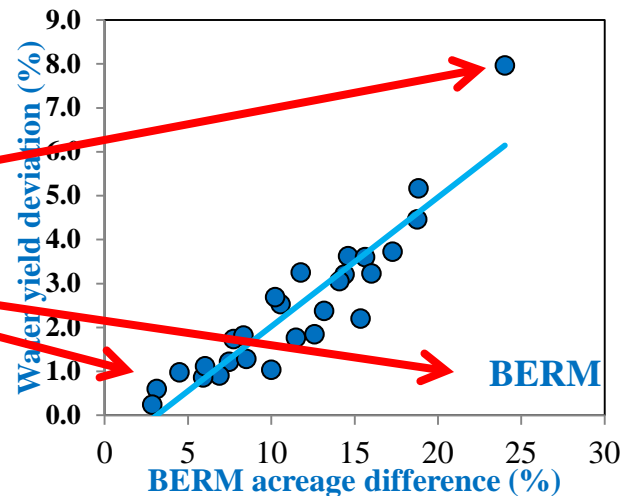
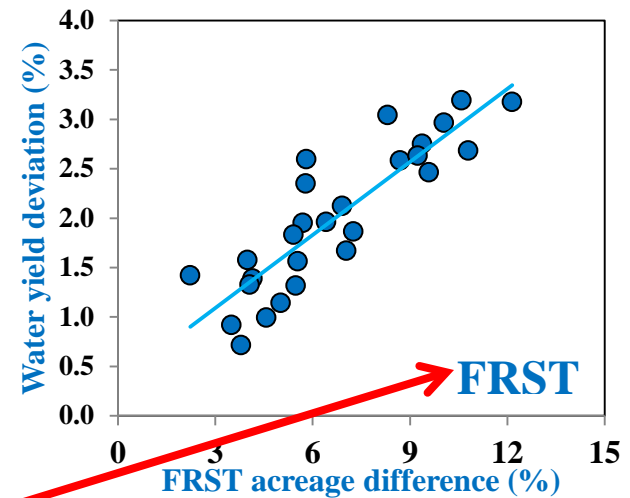
SCENARIO ANALYSIS

- Study period: 2000 – 2006
- Warm-up: 2000 – 2003
- **Temporal scale:** Annual and monthly (three seasonal)
- **Spatial scale:** subwatersheds
- **Output:** Water yield (mm)



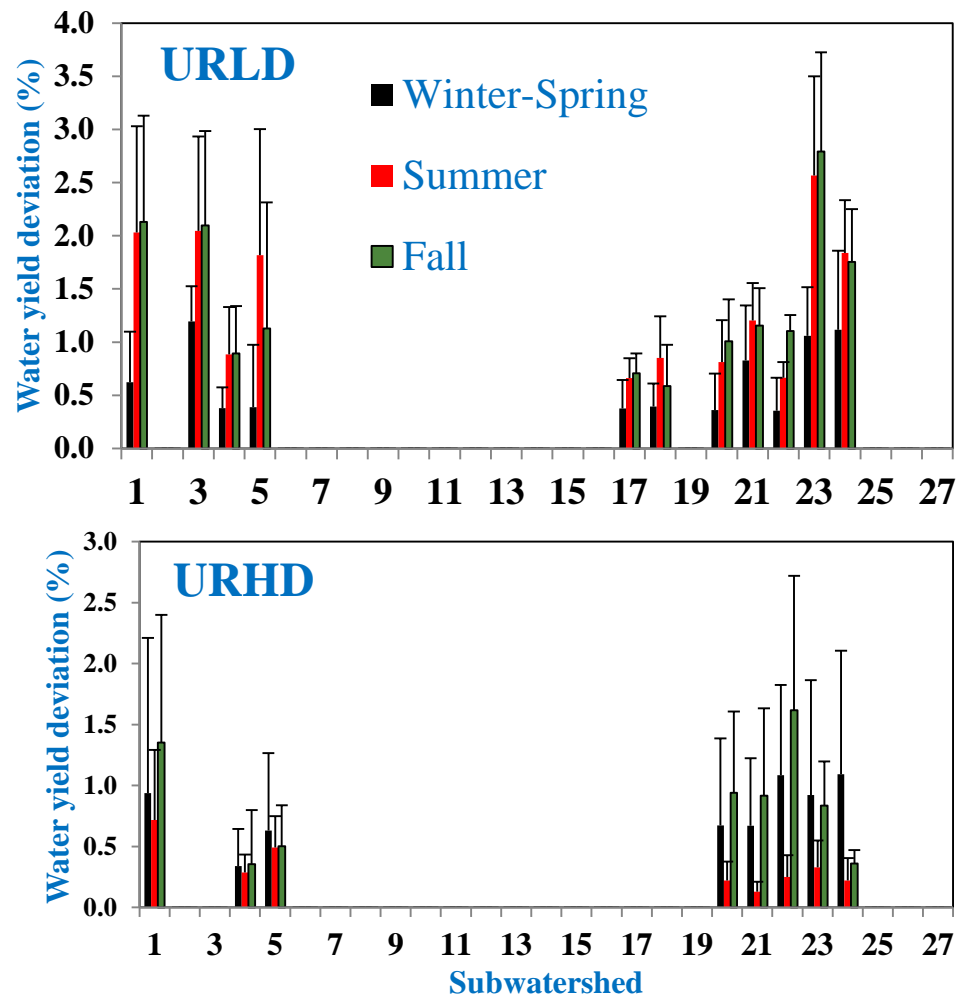
UNCERTAINTY EVALUATION- ANNUAL

- Annual percentage deviation in 10 ensemble outputs vary based on land-use
- URLD (0% - 1.6%), URHD (0.0 – 0.2%), FRST (0.7% - 3.2%), BERM (0.2% - 8.0%), FESC (0.3% - 2.8%)
- **What criteria impacts LULC categorical uncertainty in a subwatershed?**
- **Answer:**
 1. LULC type,
 2. percentage acreage of LULC in subwatershed,
 3. percentage misclassification error



UNCERTAINTY EVALUATION- MONTHLY

- Monthly output varies from 0% to 19.9%
- Demonstrates higher sensitivity at monthly scale
- Seasonal differences in sensitivity to LULC errors
- E.g. summer and fall seasons show greater variation for URLD while winter-spring and fall show greater variation for URHD



(Winter-spring: January – June, Summer: July – September, Fall: October - December)

CONCLUSIONS

- ✓ **Objective 1:** A desktop-based tool was developed to conduct LULC categorical uncertainty in SWAT
- ✓ **Objective 2:** SWAT sensitive to LULC errors but sensitivity varies based on (a) land-use, (b) LULC acreage in subwatershed, and (c) LULC misclassification error
- ✓ Tool useful for modelers wanting to evaluate impact of LULC categorical error uncertainty in ANY watershed

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QUESTIONS

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