Quantification of Urbanization Effect on Water Quality Using SWAT Model in Midwest US

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•OUTLINE

- Background
- Problems and Opportunities
- Research Goal
- Watershed details
- SWAT Model Set up
- Project Results
- Key Personnel

- **Background**


MID-WEST
NORTH EAST
WEST
MID-ATLANTIC
SOUTH WEST
SOUTH
HAWAII

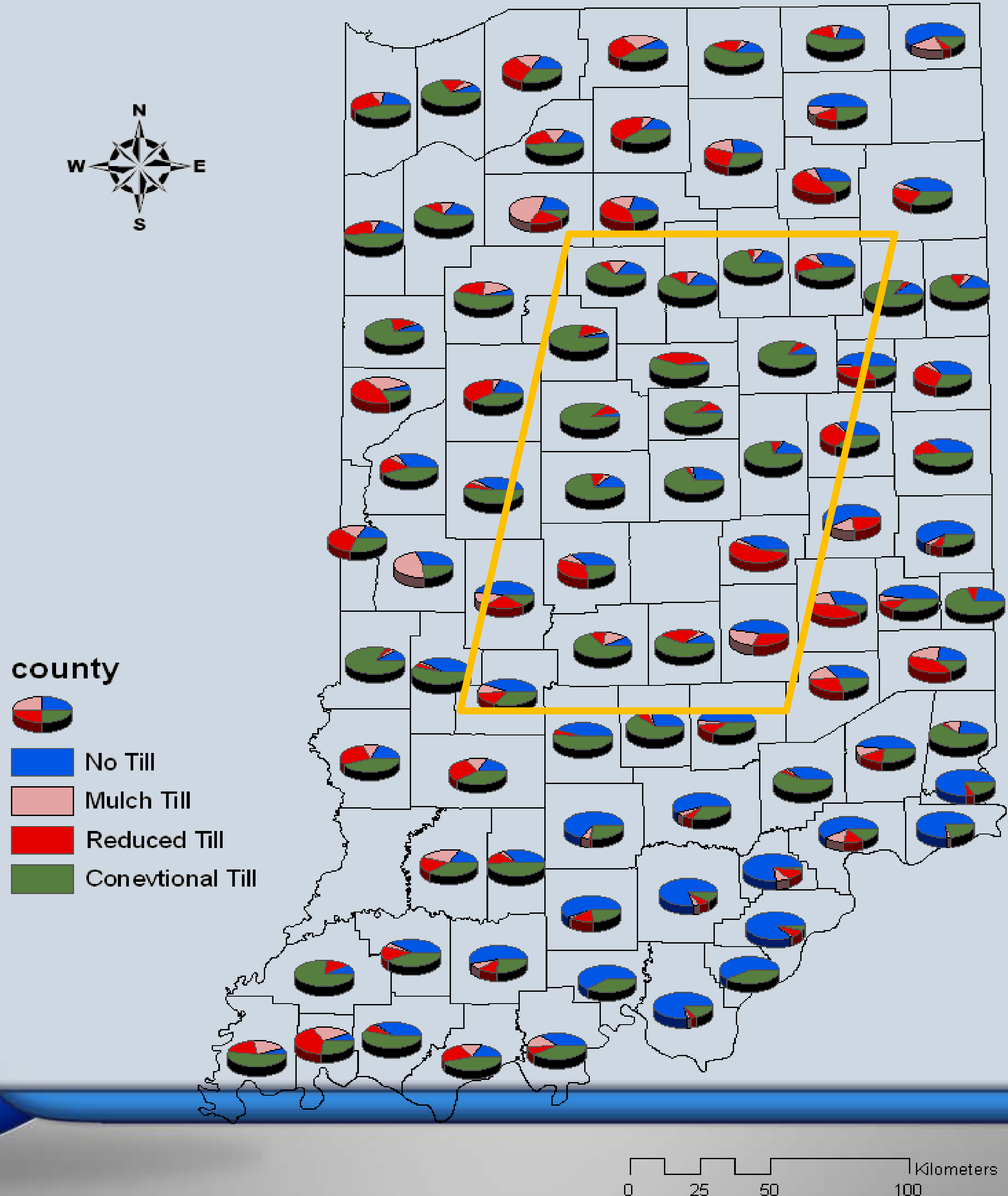
- **Background**

Over the past 25 years, the population of the United States has grown over 30% which has lead to substantial increase in urbanized areas and results in a degradation and loss of forested and agricultural lands (USDC Census Bureau, 2005).

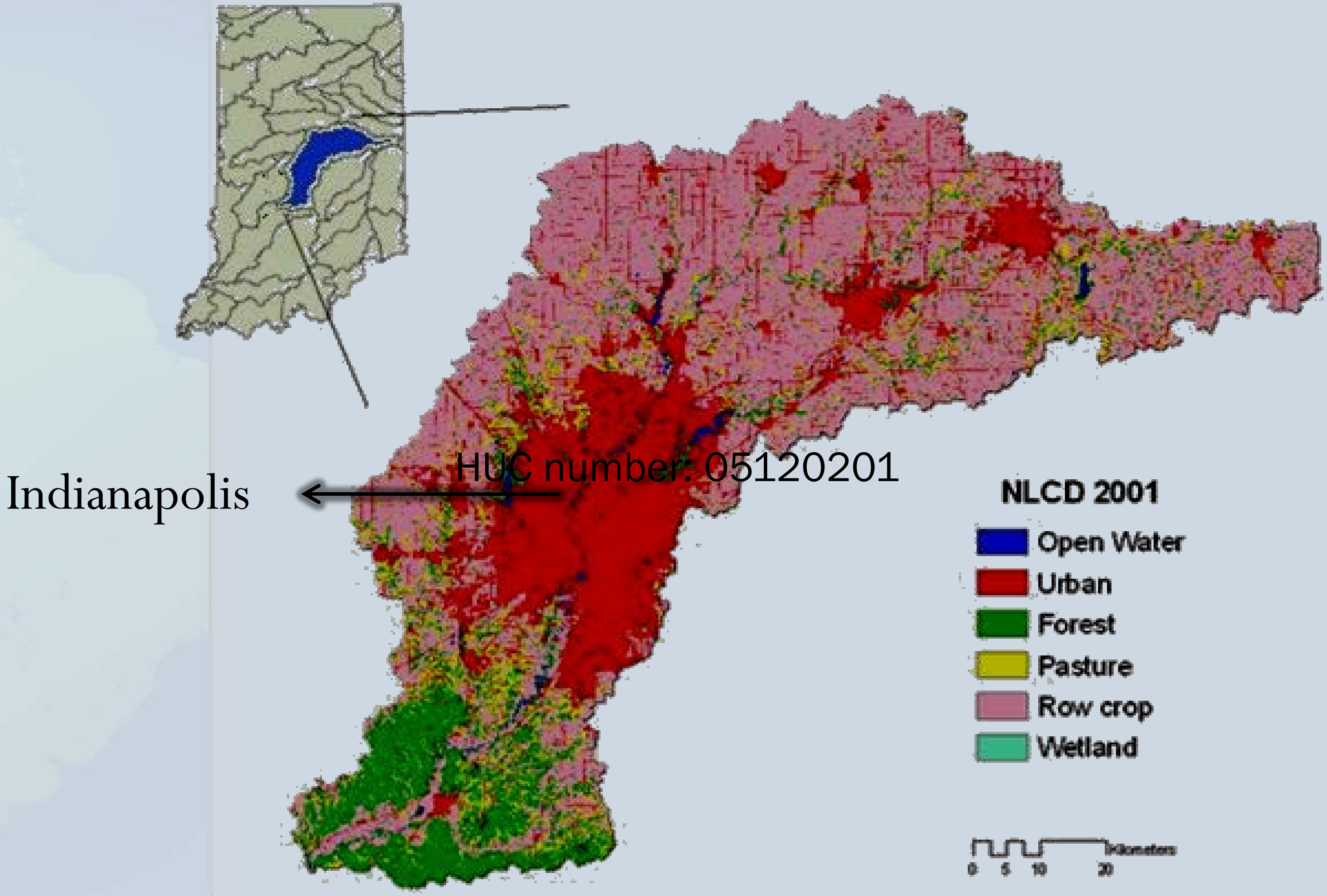
PROBLEMS AND OPPORTUNITIES

- One major concern:
  - Food vs. fuel
- Increased biofuel demand presents unprecedented economic opportunities to farmers
- There is a need to evaluate and develop land management practices that will sustain both increased corn production and environmental benefits.

Should we be concerned about growing fuel?


N
W
E
S
county
No Till
Mulch Till
Reduced Till
Conevtional Till
0
25
50
100
Kilometers

Upper White River Basin



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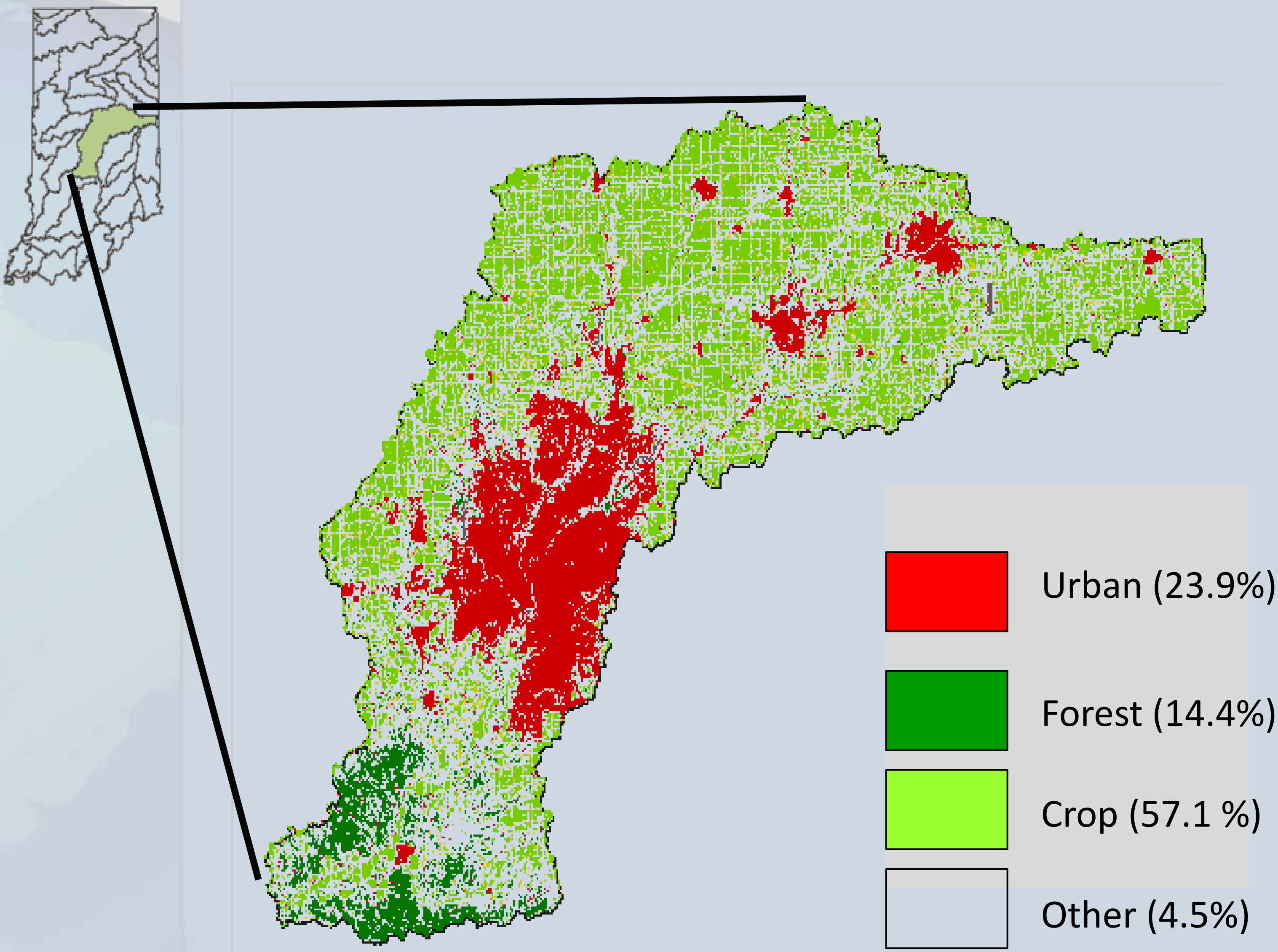
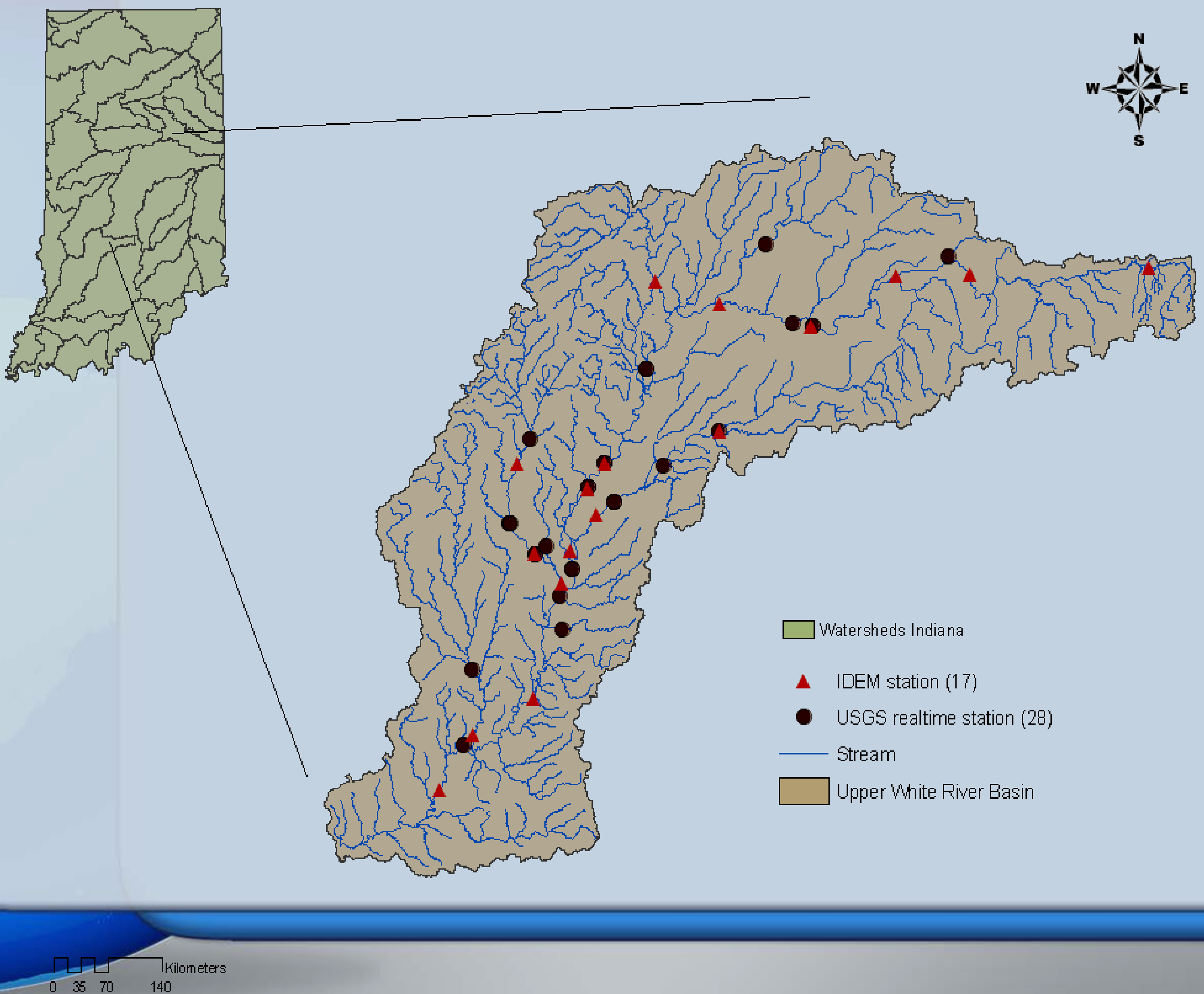
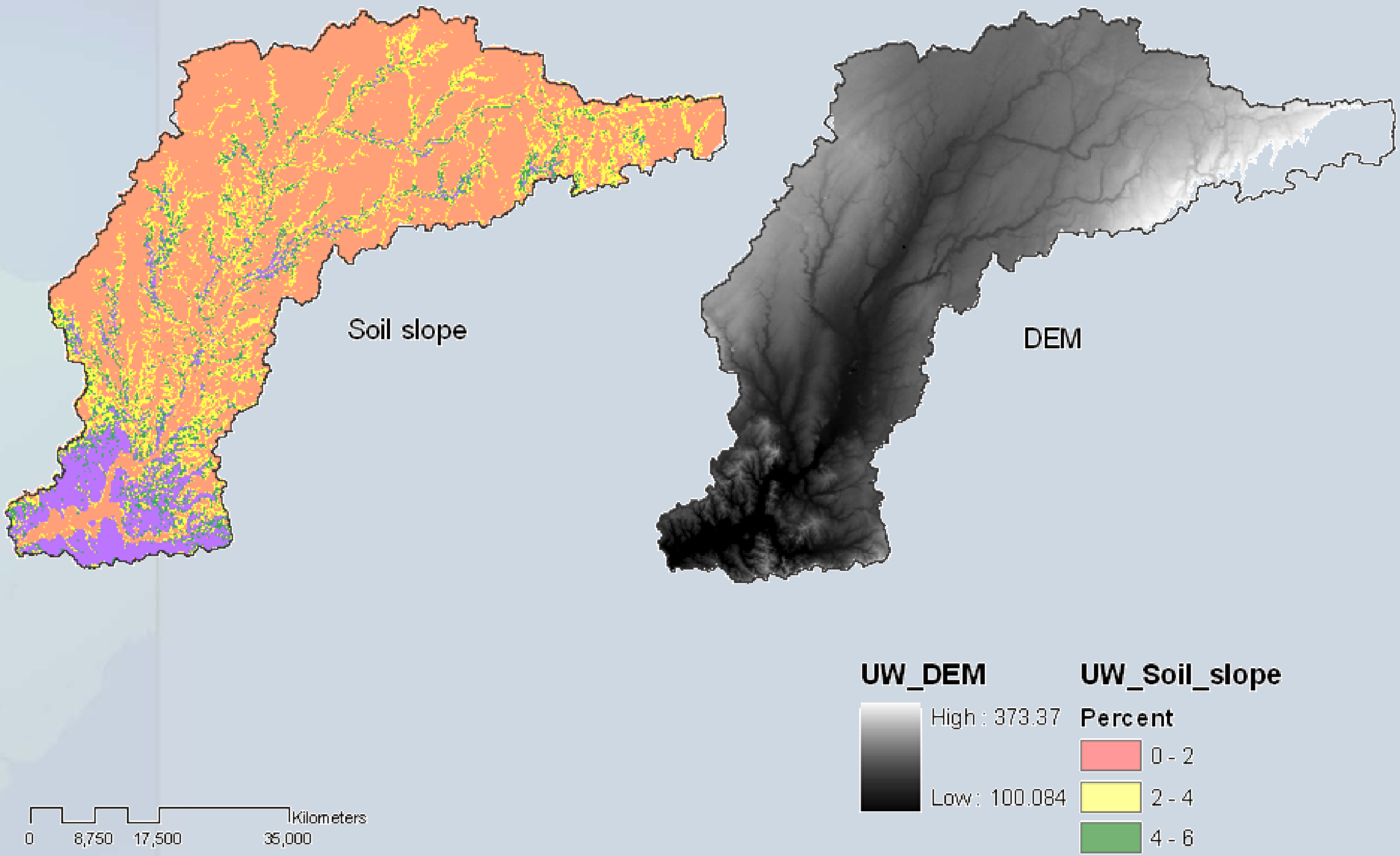


Urban (23.9%)
Forest (14.4%)
Crop (57.1 %)
Other (4.5%)


N
W
E
S
Watersheds Indiana
IDEM station (17)
USGS realtime station (28)
Stream
Upper White River Basin
Kilometers
0 35 70 140



Soil slope
DEM
UW_DEM
High : 373.37
Low : 100.084
UW_Soil_slope
Percent
0 - 2
2 - 4
4 - 6
> 6
0
8,750
17,500
35,000
Kilometers

- **PROJECT GOAL**

The overall goal of the study :

- To develop a model to study land use and land cover change due to anthropogenic activities in Mid-West US

• Research Tasks

- Quantify runoff, sediment, nutrient, losses from agricultural watersheds in Indiana.

- Use computer-based hydrologic/water quality models.

- Examples of computer-based models developed for agricultural systems:

  (1) Groundwater Loading Effects of Agricultural Management Systems (GLEAMS),
  - a field-scale, edge-of-field and bottom-of-root-zone model.

  (2) National Agricultural Pesticide Risk Analysis (NAPRA)
  -uses GLEAMS as a core engine

  (3) Long-Term Hydrologic Impact Assessment (L-THIA)
  - land use change impacts

  (4) Soil and Water Assessment Tool (SWAT),
  a river basin-scale model.

•SWAT model setup

- Digital elevation map (DEM)

(30 m grid size) was obtained from USGS

- Land use land cover

was (30 m grid) was obtained from the National Land Cover Data – (NLCD 2001).

- Soil data

The soil information was obtained in a feature format from the STATSGO

•SWAT model setup

- Climate data

The climate data was available from 1915-2006 at Agricultural and Biological Engineering department (ABE), Purdue University (Sinha et al., 2008).

12 km grid format developed for the Variable Infiltration Capacity (VIC) model

- Water quality data

Water quality data for the study was obtained from Indiana department of Environment and Management (IDEM) for all fixed and temporary stations monitoring water quality

Management information used to setup SWAT model

Corn-Soybean rotation			Continuous Corn		
Management type	Date	Rate of application	Management type	Date	Rate of application
Tillage	April 1	-	Tillage	April 1	-
Tillage	April 6	-	Tillage	April 6	-
Planting (Corn)	April 13	-	Planting (Corn)	April 13	-
Fertilizer (An. NH_3)	May 25	145 kg/ha	Fertilizer (An. NH_3)	May 25	145 kg/ha
Harvest and Kill	Oct. 30	-	Harvest and Kill	Oct. 30	-
Tillage*	Apr. 28	-	Tillage*	April 1	-
Fertilizer (P) *	May 2	32 kg/ha	Tillage*	April 6	-
Planting (Soybean) *	May 20	-	Planting (Corn) *	April 13	-
Harvest and Kill*	Oct. 1	-	Pesticide (Atrazine) *	April 16	1.5 kg/ha
Tillage*	Oct. 20	-	Fertilizer (An. NH_3) *	May 25	145 kg/ha
			Harvest and Kill*	Oct. 30	-

CALCULATION OF FERTILIZER APPLICATION RATE

Tri-state N recommendation (lb/ac) = -27 + [1.36 x yield potential (bushels per acre)] – N credit

Nitrogen credits of 30 pounds of N per acre for corn following soybeans and 0 pounds of N per acre for corn after corn are the most recognized and utilized credits.

Average corn yield for UWRB was calculated as 154.1 bushels/acre, therefore, nitrogen requirement from the equation is 153 (lb/acre) or (171 kg/ha).

CALCULATION OF FERTILIZER APPLICATION RATE

Nitrogen application (kg/ha)	Neilson (NEPAC-site)	Neilson (AONR)	Ale (CC)	Ale (CS)	Present study (CS)	Present study (CC)
low	78	> 135	157	179	90	120
medium			179	201	157	187
High	248	< 247	202	224	197	227

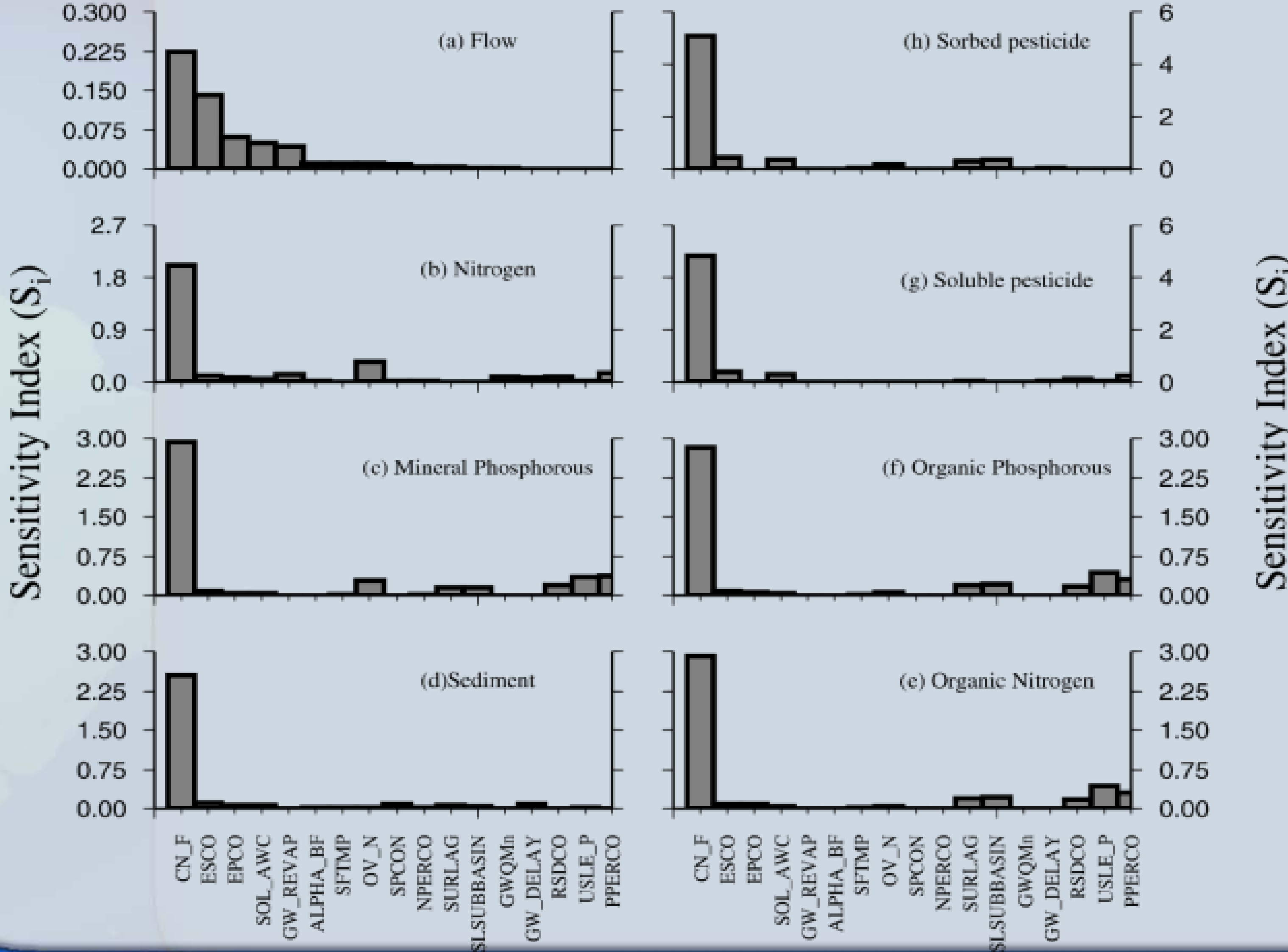
•Sensitivity Analysis

$$Sr = \frac{\overline{P}}{\overline{O}}\left(\frac{O_2 - O_1}{P_2 - P_1}\right)$$

Parameter	Sr	Ranking
Curve Number (CN-II)	1.6	1
Soil evaporation compensation factor (ESCO)	0.4	2
Soil available water content (SOL-AWC)	0.04	3
Groundwater “revap” coefficient (GW_REVAP)	0.03	4
Groundwater delay (GWDELAY)	0.01	5
Ground water threshold depth required in shallow aquifer for return flow (GWQMN)	0.007	6
Base flow factor (Alpha_bf)	0.0003	7

Result

Sensitivity Analysis



Result

The calibration period for the SWAT model was taken 1988-2000 with initial three years 1988-1990 as warm up years for monthly stream flow calibration.

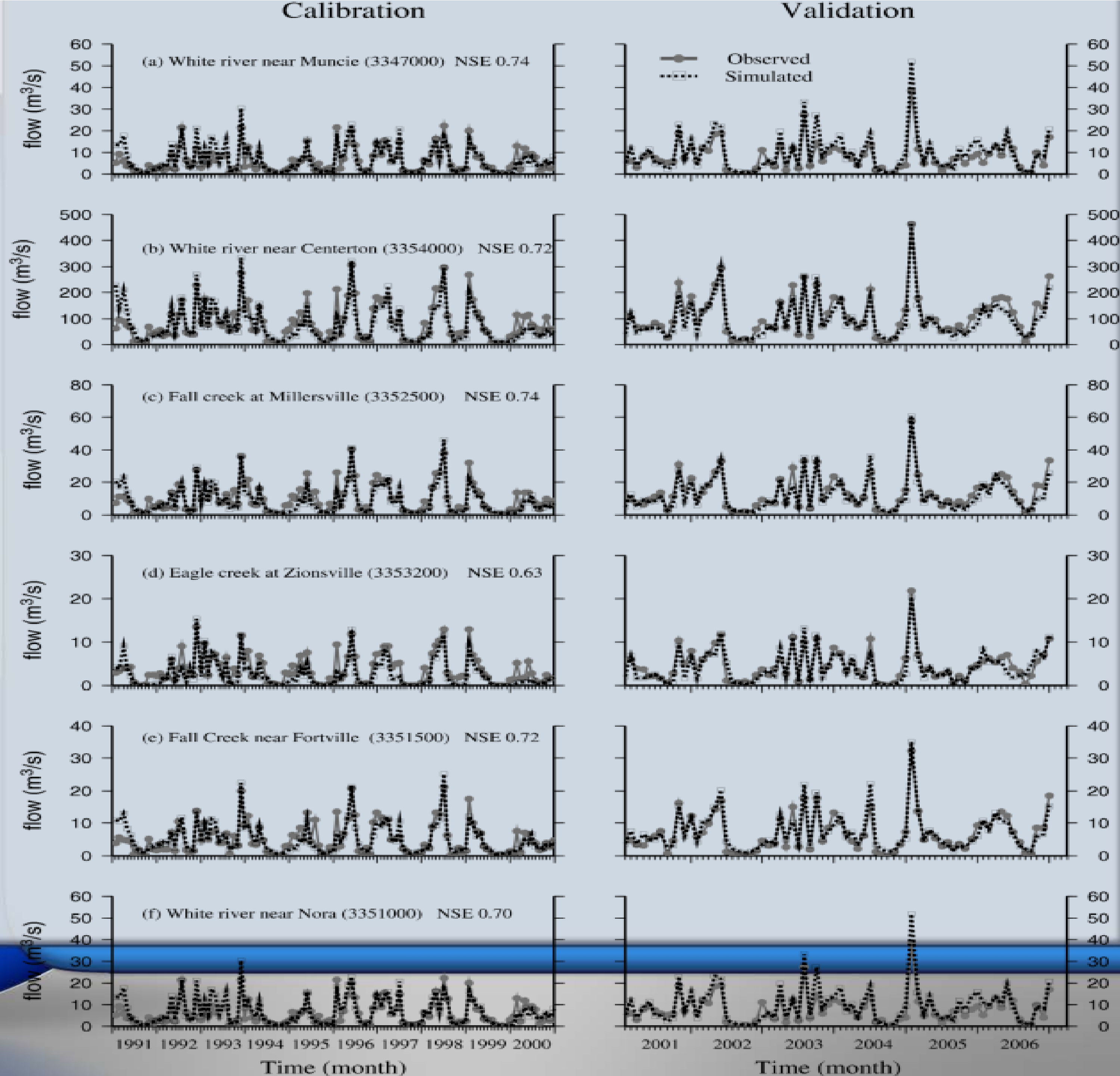
The SWAT model was validated for the 2001-2006 for monthly stream flow.

Result

Calibrated model parameters for SWAT

Symbol	Input file	Calibrated value	Default value
SURLAG	.bsn	2	4
ALPHA_BF	.gw	0.05	0.048
GW_DELAY	.gw	3	-
GW_REVAP	.gw	0.13	0.02
GWQMN	.gw	830	-
USLE_P	.mgt	0.55	-
P_UPDIS	.bsn	70	20
PPERCO	.bsn	16	10
PSP	.bsn	0.6	0.4

Result



Calibration
Validation
(a) White river near Muncie (3347000) NSE 0.74
Observed
Simulated
(b) White river near Centerton (3354000) NSE 0.72
(c) Fall creek at Millersville (3352500) NSE 0.74
(d) Eagle creek at Zionsville (3353200) NSE 0.63
(e) Fall Creek near Fortville (3351500) NSE 0.72
(f) White river near Nora (3351000) NSE 0.70
flow (m3/s)
1991 1992 1993 1994 1995 1996 1997 1998 1999 2000
2001 2002 2003 2004 2005 2006
Time (month)

Result

	Calibration		Validation	
	NSE	R	NSE	R
3354000	0.72	0.86	0.86	0.95
3353200	0.63	0.88	0.82	0.91
3352500	0.74	0.88	0.86	0.94
3351500	0.72	0.87	0.88	0.94
3351000	0.70	0.89	0.72	0.93
3347000	0.74	0.87	0.80	0.94

Result

Crop rotation	Total nitrogen (kg/ha)	Baseline (kg/ha)	P-Value	Criteria
CSlow	8.71	10.99	0.05	Do not reject
CSmed	10.54	10.99	0.33	Do not reject
CShigh	11.83	10.99	0.05	Do not reject
CClow	6.58	10.99	0.00	Reject
CCmed	10.01	10.99	0.58	Do not reject
CChigh	13.40	10.99	0.09	Do not reject
CCSlow	7.69	10.99	0.05	Reject
CCSmed	10.35	10.99	0.48	Do not reject
CCShigh	12.30	10.99	0.03	Reject

Result

IDEM station ID	USGS station	Location description IDEM station	Nitrate
2434	03351000	86th St, Nora. Aka	1991-2006
2410	03351500	SR 238 near Fortville	1991-2006

Result

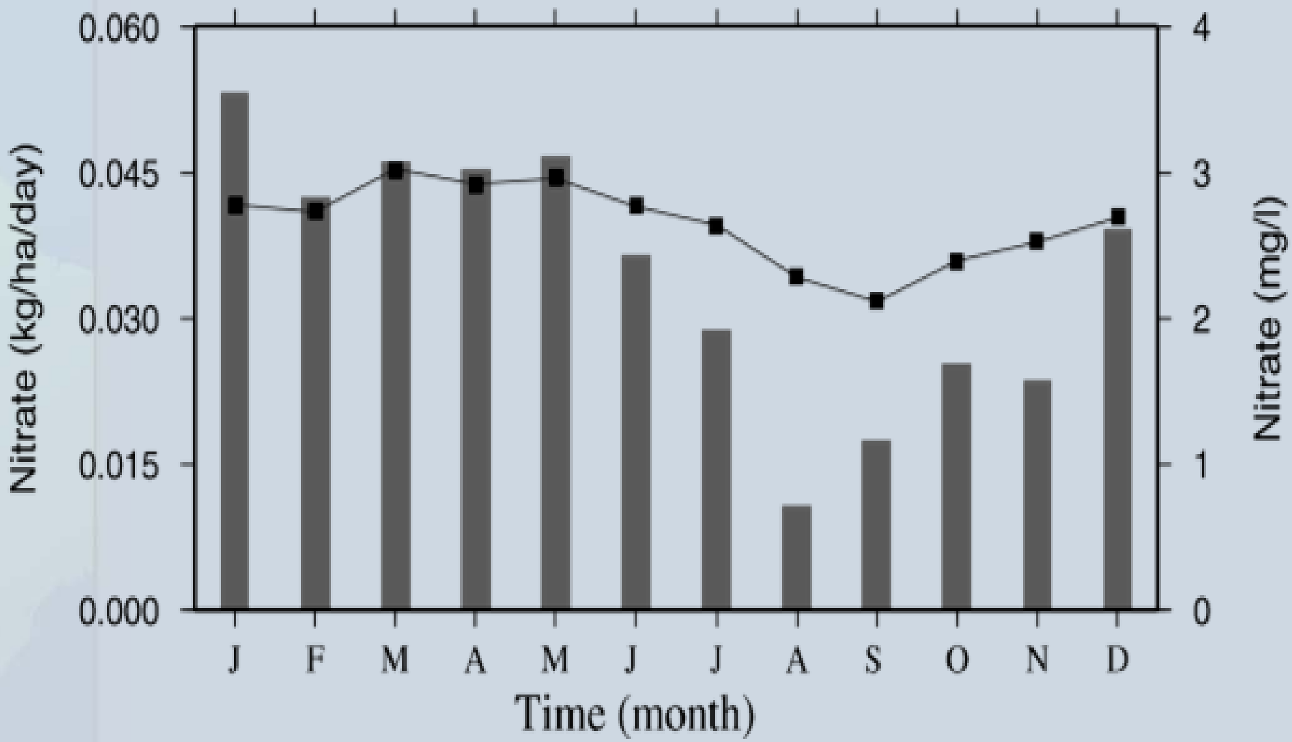


Figure : Average mean monthly nitrate (kg/ha/day) at IDEM station# 2410

Result

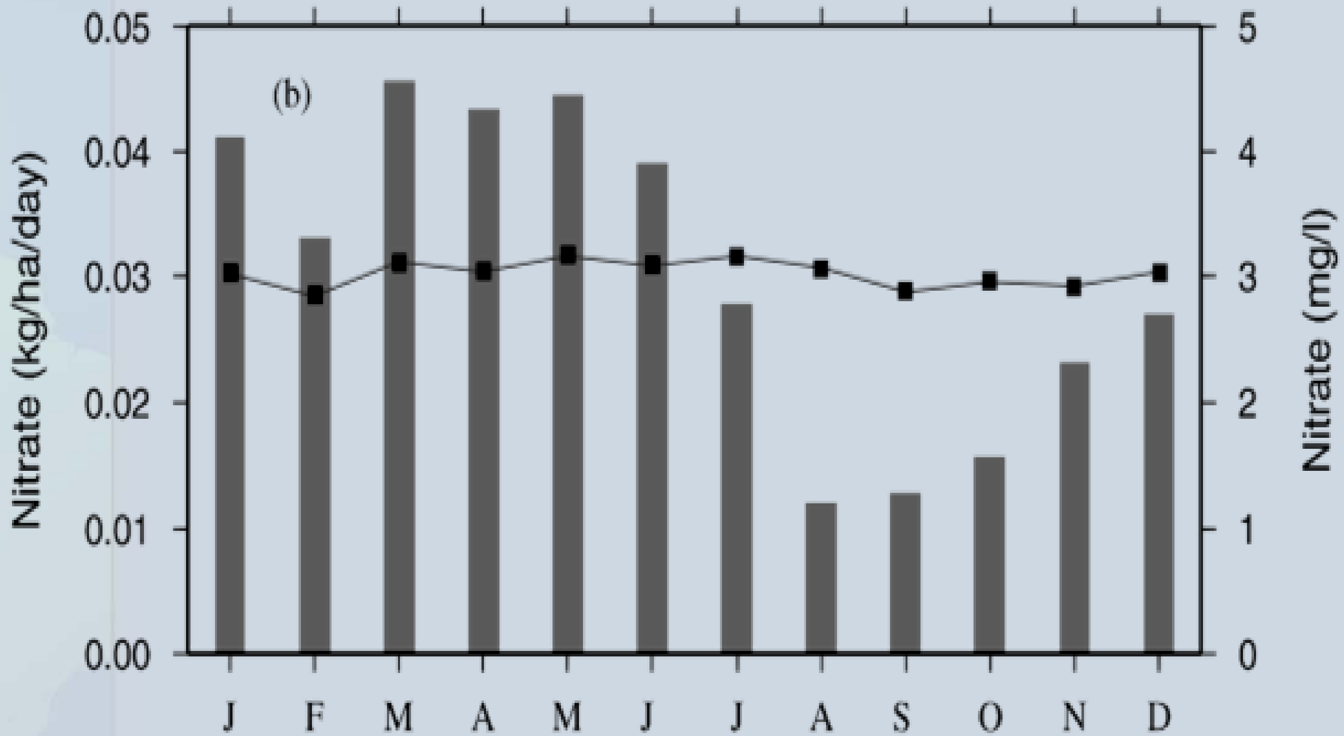


Figure : Average mean monthly nitrate (kg/ha/day) at IDEM station# 2434

Result

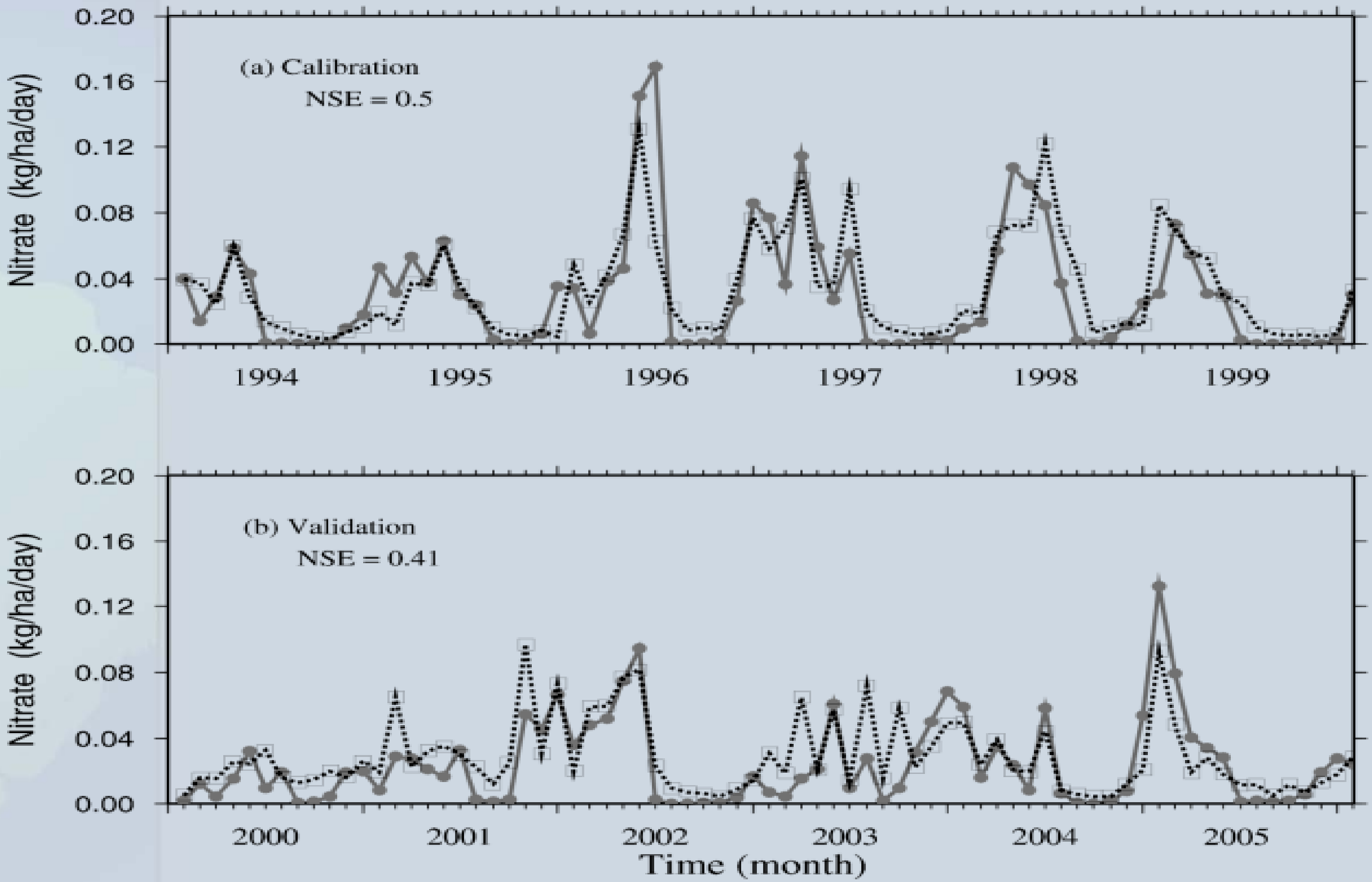
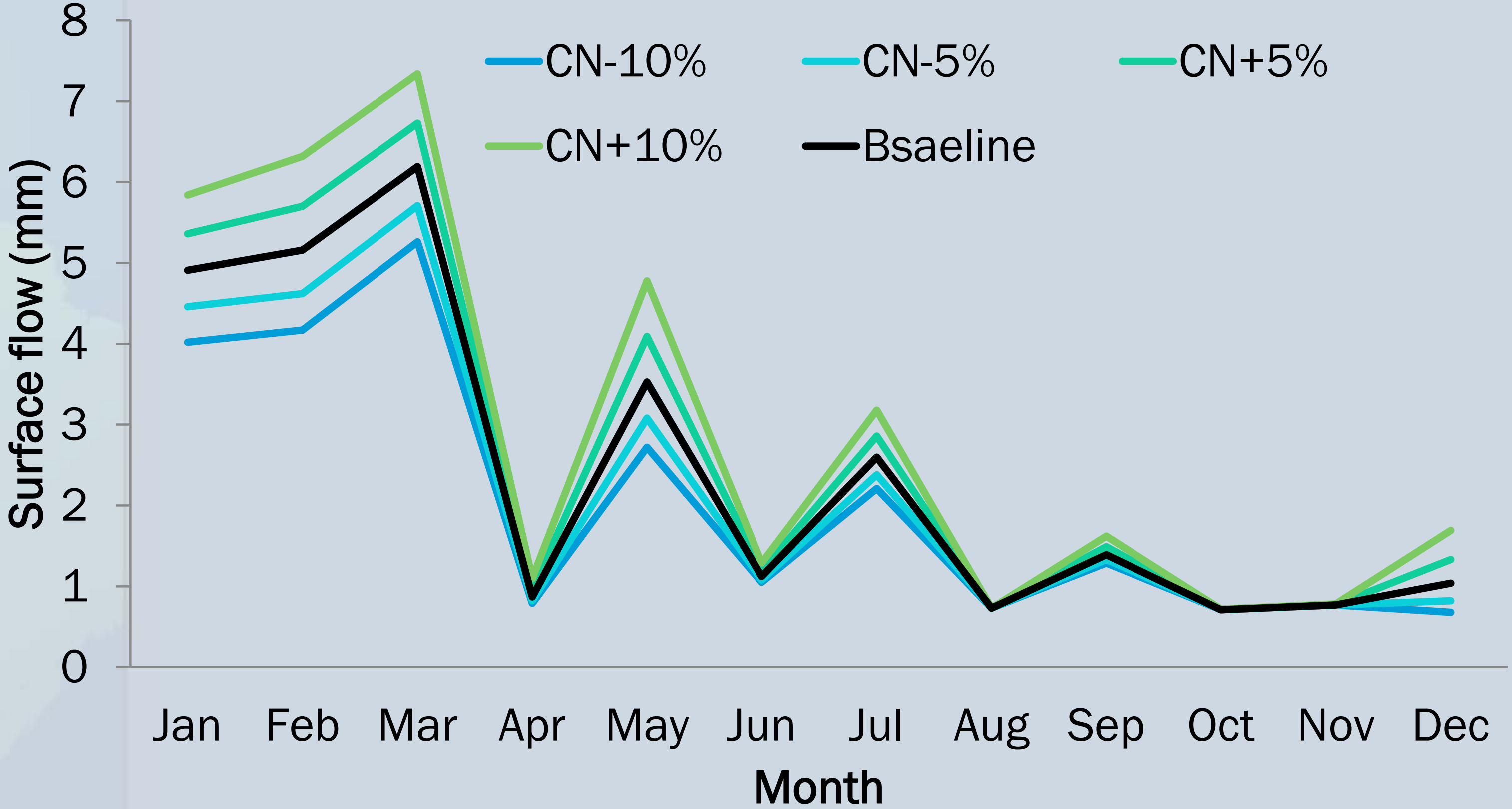


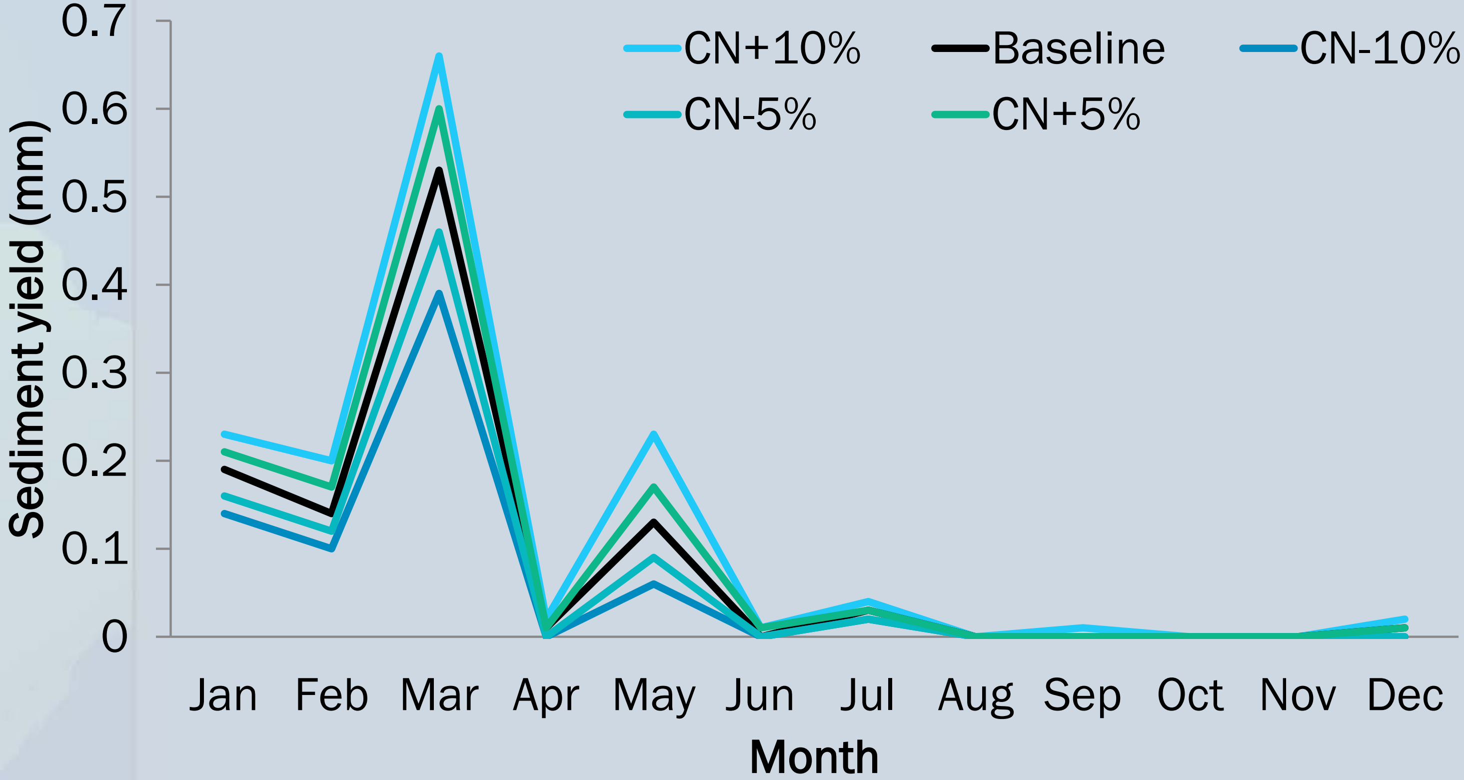
Figure : Hydrograph for calibrated and validated nitrate at IDEM station# 2434

Result



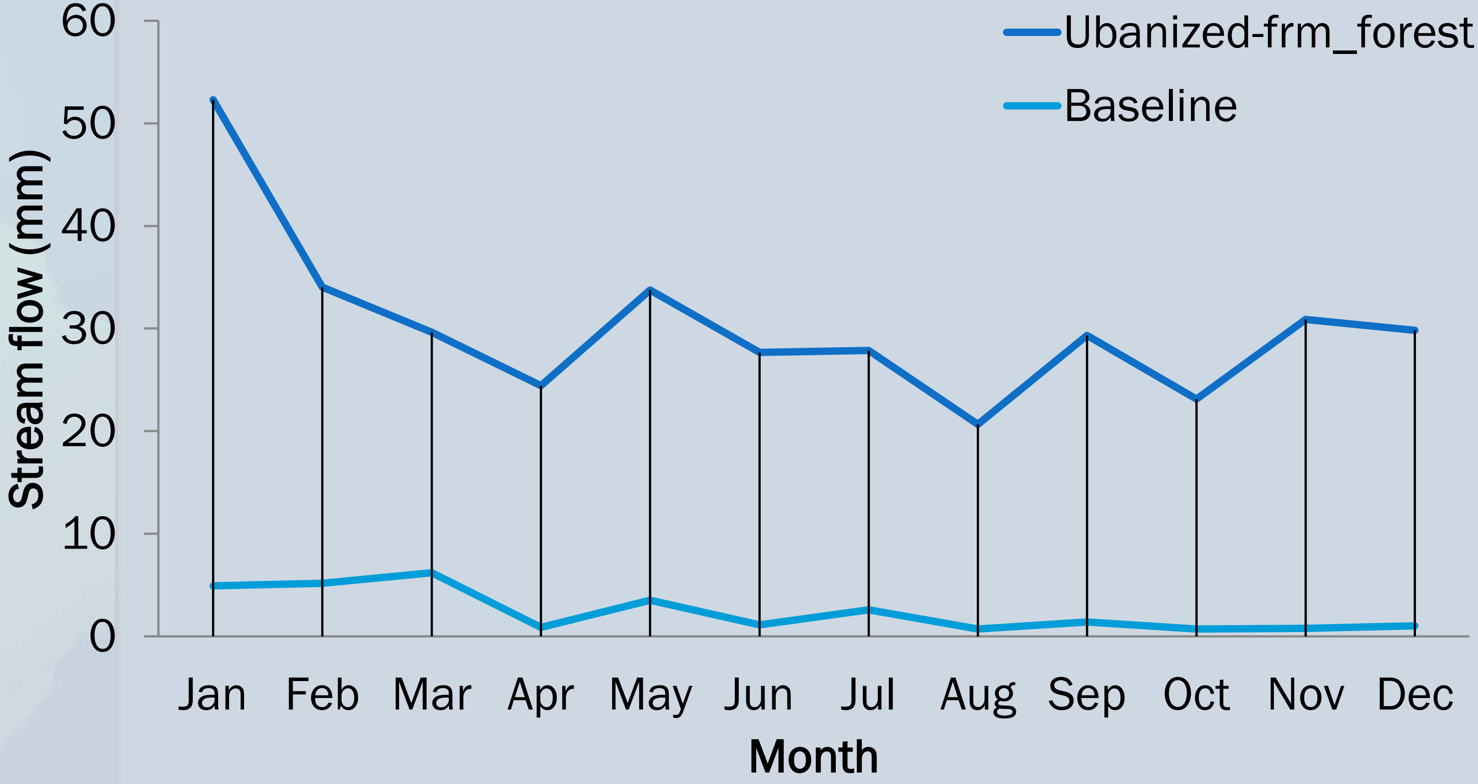
Monthly stream flow (mm) from watershed with changing curve number (CN)

Result



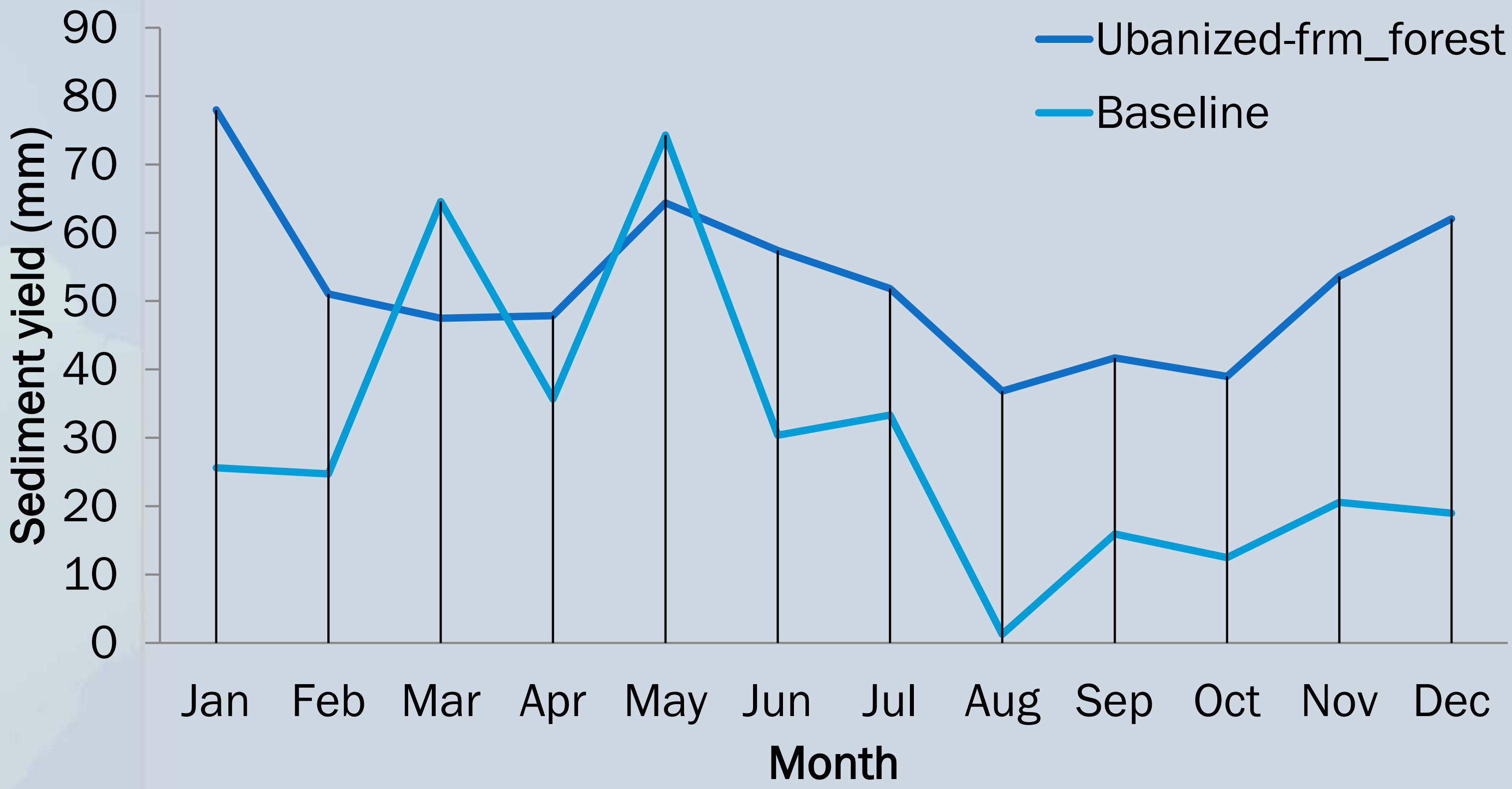
Monthly sediment yield (mm) from watershed with changing curve number (CN))

Result



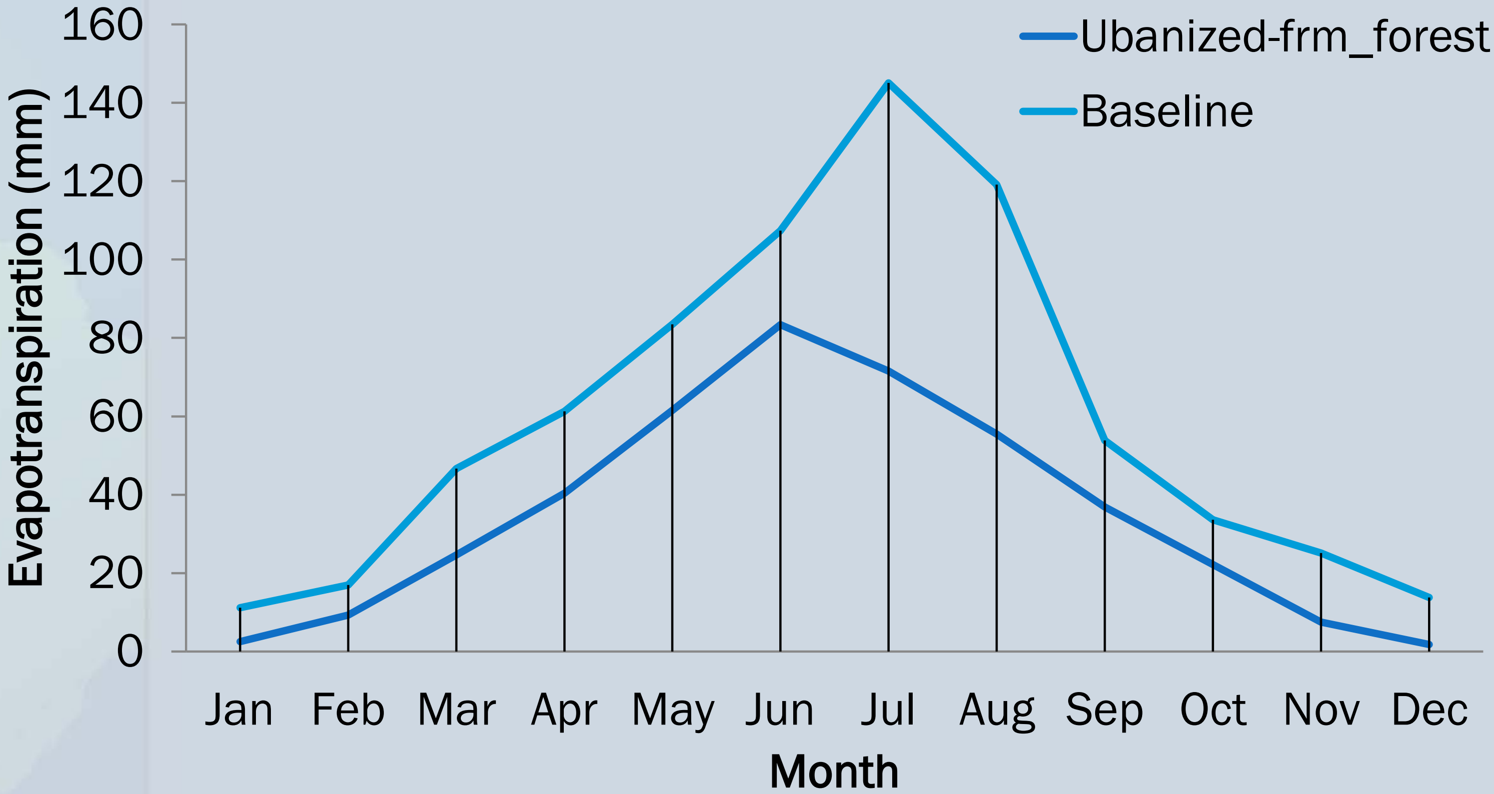
Monthly stream flow (mm) from watershed with forest land classified as low density urban area

Result



Monthly sediment yield (mm) from watershed with forest land classified as low density urban area

Result



Monthly evapotranspiration (mm) from watershed with forest land classified as low density urban area

- **Key Personnel**
  - Indrajeet Chaubey, Ph.D., Associate Professor
  - Bernie Engel, Ph.D., P.E., Professor
  - Chetan Maringanti, Ph.D., Agricultural and Biological Engineering

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Thanks for giving your valuable time.

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