Impact of Parametric Uncertainty in Land use Planning Decisions

Nithya Krishnan, IIT Madras, India
Dr. Cibin Raj, Purdue University
Dr. KP Sudheer , IIT Madras, India
Dr. Indrajeet Chaubey, Purdue University

Does parametric uncertainty affect decision making?

- Watershed models to evaluate ‘what if’ questions and decision making

- Model parameter uncertainty is one major very known issue with simulation models

- Model parameter uncertainty can affect model simulation results and consequent decisions

Research objectives

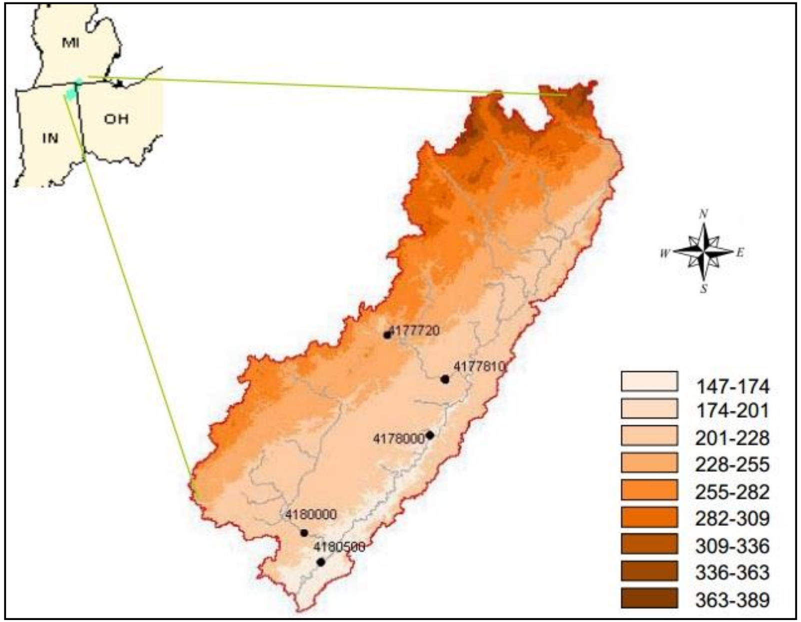
- To evaluate parameter uncertainty of SWAT model
- To evaluate potential impacts of uncertainty in model simulations on the decisions suggested for land use planning

Methodology

- Calibrate and estimate model parameter uncertainty using SCEM-UA
- Select five parameter sets from uncertainty range
- Formulate a land use planning optimization case study
- Do optimization cast study with these five parameter set
- Analyze optimization results to evaluate impact of parameter uncertainty

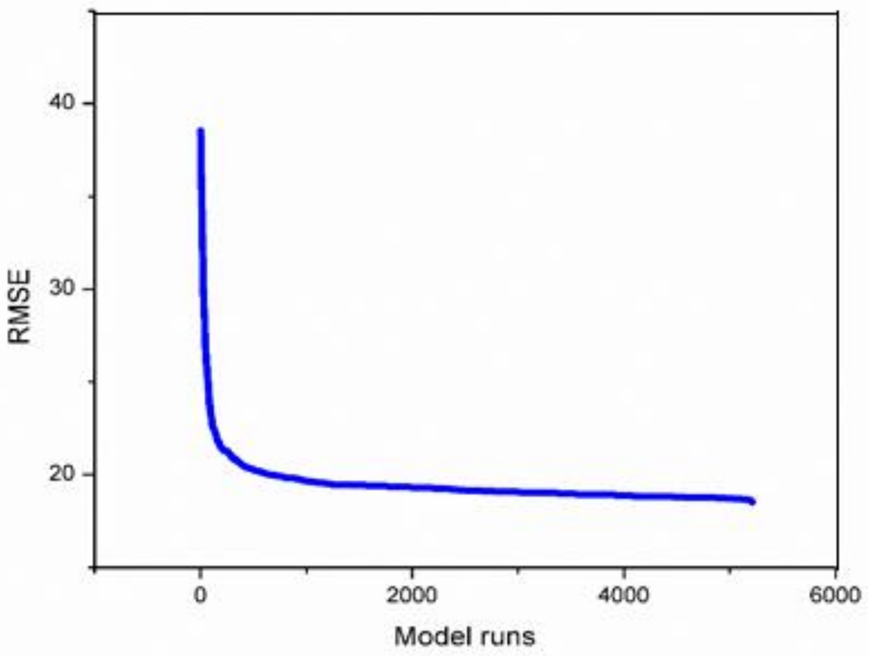
St. Joseph River Watershed

- 8 digit HUC: 2,800 km^2
- Mixed landuse, 37% corn/soybean, 25% pasture, 12% forest, 10% urban
- Model developed with 54 subbasins and 3062 HRUs

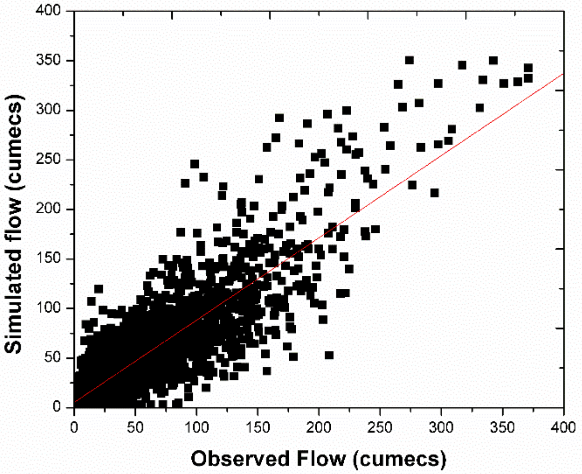


Calibration and uncertainty analysis

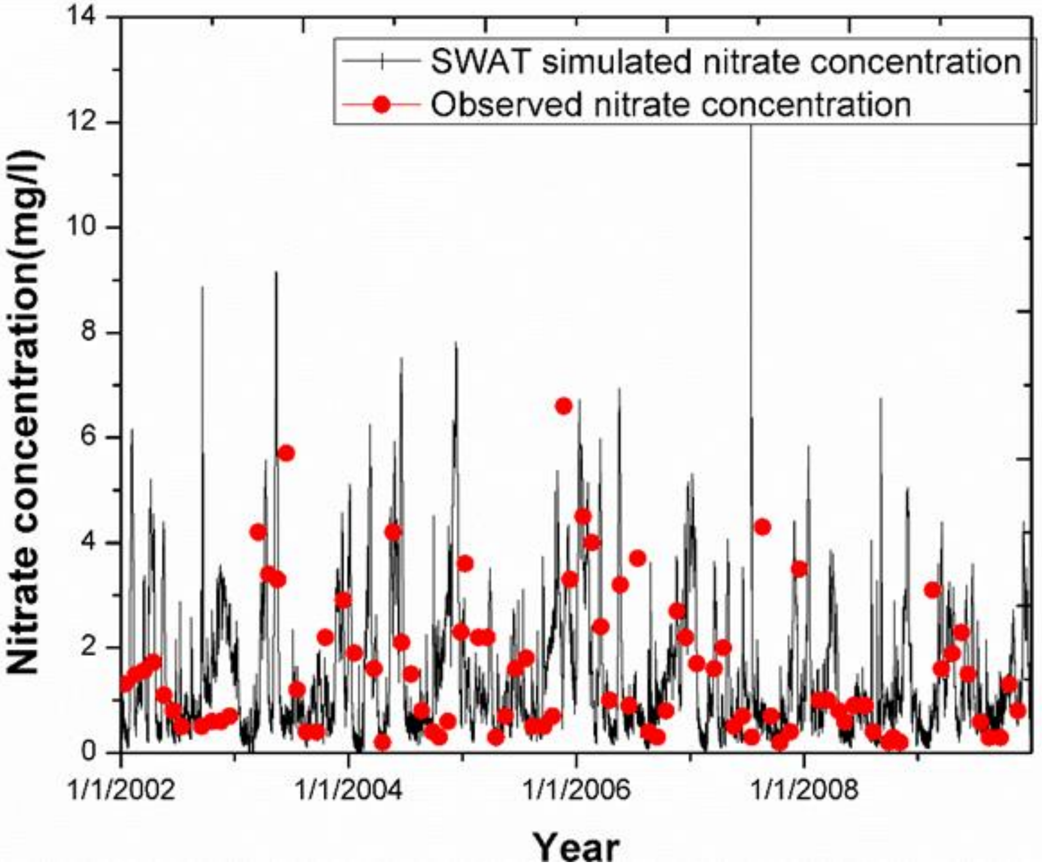
- 15 flow related parameters for calibration
- Root Mean Square Error (RMSE)as criteria
- RMSE converged with in 25 generations



Model calibrated for streamflow and water quality



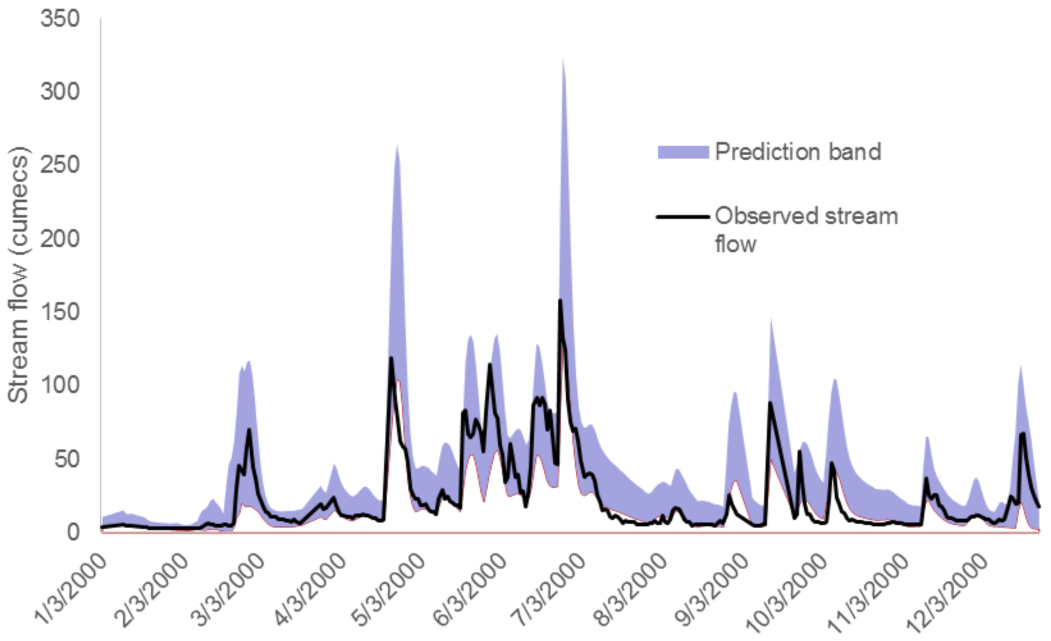
Daily	R^2	NSE
Calibration	0.81	0.81
Validation	0.79	0.78



PURDUE UNIVERSITY

Parameter uncertainty: 95% confidence interval

Range of parameters corresponding to 95% CI		
Parameter	Lower bound	Upper Bound
CN_F	-0.083	-0.0349
SOL_AWC	0.301	0.640
ESCO	0.785	0.896
SURLAG	1.223	1.875



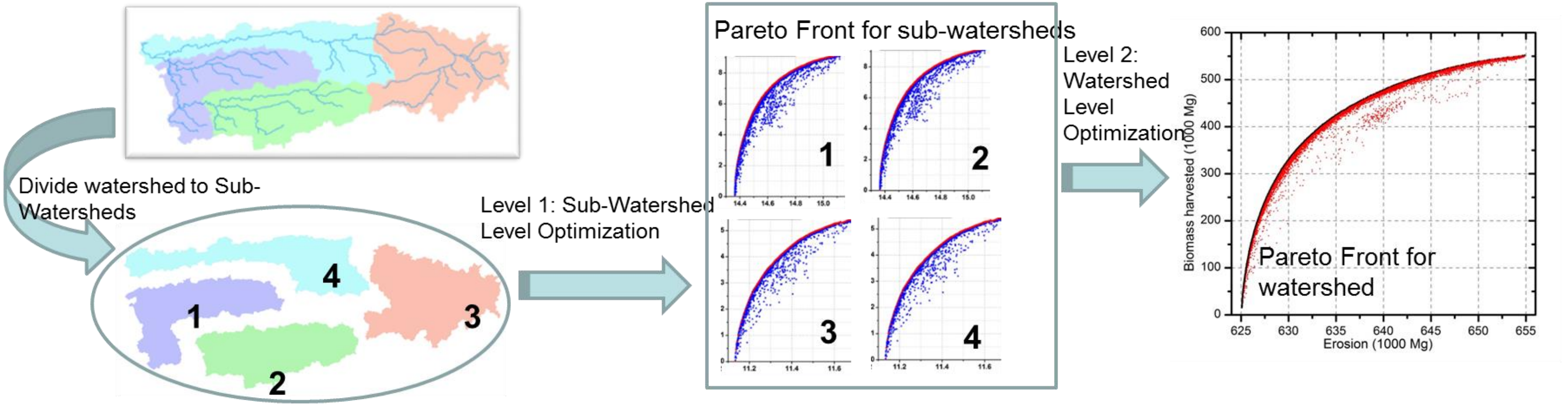
Five parameter sets were selected from uncertainty range

Parameter	Parset 1	Parset 2	Parset 3	Parset 4	Parset 5
SFTMP	-4.79	-1.96	-4.10	-4.31	-2.61
SURLAG	1.51	1.39	1.44	1.76	1.48
SMFMX	2.28	2.28	1.37	3.26	1.02
TIMP	0.93	0.88	0.44	0.44	0.57
ESCO	0.79	0.88	0.81	0.79	0.80
SLOPE	0.20	0.39	0.24	0.27	0.82
SLSBBSN	-0.18	-0.34	-0.21	-0.19	-0.24
DEP_IMP	-0.01	0.02	0.04	0.04	0.02
EPCO	0.62	0.43	0.35	0.57	0.24
ALPHA_BF	0.13	0.09	0.13	0.12	0.11
GWQMN	460.10	557.76	797.05	1130.79	261.60
CN_2	-0.07	-0.06	-0.08	-0.05	-0.07
SOL_AWC	0.34	0.40	0.49	0.33	0.42
SOL_k	-0.13	-0.08	-0.13	-0.01	0.04
SOL_z	0.03	0.03	0.03	0.02	0.01

Land use planning case study

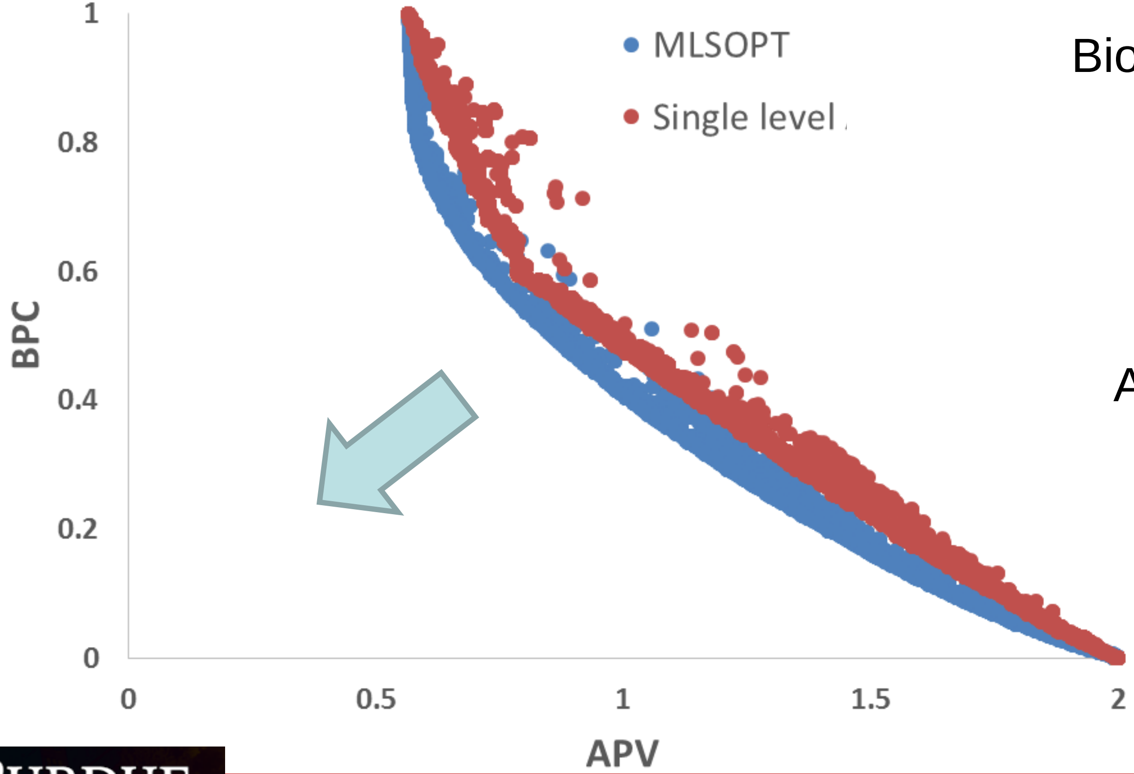
- Optimum land use planning for bioenergy production
- Perennial grasses (switchgrass and *Miscanthus*) and crop residue (stover removal at 30% and 50%) are considered as biofeedstocks
- Multi-objective optimization to minimize production cost and maximize environmental benefits
- Multi Level Spatial Optimization Technique (MLSOPT) was used as optimization framework

Multi Level Spatial Optimization Technique (MLSOPT)



(Cibin and Chaubey, 2015)

MLSOPT: Efficient and better in convergence



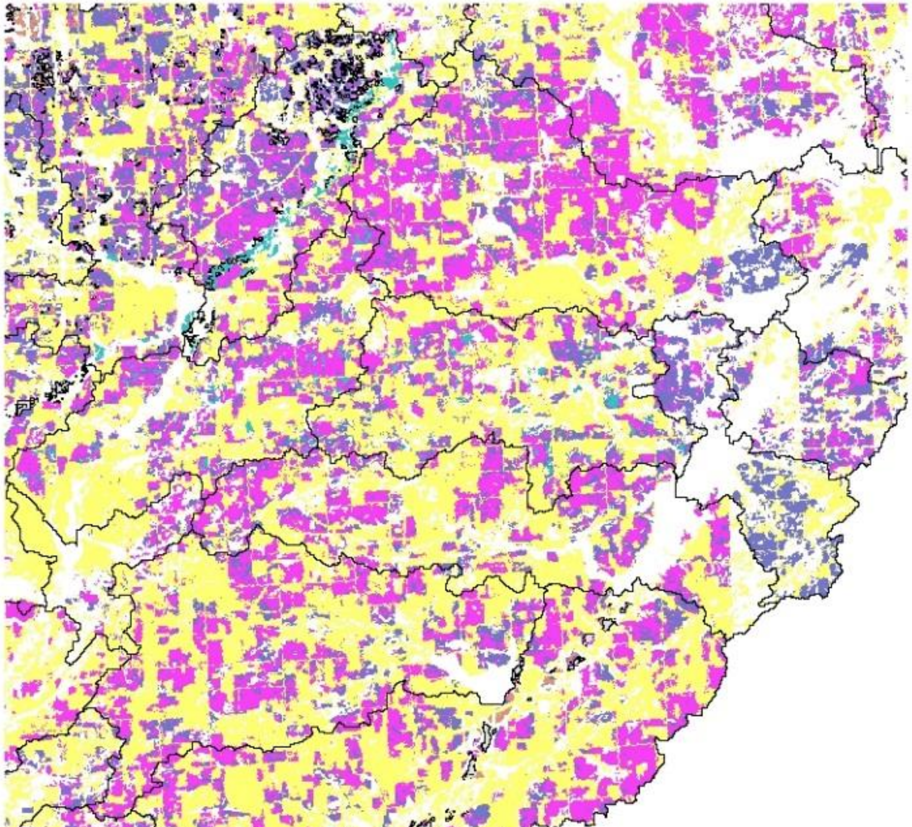
Biomass Production Cost (BPC)

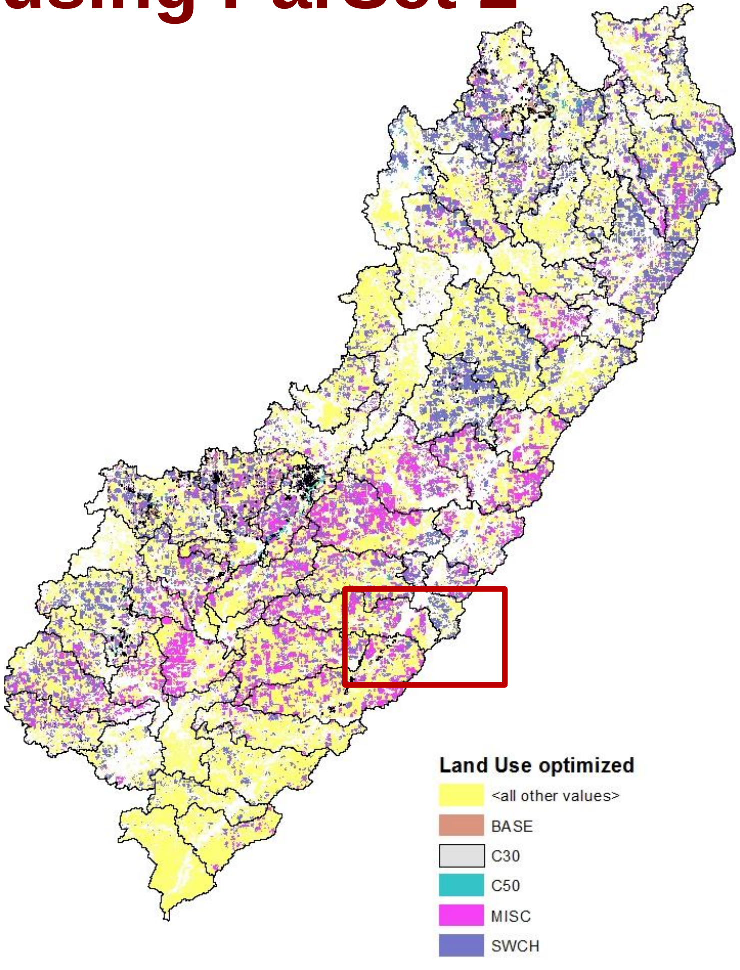
$$BPC = \frac{BPC_{sub}}{BPC_{Max}}$$

Aggregate Pollutant Value (APV)

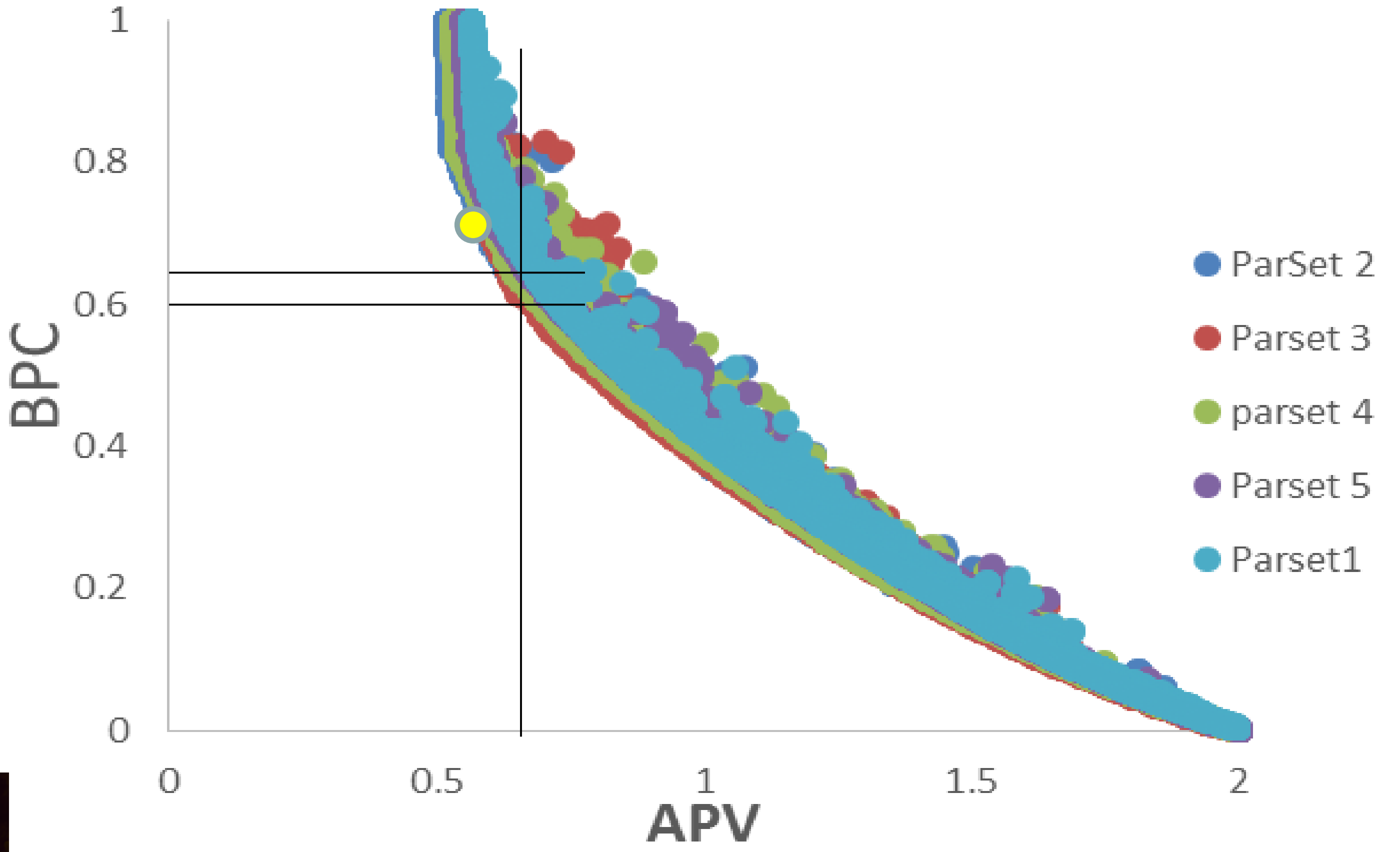
$$APV = \frac{N_{sub}}{N_{baseline}} + \frac{TP_{sub}}{TP_{baseline}}$$

Optimized cropping pattern using ParSet 2





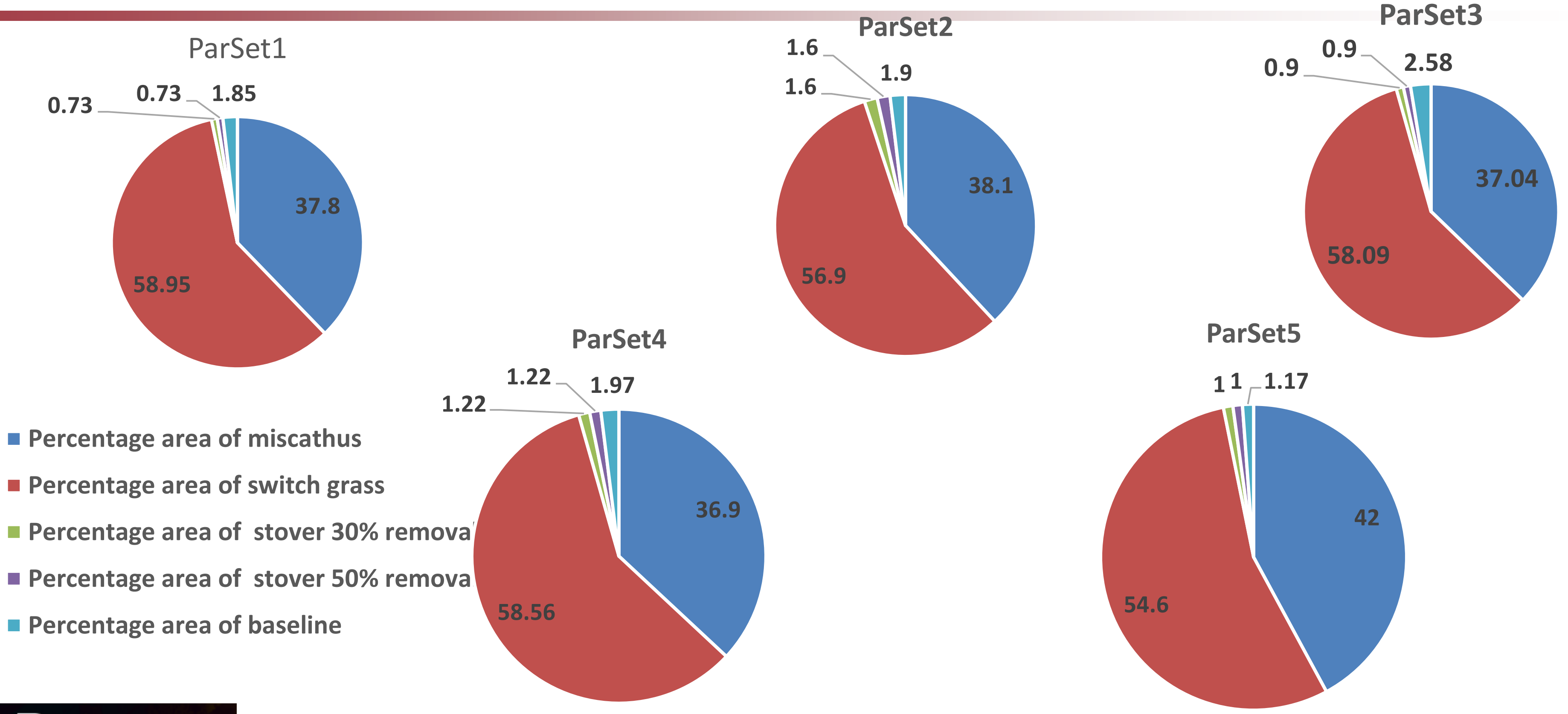
Pareto optimal solutions are different



Parameter uncertainty affected baseline and scenario simulations

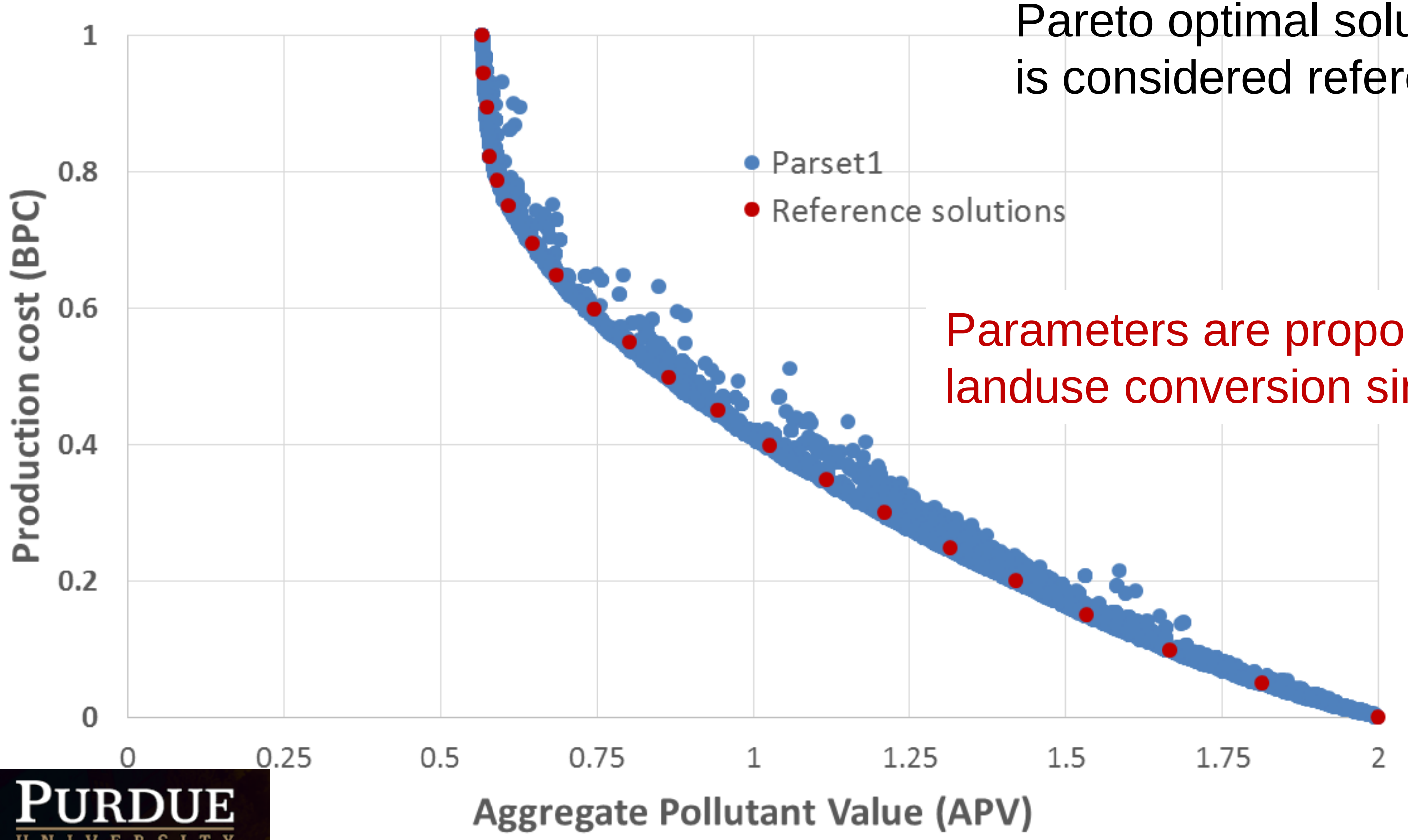
Parameter set Number	1	2	3	4	5
Nitrate(Kg/ha/year)	11.0	9.6	7.9	9.9	10.0
Total Phosphorous(kg/ha/year)	0.90	0.80	0.81	0.88	1.00
Cost(Million $)	158	159	159	159	158
Nitrate Baseline(kg/ha/year)	21.5	20.7	16.3	20.7	20.6
Percentage reduction nitrate	49.3	53.4	51.6	51.7	51.5
Percentage reduction Total Phosphorus	89.2	88.5	88.7	88.9	88.5

Percentage of land use change after optimization



Optimum placement solutions remain similar with different parameter sets

Pareto optimal solutions from ParSet 5 is considered reference solution



Parameters are proportionally changed for landuse conversion similar to baseline

Conclusions

- Parameter uncertainty quantified using SCEM_UA
- Parameter uncertainty affected baseline hydrology and water quality simulations
- Parameter uncertainty affects optimal placement decision making if the decision is made using cost or pollutant reduction targets
- Parameter uncertainty did not affect optimal placement solutions in pareto-front
- Detailed analysis is in progress

Additional slides

Calibrated value for stream flow parameters

Parameter	Description	Parameter Lower Bound	Parameter Upper Bound	Calibrated value
SFTMP	Snow melt base temperature(ºC)	-5	5	-1.69
SURLAG	Surface runoff lag co-efficient (days)	0	12	1.83
SMFMX	Maximum snowmelt factor for June 21(mm $H_2O/^oC^{-1}$ day^{-1})	0	10	1.87
TIMP	Snow pack temperature lag factor	0.01	1	0.83
ESCO	Soil evaporation compensation factor	0	1	0.88
SLOPE	Average HRU slope steepness	-0.5%	1%	0.58
SLSBBSN	Average slope length of HRU	-0.5	0.5	-0.48
DEP_IMP	Depth to impervious layer	-0.1%	0.1%	0.02
EPCO	Plant uptake compensation factor	0	1	0.52
ALPHA_BF	Base flow recession co-efficient	0.05	0.15	0.15
GWQMN	Threshold depth of water in the shallow aquifer for return flow to occur (mm H_2O)	0	2000	1027.44
CN_2	Curve number	-0.25%	0.1%	-0.07
SOL_AWC	Available soil water capacity	0.3	1	0.48
SOL_k	Saturated hydraulic conductivity	-0.25%	0.25%	0.17
SOL_z	Depth from soil surface to the bottom layer	-0.5%	1%	0.05