Modeling uncertainties for national assessments of conservation practices

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National Assessment of the Conservation Effects Assessment Project (CEAP)

- Sampling and modeling approach based on a subset of National Resources Inventory (NRI) sample points;
- Field−level modeling conducted for each of the NRI sample points comprising the CEAP sample using Agricultural Policy/Environmental eXtender (APEX);
- Field-level estimates aggregated within 8-digit watershed using statistical weighting factors associated with the NRI;
- Off-site estimates obtained by incorporating aggregated field-level estimates into a large-scale water quality model (HUMUS/SWAT).

Conservation effects assessment

- **With practices**: simulating effects from cropland with conservation practices currently present over a 42-yr simulation period;
- **Without practices**: stripping away current conservation practices and simulating effects from cropland over a 42-yr simulation period;
- **Conservation effects**: model output difference between with practices and without practices.

APEX (Agricultural Policy/Environmental eXtender)

Whole Farm Management

Small Watershed Management

Continuous simulation (Time step – Daily or less)

Sub Area - EPIC (Environmental Policy Integrated Climate):

Weather, Hydrology, Erosion (wind and water), Carbon, Nutrients (N, P, & K), Pesticides, Salinity, Crop Growth, Tillage, Grazing, Manure Management, Economics

Routing

Groundwater

Reservoirs

APEX Inputs and Parameters

- Daily weather (or generated)
- Soil (layer depth, bulk density, % sand, % silt, % organic C, etc.)
- Field management and site information
- Model parameters in APEX database include crop growth parameters, fertilizer types, operations (machinery), pesticide types and descriptions, process model options; and a parameter file containing many equation coefficients, definitions of s−curve, and miscellaneous parameters.

Uncertainty in Modeling

Uncertainty sources

- Model structure (not possible to fully characterize real world processes);
- Input data (such as soils, N rates);
- Model parameters (tunable); and
- Errors of observations on which model calibration is based.

Uncertainty Analysis Methods

- First Order Analysis (FOA)
- Monte Carlo Simulations (MCS)
- Fourier Amplitude Sensitivity Test (FAST)
- Generalized Likelihood Uncertainty Estimation (GLUE)

Latin Hypercube (LH) Sampling

Stratified sampling technique to achieve a better coverage of the sample space of the input parameters.

APEX Output Variables Analyzed

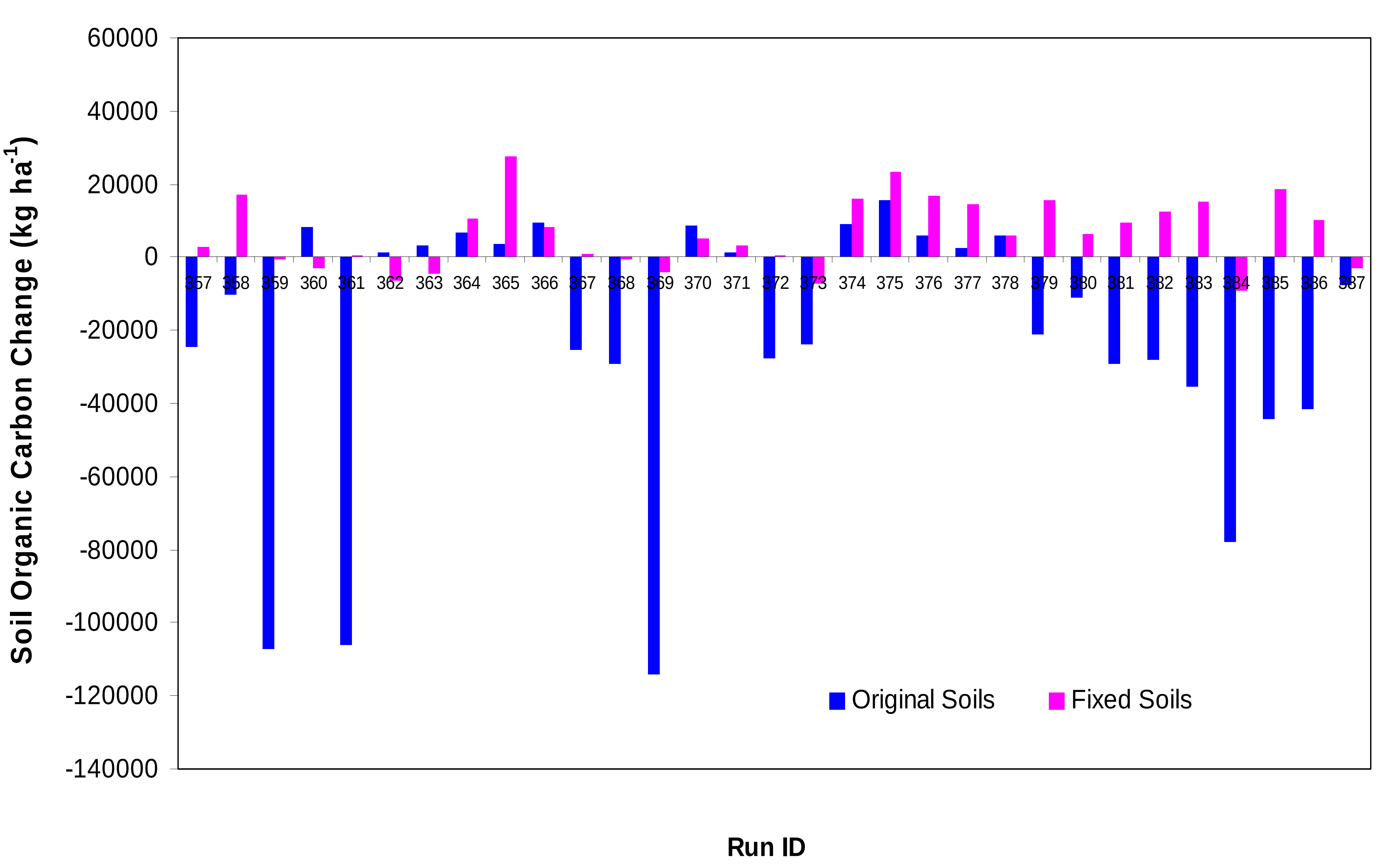
Crop grain yield (YLD), water erosion/sediment (SED), wind erosion (YWND), surface runoff (Q), organic N and P loss (YN & YP), soluble N and P loss (QN & QP), and soil organic carbon change (WOC).

Input uncertainty - soil

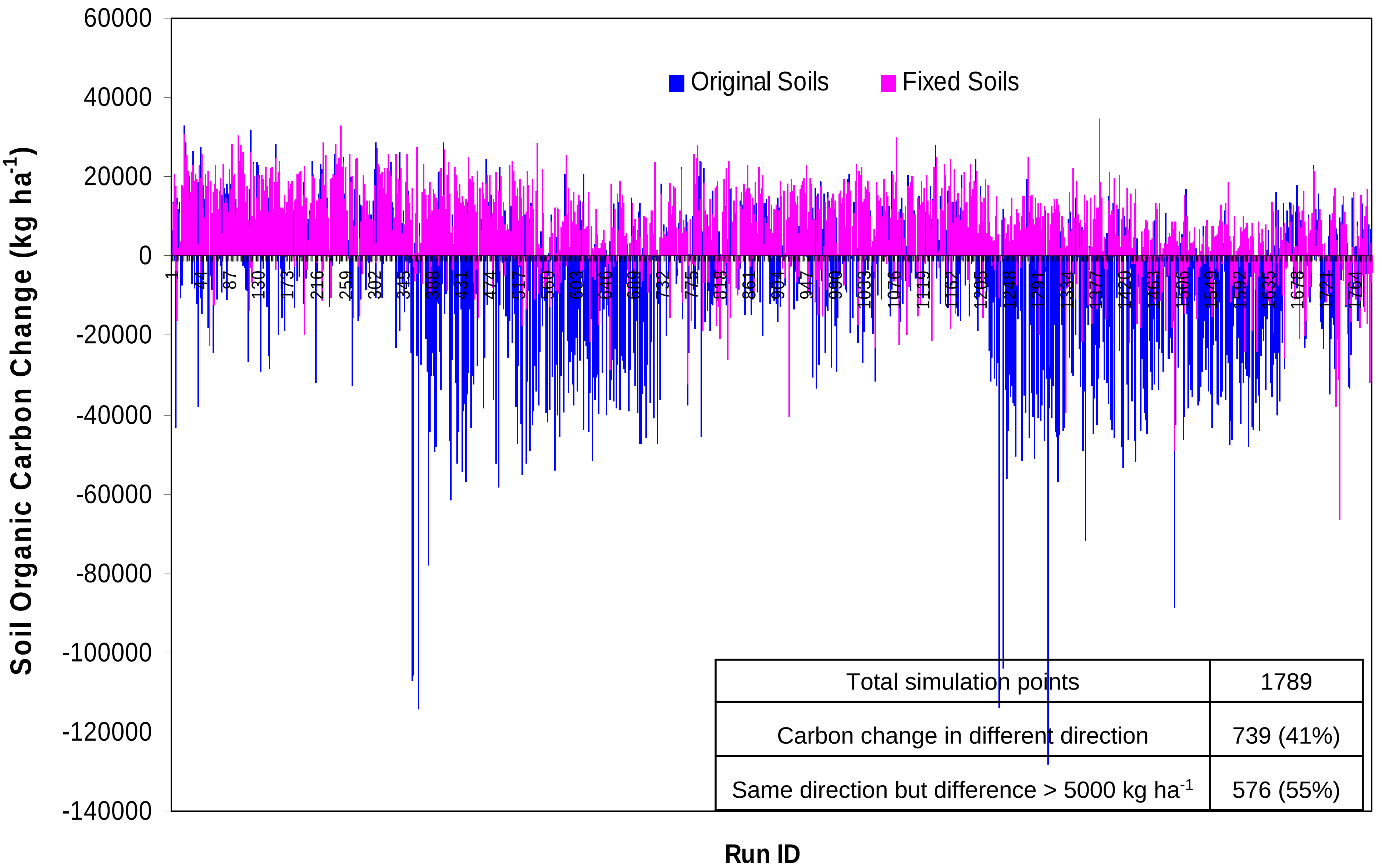
Soil data for CEAP

- set of soils defined for NNLSC project (referred as original soils);
- fixed soils:
  1) divided the first layer of original soils in cases where it was very deep; and
  2) set initial soil carbon to reflect previously cropped situations.

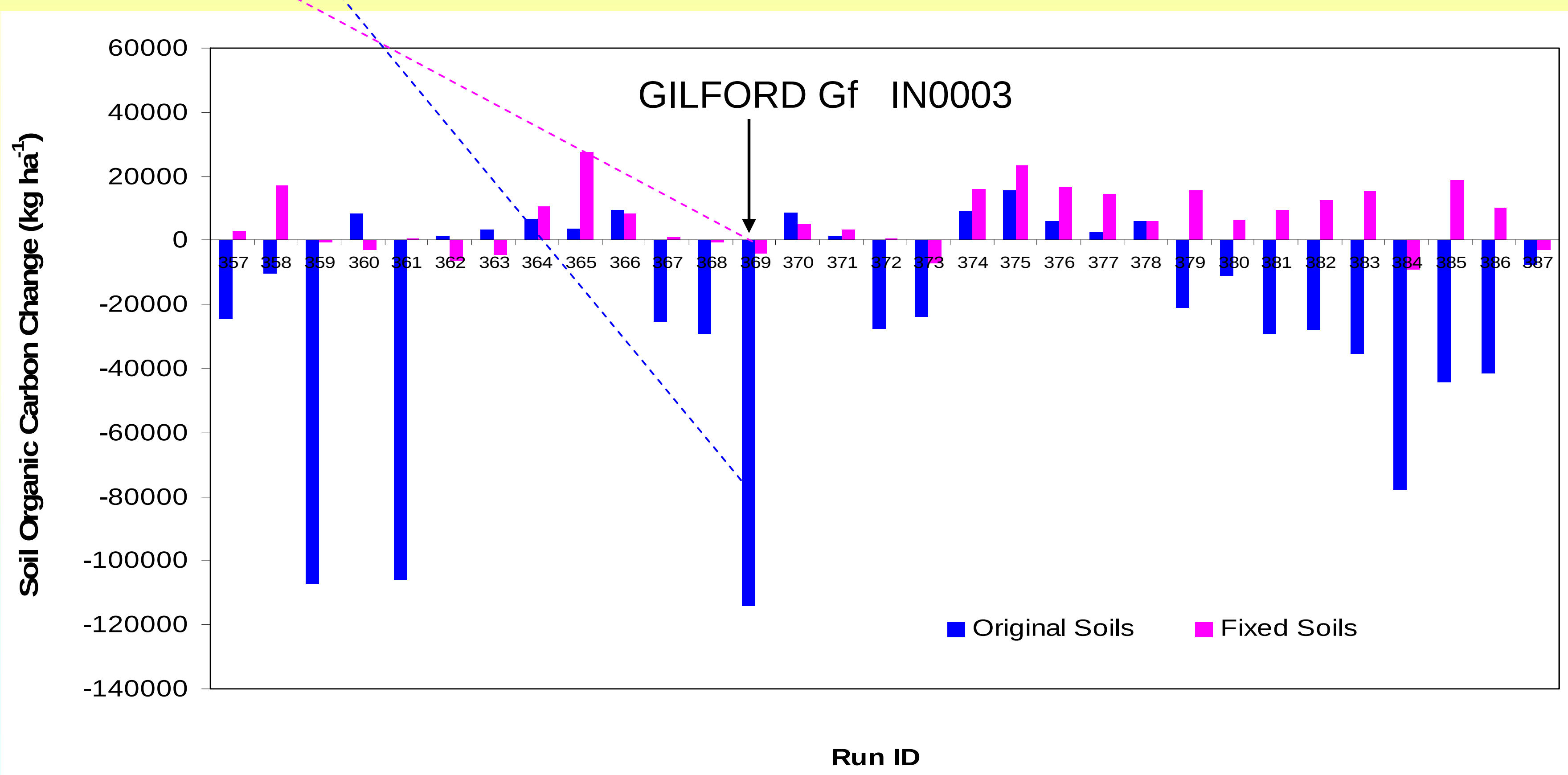
Carbon change over 42-year simulation period using different soil data for Upper Mississippi CEAP points



Carbon change over 42-year simulation period using different soil data for Upper Mississippi CEAP points



		Layer					Soil organic C (kg ha^{-1})		
		1	2	3	4	5	Initial	End of 42-yr continuous corn	Change
Original soil	Z (m)	0.3	0.79	1.22	1.52				
	WOC (%)	8.82	0.35	0.15	0.03		465749	351470	-114279 (-25%)
Fixed soil	Z (m)	0.2	0.3	0.79	1.22	1.52			
	WOC (%)	1.22	0.82	0.08	0.01	0.001	60003	55916	-4087 (-7%)



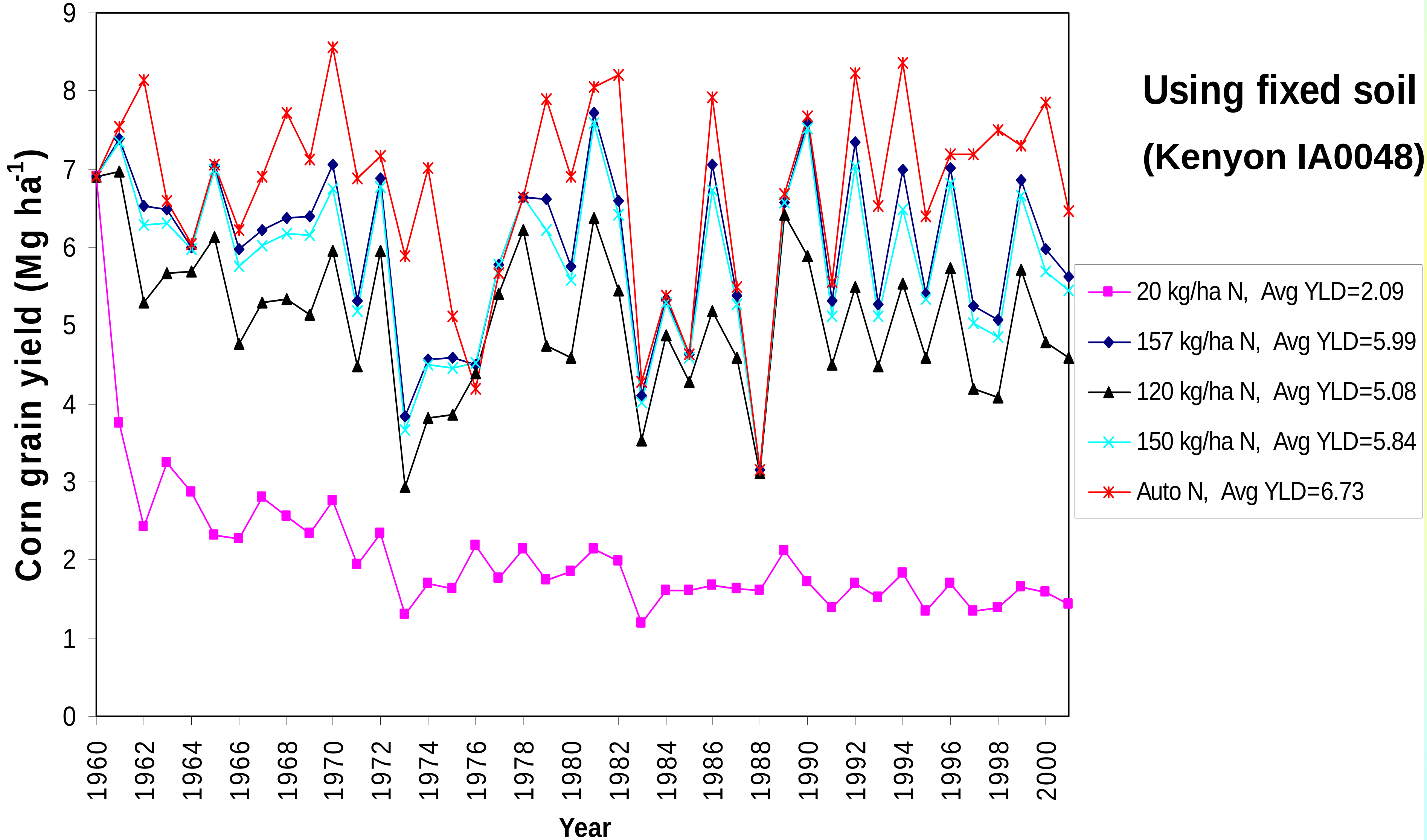
Input uncertainty – N rate

Rates selected (kg ha^{-1}):

20-150; and

Automatic fertilization in APEX.

Corn grain yields for the 42-year simulation period using different N application rates



Using fixed soil

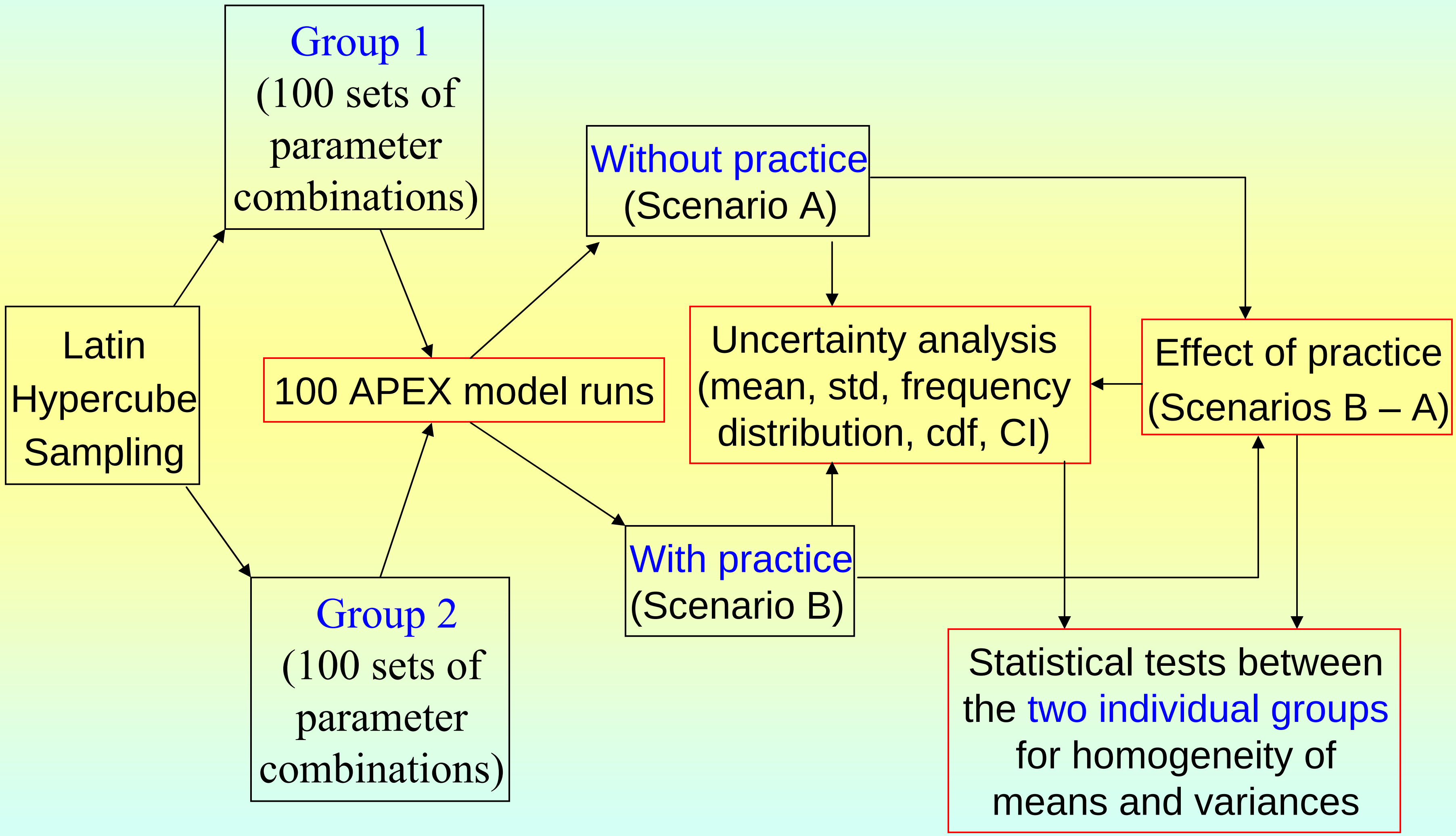
(Kenyon IA0048)

Parameter uncertainty

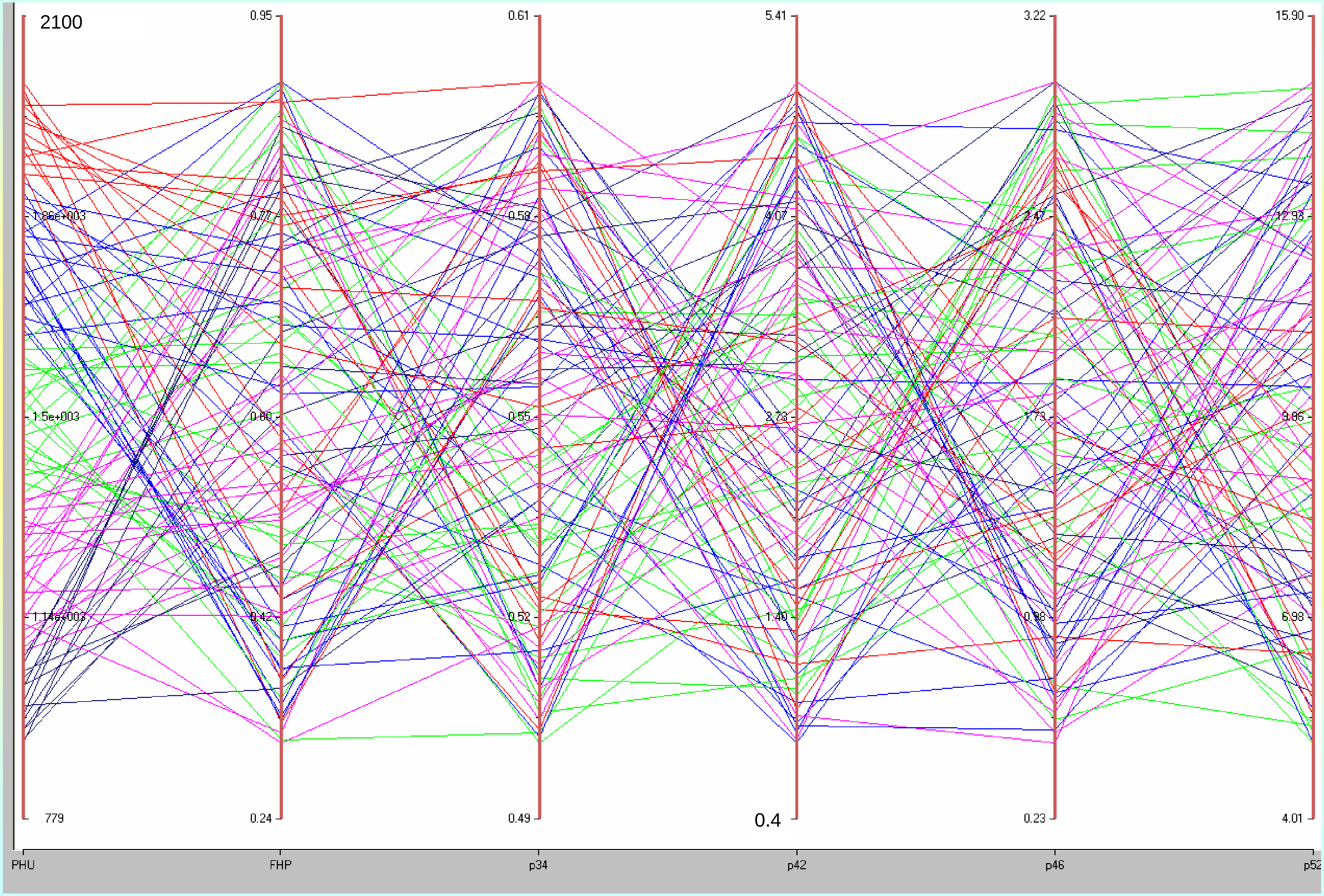
Parameter	Description	Lower range	Upper range
PHU	Potential heat units (℃)	800	2400
FHP	Fraction of humus in passive pool	0.3	0.9
Parm(34)	Hargreaves PET equation exponent	0.5	0.6
Parm(42)	SCS curve number index coefficient	0.5	5
Parm(46)	RUSLE C factor coefficient in exponential residue function in residue factor	0.5	3
Parm(52)	Exponential coefficient of tillage effect on residue decay rate	5	15

Wang et al., 2006. Sensitivity analysis of APEX for national assessment. *Trans ASABE* 49(3):679-688.

Structure of Uncertainty analysis and evaluation of Monte Carlo runs



Generated Parameter Sets (N = 100 sets)



Evaluation of the results of 100 Monte Carlo runs

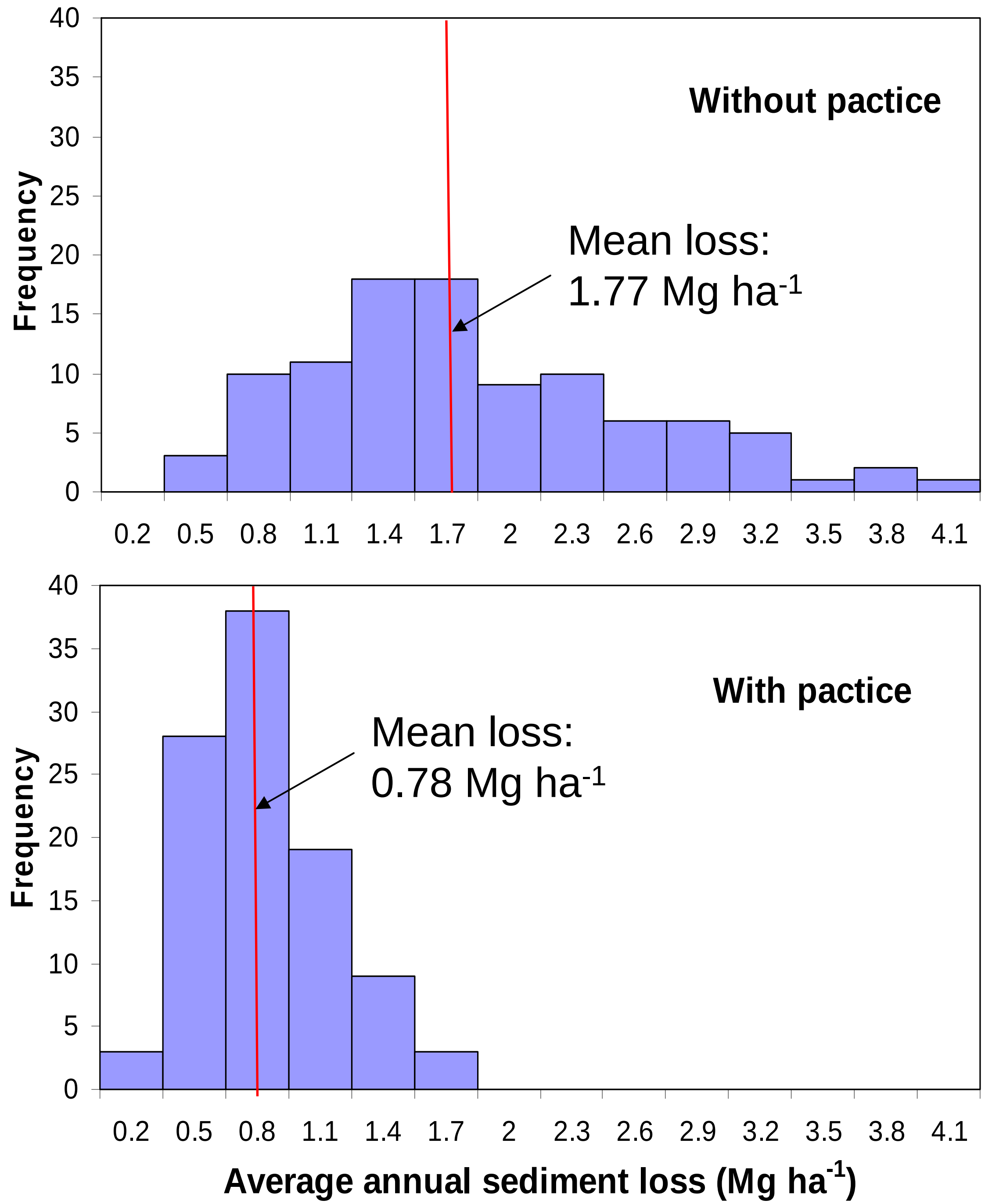
Outputs (average of 42-yr)	Effect of practice (Scenarios B - A)			
	Mean (Simulations: 1-100)	**Mean** (Simulations : 101-200)	**Std** (Simulations : 1-100)	**Std** (Simulations :101-200)
YLD (Mg ha^{-1})	0.01	0.01	0.04	0.04
SED (Mg ha^{-1})	-0.99	-0.99	0.47	0.37
YWND (Mg ha^{-1})	-0.02	-0.02	0.02	0.02
Q (mm)	-24.27	-24.88	4.07	2.85
YN (kg ha^{-1})	-1.79	-1.78	0.75	0.63
QN (kg ha^{-1})	-0.75	-0.76	0.20	0.20
YP (kg ha^{-1})	-0.31	-0.31	0.13	0.11
QP (kg ha^{-1})	-0.04	-0.04	0.01	0.01
WOC (kg ha^{-1})	21.22	20.99	9.65	9.07

Homogeneity of means and variances accepted by F-test — indicating that 100 Monte Carlo runs were sufficient to access the uncertainty on the simulation results.

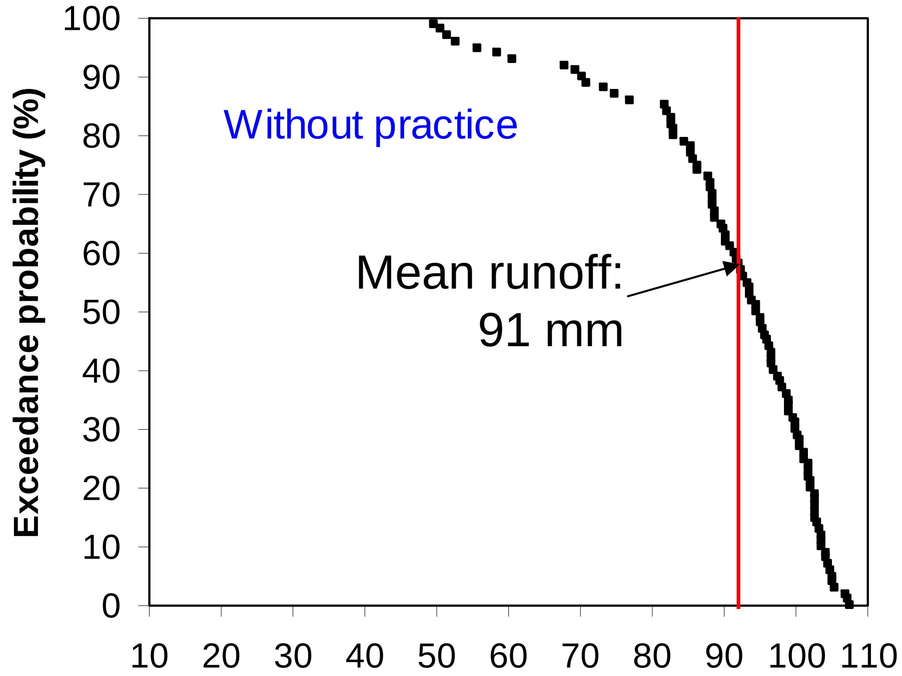
Effects of contour practice on model outputs based on 100 Monte Carlo runs

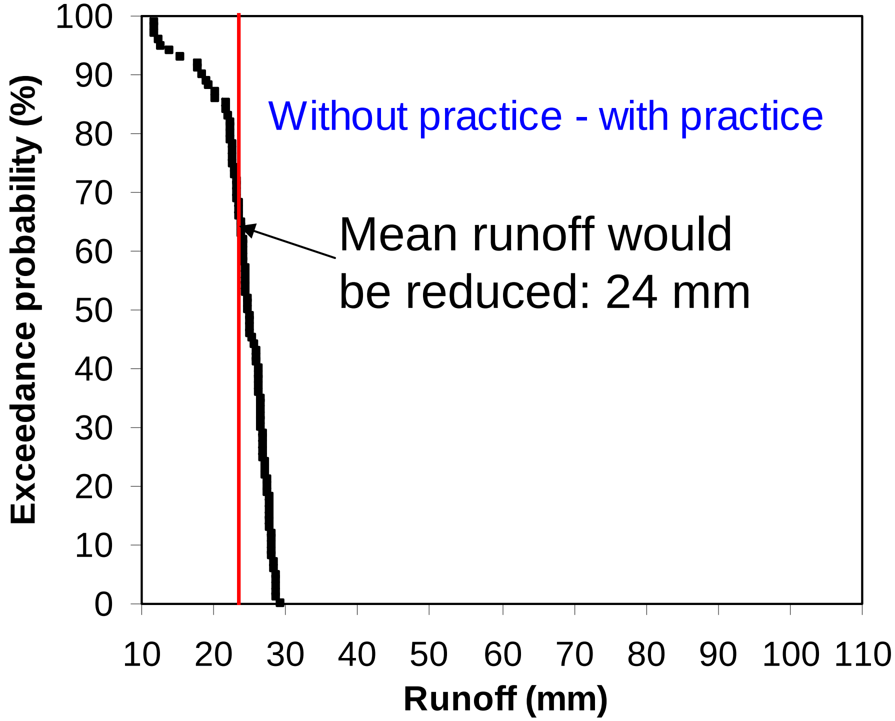
Outputs (average annual)	Without practice (Scenario A)		With practice (Scenario B)		Effect of practice (Scenarios B - A)				
							% change		
	Mean	Std	Mean	Std	Mean	Std	100(Scenarios B - A) / Scenario A	min	max
YLD	5.52	0.58	5.51	0.55	0.01	0.04	0.1	-1.7	1.6
SED	1.77	0.79	0.78	0.33	-0.99	0.47	-55.7	-59.3	-44.5
YWND	0.54	0.12	0.52	0.11	-0.02	0.02	-4.5	-16.9	12.5
Q	91.26	13.65	66.98	9.66	-24.27	4.07	-26.6	-28.4	-22.9
YN	3.44	1.46	1.65	0.71	-1.79	0.75	-52.1	-56.2	-47.6
QN	1.50	0.31	0.75	0.17	-0.75	0.20	-49.8	-63.1	-30.5
YP	0.59	0.24	0.28	0.11	-0.31	0.13	-52.6	-56.1	-45.3
QP	0.15	0.03	0.11	0.02	-0.04	0.01	-28.1	-31.1	-23.3
WOC	117.89	192.82	139.11	190.40	21.22	9.65	18.0	0.2	193.3

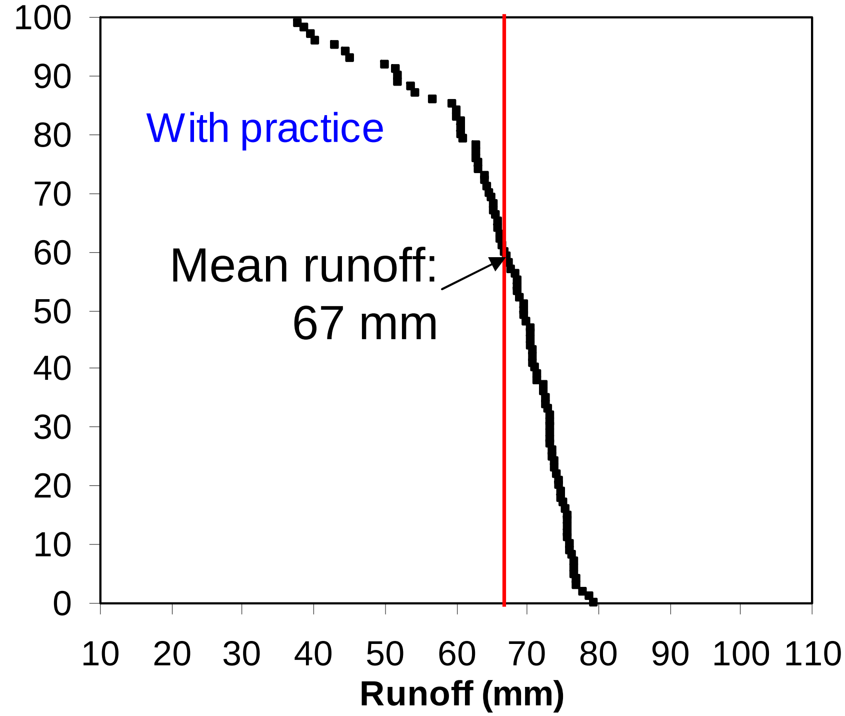
Statistical distribution of annual sediment loss over 100 Monte Carlo runs for scenarios A and B



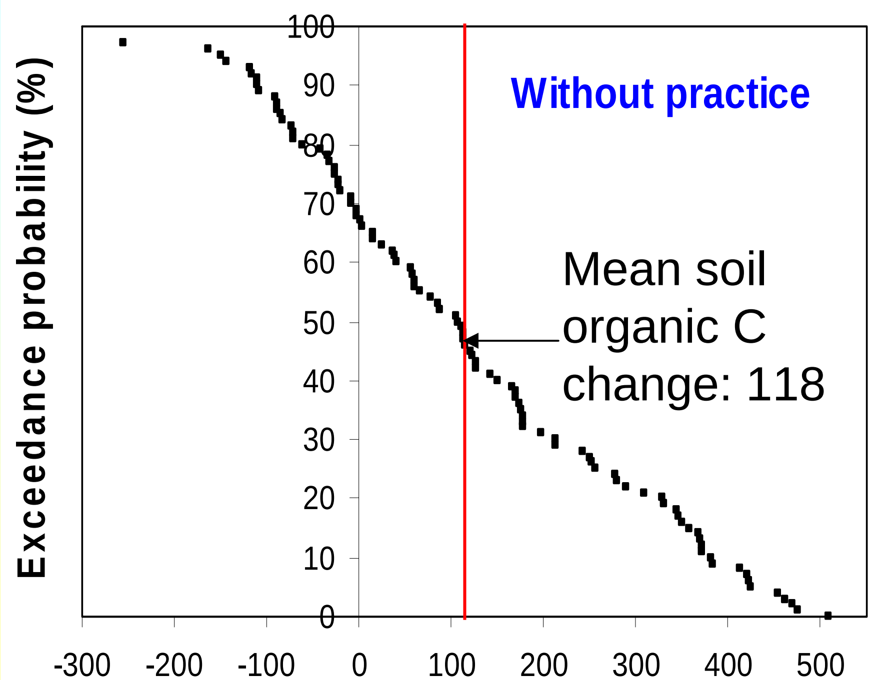
Exceedance probability of annual runoff over 100 Monte Carlo runs for scenarios A and B

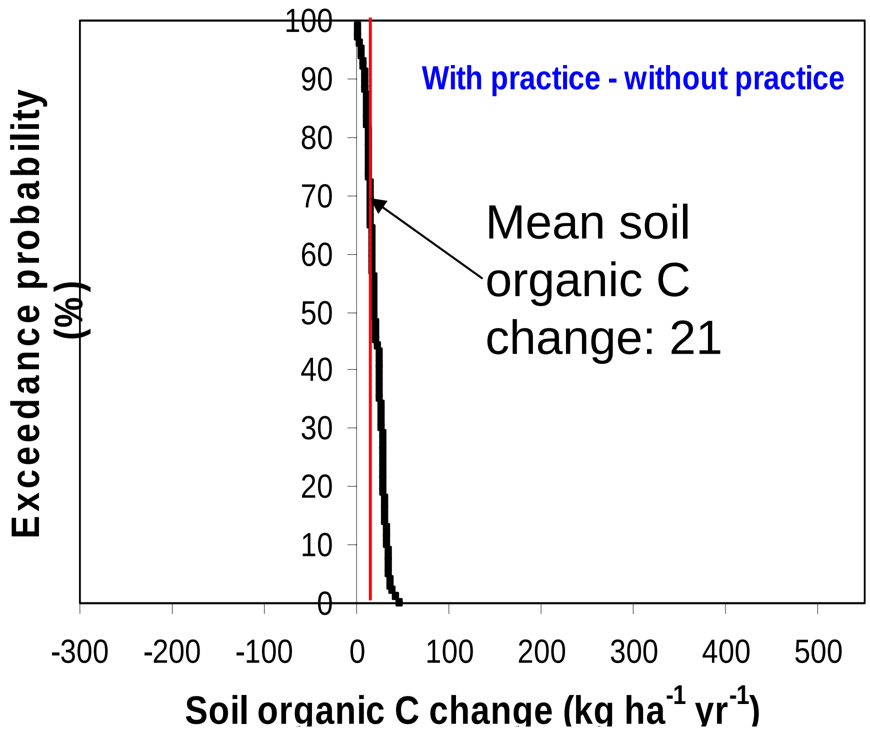


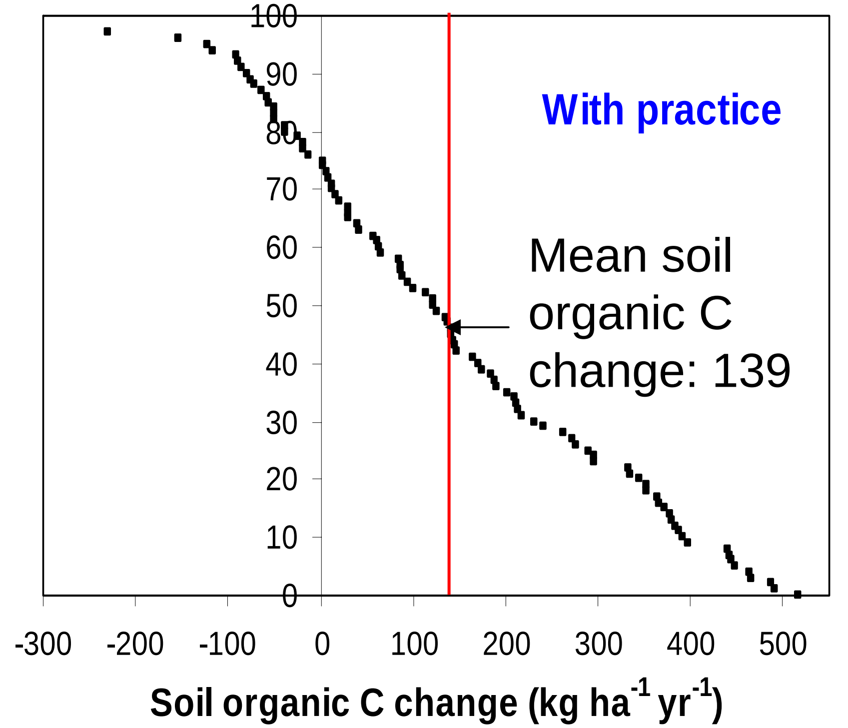




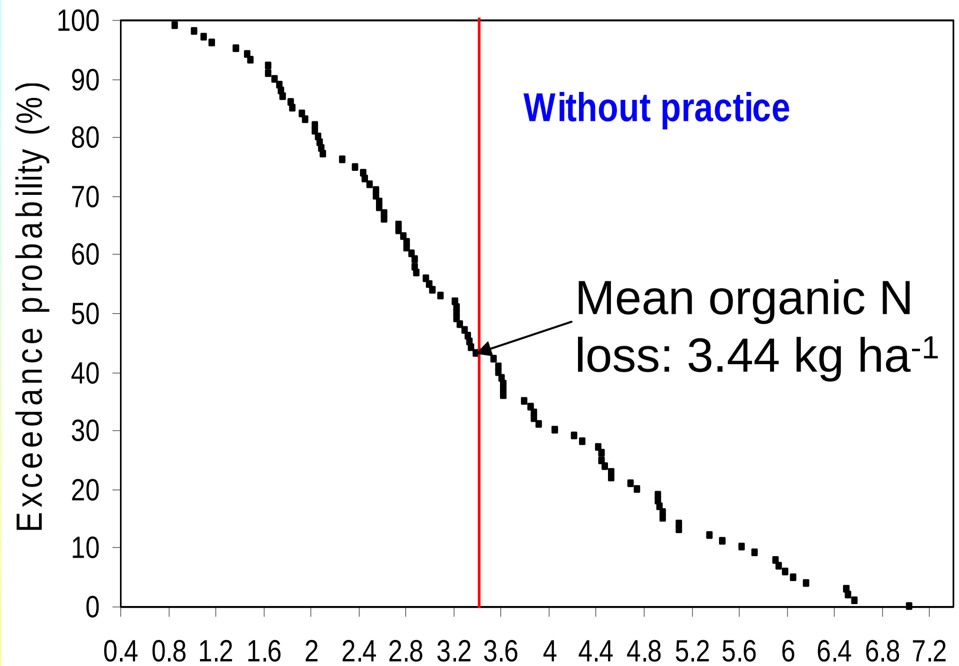
Exceedance probability of annual soil organic C change over 100 Monte Carlo runs for scenarios A and B

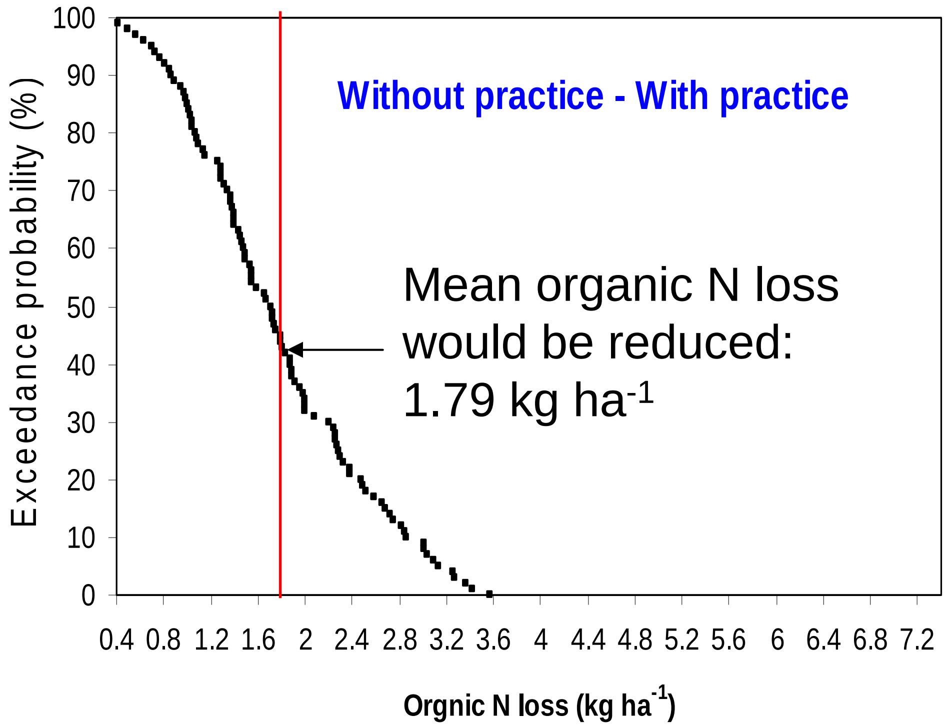


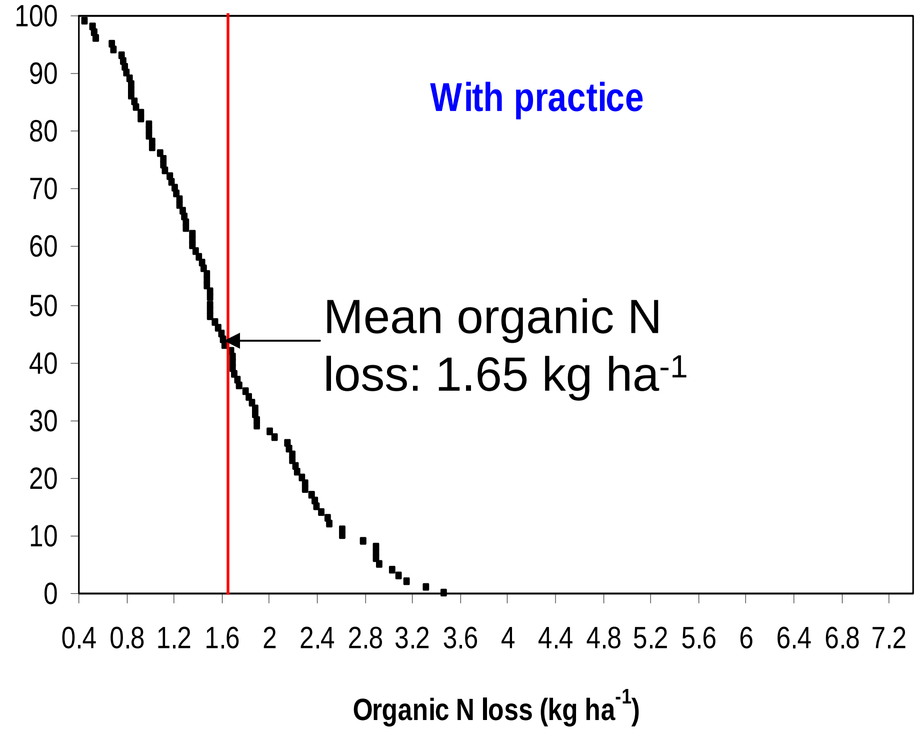




Exceedance probability of annual organic N loss over 100 Monte Carlo runs for scenarios A and B







Conclusions

- Inputs, such as initial soil organic carbon contents and fertilizer application rates, can contribute a great deal to the overall uncertainties of the predictions;
- The uncertainty analysis shows that the means and ranges of the scenario predictions are discriminable between scenarios where the applied practices do have impacts on the outputs;
- In the case of contour practice, it reduces over 25% of runoff and soluble P, and about 50% of sediment, organic N and P losses;
- The resulting uncertainties of the output differences between without practice and with practice scenarios, which represent the practice effects, are in general smaller than the uncertainties in each individual scenario; and
- The uncertainty analysis procedure used in this study is applicable to any deterministic model and for different scenario predictions.