STOCHASTIC APPROACH TO EVALUATE PESTICIDE FATE IN PADDY AREA USING THE RICEWQ MODEL.

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CONTENTS

- Model overview
- Input data
- Results
- Upscaling
- Conclusion

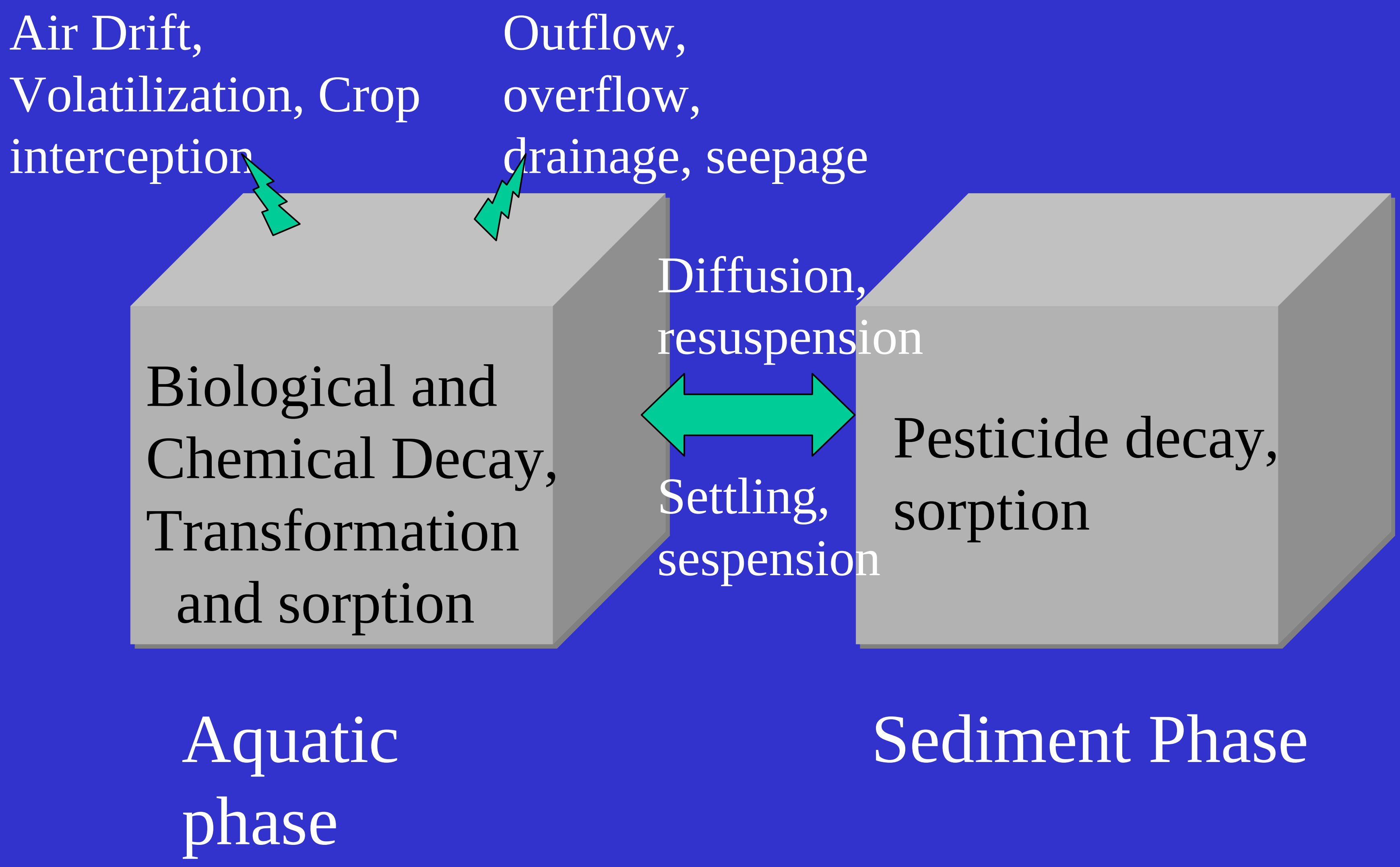
RICEWQ MODEL

(Pesticide Runoff Model for Rice Crops)

Version: 1.6.1 (February 1999)

RICEWQ was developed to evaluate the dissipation and runoff of pesticides from their use on aquatic crops and to predict the runoff losses of pesticides to receiving waters

RICEWQ PROCESS



RICEWQ MASS BALANCE

• Mass balance principles were employed in the model:

$$V\frac{\partial C}{\partial t} = \Sigma M_{\inf lux} - \Sigma M_{outflux} - \Sigma M_{react}$$

• Major pesticide mass balance models were listed as follows:

RICEWQ MASS BALANCE

- Pesticide mass balance in sediment:

$$\frac{\partial M_S}{\partial t} = -M_{S\deg} + M_{Stran} \mp M_{bed} + M_{setl} - M_{resus} \pm M_{difus}$$

- Pesticide mass balance in foliage:

$$\frac{\partial M_F}{\partial t} = +M_{Fapp} - M_{F\deg} + M_{Ftran} - M_{wash} - M_{harv}$$

RICEWQ MASS BALANCE

- Pesticide mass balance principle in paddy water:

$$\frac{\partial M_W}{\partial t} = M_{Wapp} + M_{wash} - M_{Wdeg} + M_{Wtran} - M_{volat} - M_{out} - M_{seep} - M_{bed} - M_{setl} + M_{resus} \pm M_{difu}$$

RICEWQ WATER BALANCE

- Water balance: $$\frac{\partial S}{\partial t} = \sum I - \sum O$$

Water balance algorithms account for

INPUT

- precipitation,
- irrigation

OUTPUT

- seepage,
- evaporation,
- release and overflow from various paddy outlet configurations
- controlled drainage prior to harvest

Water quality algorithms include

- dilution,
- volatilisation,
- partitioning between water and bed sediments,
- decay in water and sediment,
- resuspension from bed sediments

Crop algorithms include

- plant growth,
- associated pesticide washoff and degradation on foliage
- deposition of pesticide residues of foliage after harvest

RICEWQ APPLICATION

One very large area (about 20,000 ha) with stochastic variation of input data.

MONTECARLO approach with simultaneous modification of variables.

Why stochastic approach ?

To take into account the uncertainty related with the inputs

such as

- **water management data**
- **sediment characteristics**
- **pesticide properties**
- **etc.**

NUMBER OF MONTECARLO RANDOM VALUES

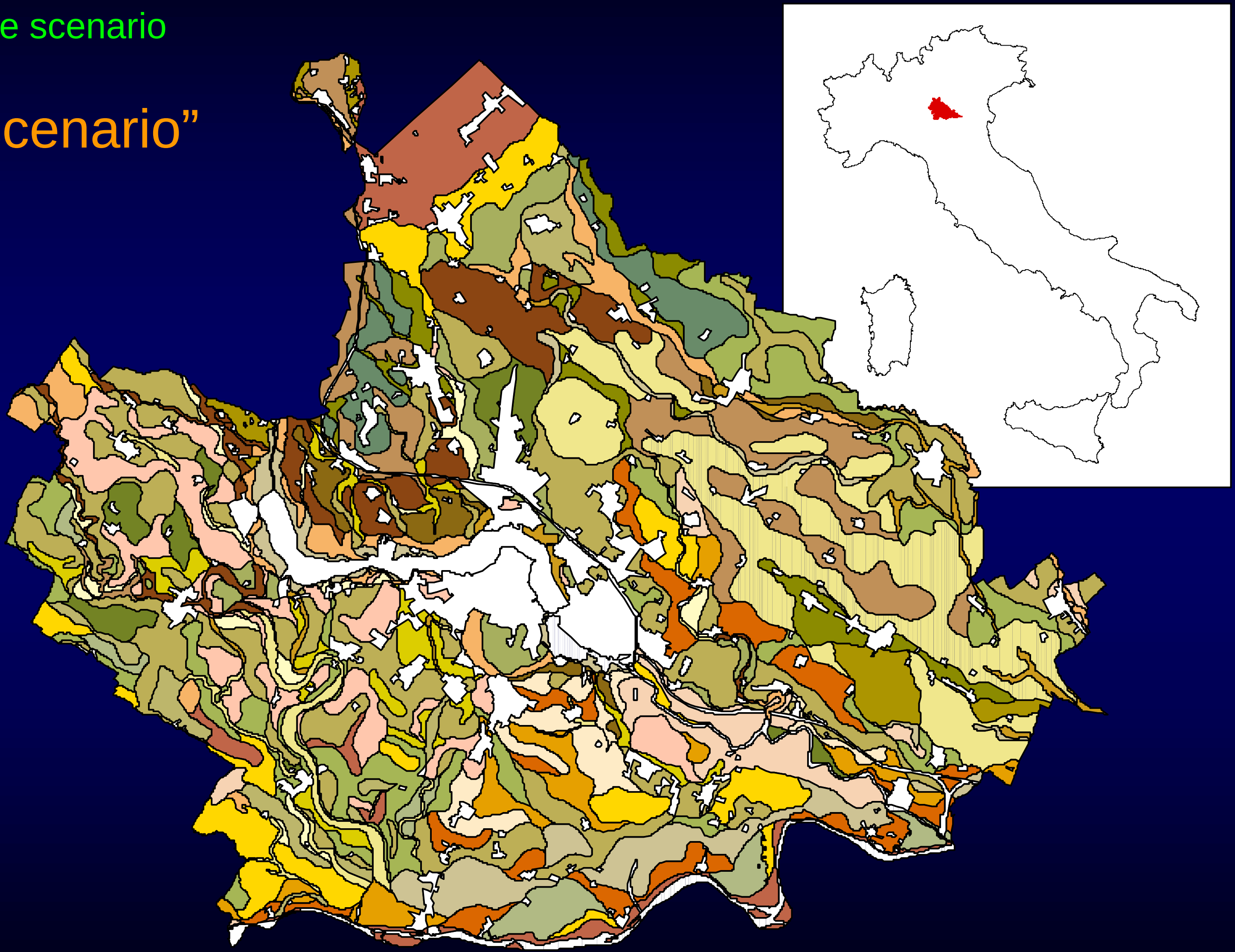
$$n = 4pq / L^2$$

where p and q are the event probability and L is the error interval beyond the confidential interval of 95%

$$n = 4*50*50 / 5^2 = 400$$

MANTOVA rice scenario

"worst case scenario"



Scale: 1:200000

MODELLING: INPUT data

Crop related properties (rice)

Emergence: 20 May

Maturation: 20 July

Harvest: 3 October

Paddy field

Surface area: 1 ha

Pesticide application

Number of application: single application

Pesticide relevant properties

Solubility in water (25°C): 1.6 g/l

RANGE AND TYPE OF DISTRIBUTION OF INPUT DATA

Crop related properties (rice)

Max. area coverage of crop: 0.90-1.00

Washoff per cm precipitation: 0-0.1 cm

Water management

Depth of water: *June* 5-10 cm

July 15-20 cm

August 25-30 cm

September drain

Pesticide application

Date: 15 June - 15 August

Rate: 0.3-0.6 kg/ha formulate

Application efficiency: 0.90-1.00

RANGE AND TYPE OF DISTRIBUTION OF INPUT DATA

Paddy field

Initial water depth: 0-10 cm

Seepage rate: 0.1- 0.3 cm/ha/day

Irrigation rate: 1.5-3.5 cm/day

Drainage rate: 1-3 cm/day

Depth active sediment layer: 3-7 cm

Mixing depth of sediment: 0.05-0.15 m

Weather

Daily precipitation and pan evaporation :

1991-1999

RANGE AND TYPE OF DISTRIBUTION OF INPUT DATA

Pesticide relevant properties

- Degradation rate (water): 30 ± 2 days
- Degradation rate (sediment): 5-15 days
- Degradation rate (plant): 3-33 days
- Sorption coefficient K_{oc}: 1147-5701 l/kg

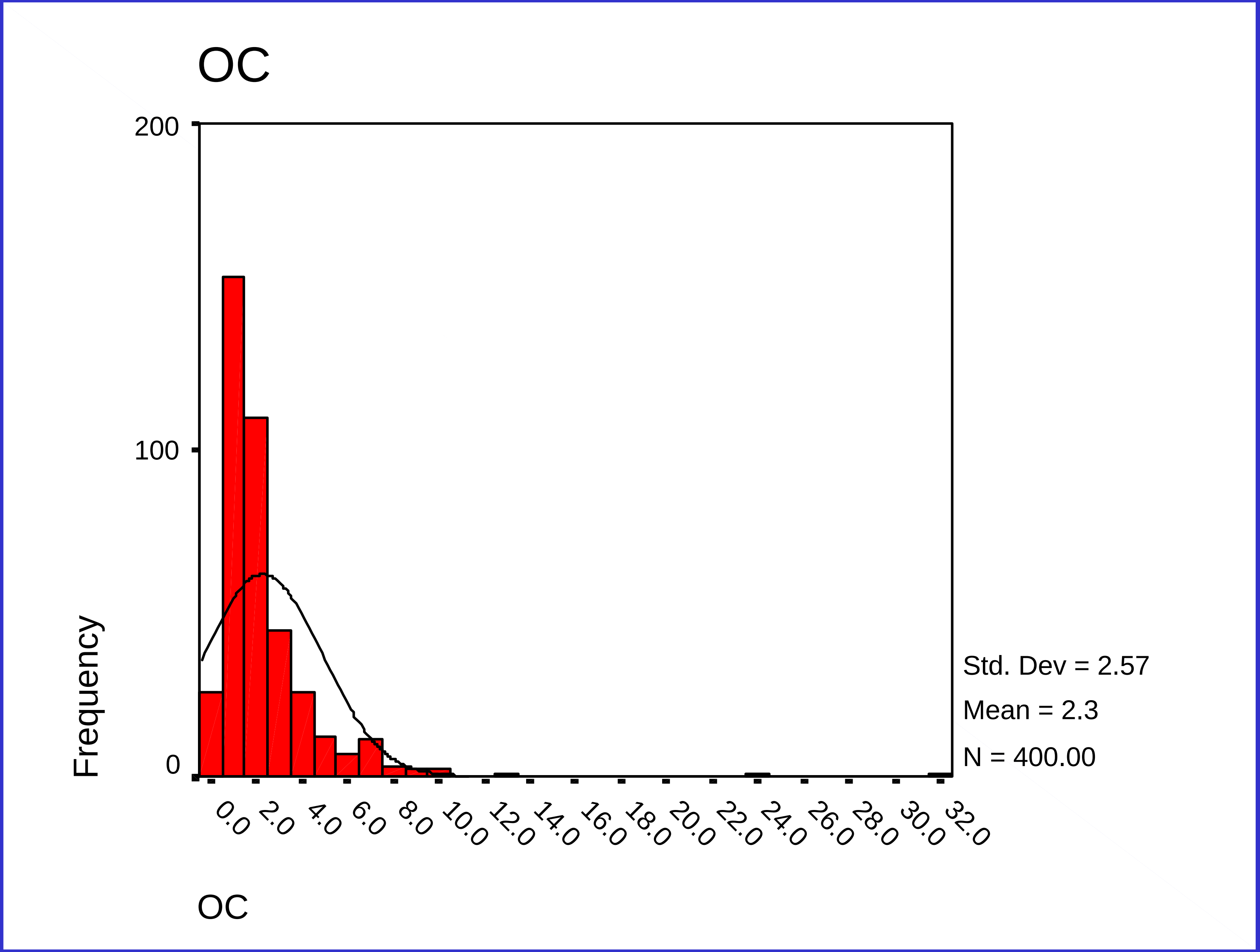
Soil

- Organic Carbon: log 0.437 ± 0.771
- Bulk density: 1.42 ± 0.12 g/ml
- Wilting Point: 0.1-0.489 v/v

DERIVED VARIABLE

$$Kd = Koc * OC / 100$$

DISTRIBUTION OF THE SOIL ORGANIC CARBON CONTENT



LEGENDA

COVMAX	Max. area coverage of crop
JUNE	Depth of water: *June*
JULY	Depth of water: *July*
AUG	Depth of water: *August*
DLAKED	Initial water depth
SEEP	Seepage rate
DR8MAX	Drainage rate
IRATE	Irrigation rate
DACT	Depth active sediment layer
WP	Wilting point soil
BD	Bulk density soil
APP	Application rate
APPEF	Application efficiency
KW	Degradation rate in water of pesticide
KS	Degradation rate in sediment of pesticide
KF	Degradation rate in plant of pesticide
W0	Washoff per cm precipitation
KD	Sorption coefficient obtained Koc * OC / 100
VBIND	Mixing depth of sediment
KOC	Sorption coefficient K_{oc} of pesticide
OC	Organic Carbon content of soil

Distribution of generate random variable

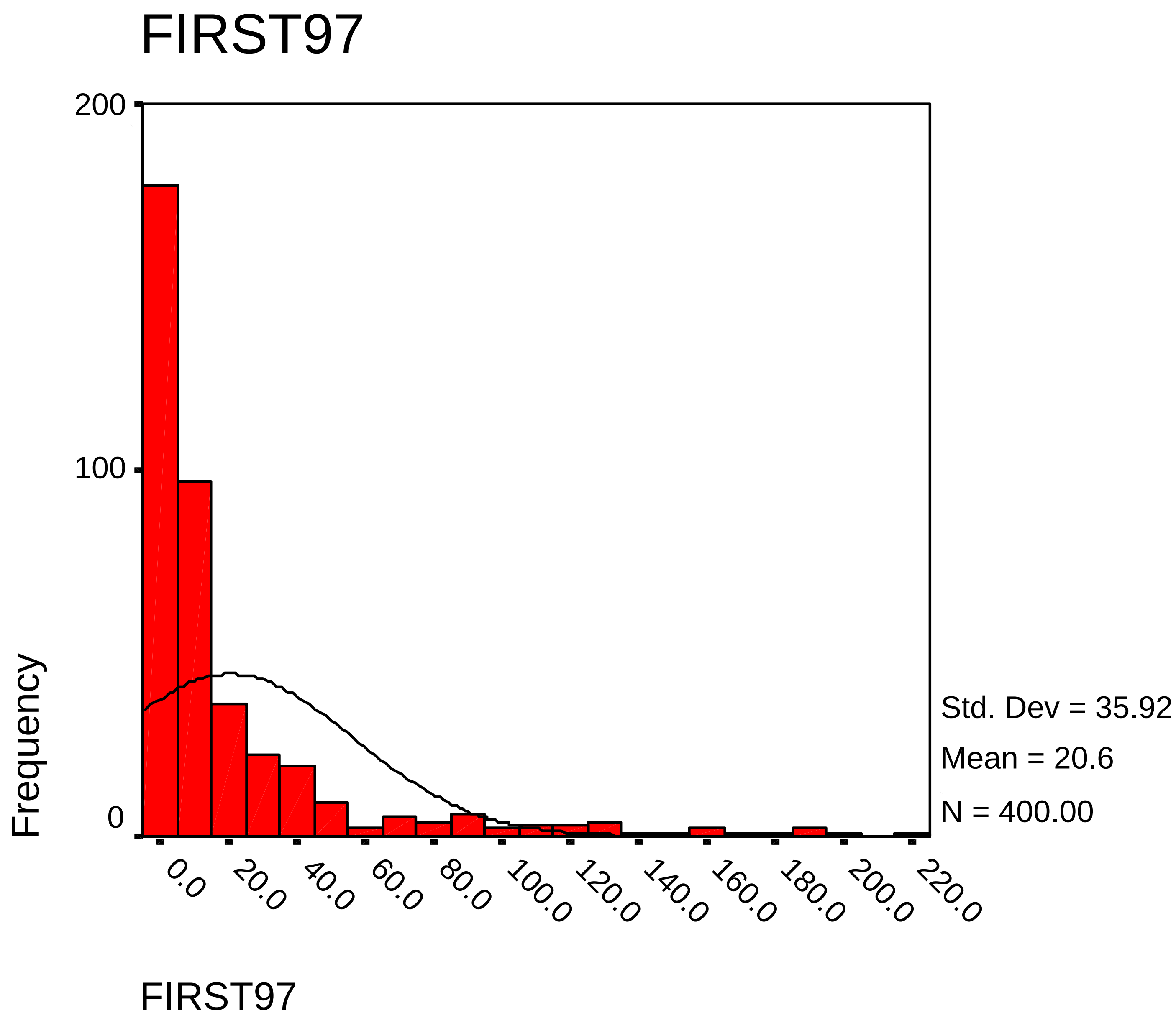
Descriptive Statistics

	N	Minimum	Maximum	Mean	Std. Deviation
COVMAX	400	.9001	1.0000	.949170	3.02033E-02
JUNE	400	5.02	10.00	7.4586	1.4629
JULY	400	15.00	19.97	17.4645	1.4094
AUG.	400	25.01	29.97	27.4803	1.4004
DLAKED	400	.006	9.957	4.89042	2.87899
SEEP	400	.101	.300	.20497	5.6196E-02
DR8MAX	400	1.000	2.997	2.00797	.59341
IRATE	400	1.511	3.496	2.50683	.57624
DACT	400	3.008	6.997	5.04939	1.18012
WP	400	.010	.239	.10272	6.6619E-02
BD	400	1.0759	1.7513	1.430797	.116102
APP	400	.300	.600	.45187	8.6423E-02
APPEF	400	.9002	1.0000	.950674	2.86403E-02
KW	400	.0187	.0289	2.33E-02	1.56973E-03
KS	400	.0462	.1386	7.52E-02	2.78519E-02
KF	400	.0210	.2310	5.91E-02	4.96899E-02
W0	400	.000	.100	4.97E-02	2.8785E-02
KD	400	2.2788	502.1324	74.704183	74.405624
VBIND	400	.050	.149	.10118	2.8635E-02
KOC	400	1152.59	5660.59	3393.0133	1270.0944
OC	400	.12	31.84	2.2794	2.5732
Valid N (listwise)	400				

OUTPUT data

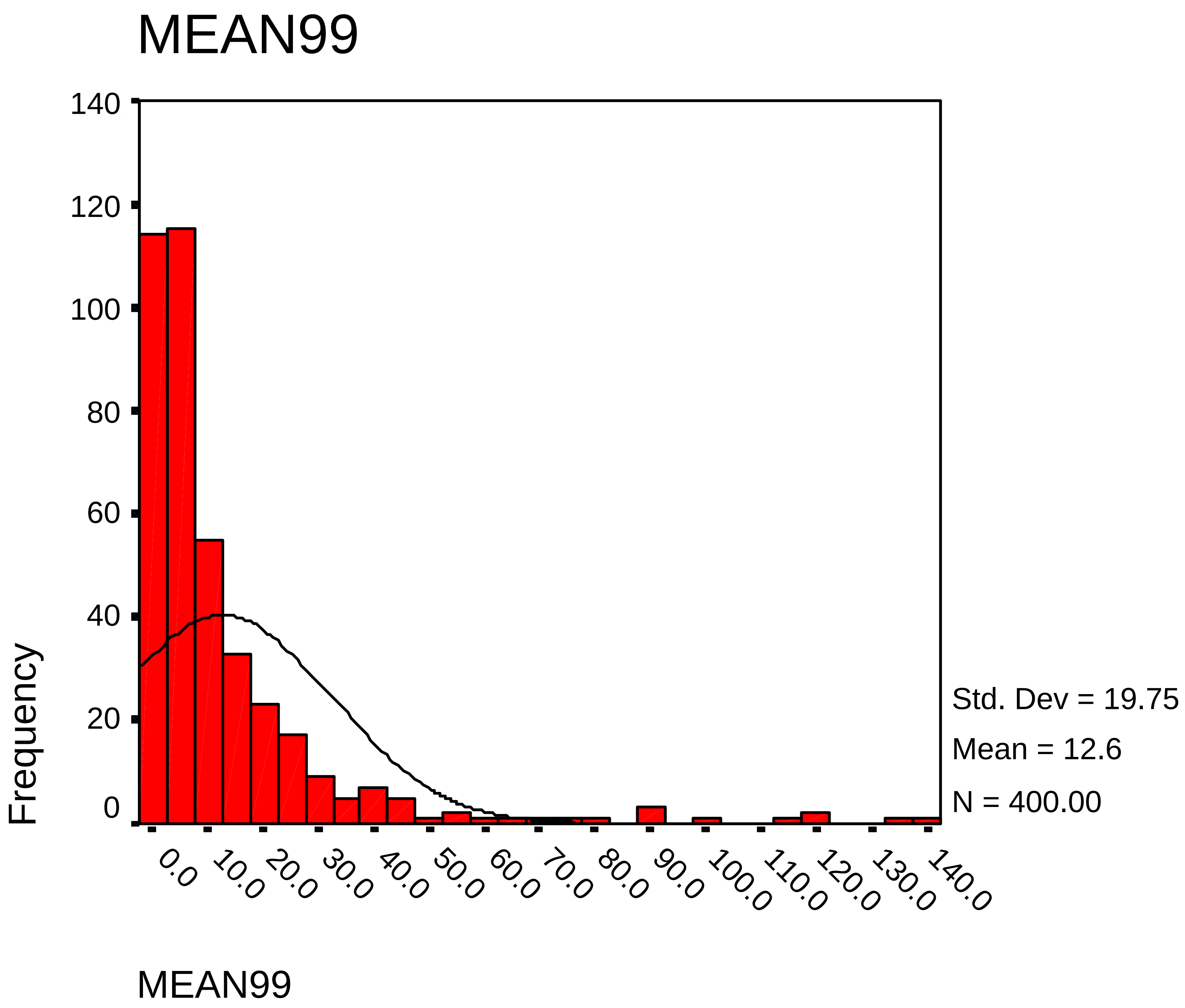
Pesticide concentration in the outflow (μg/l in dissolved phase) calculated as

- concentration of first day with water outflow after treatment
- cumulative concentration 21 days after the treatment
- time weighted average concentration 21 days after the treatment


FIRST97
200
100
0
Frequency
0.0
20.0
40.0
60.0
80.0
100.0
120.0
140.0
160.0
180.0
200.0
220.0
Std. Dev = 35.92
Mean = 20.6
N = 400.00
FIRST97

Statistics

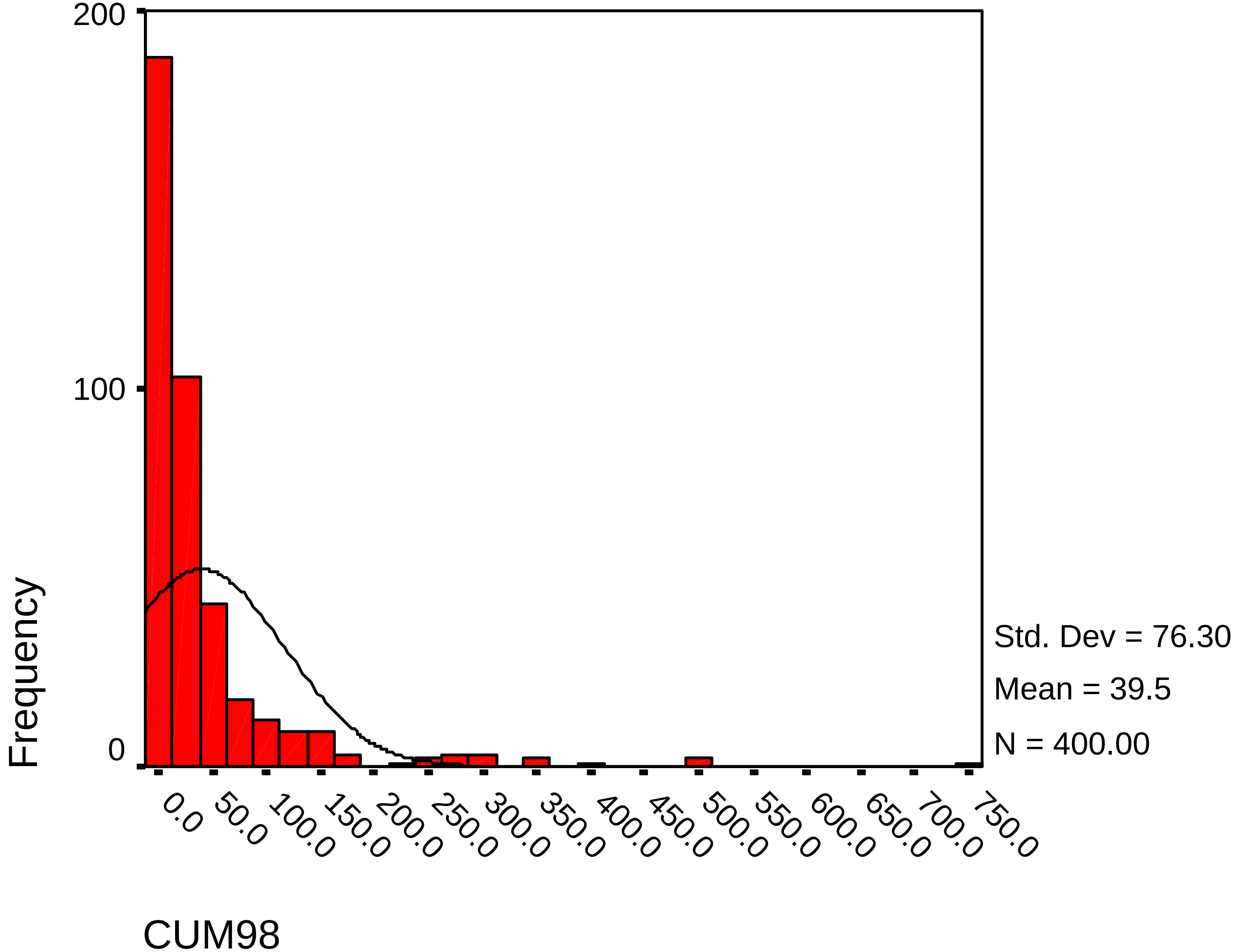
		FIRST91	FIRST92	FIRST93	FIRST95	FIRST94	FIRST96	FIRST97	FIRST98	FIRST99
N	Valid	400	400	400	400	400	400	400	400	400
	Missing	0	0	0	0	0	0	0	0	0
Mean		21.6023	2.2E+01	21.3464	2.1E+01	2.2E+01	20.7930	20.6152	21.2925	20.2609
Median		8.7750	7.2E+00	6.7970	1.1E+01	6.4E+00	6.6780	6.1250	6.3330	7.0830
Std. Deviation		36.0319	3.8E+01	38.9234	3.4E+01	4.1E+01	37.5175	35.9194	37.7711	34.9854
Percentiles	95	112.9500	1.1E+02	104.6850	8.6E+01	1.3E+02	100.6850	107.3300	109.3450	109.7330


MEAN99
140
120
100
80
60
40
20
0
Frequency
0.0
10.0
20.0
30.0
40.0
50.0
60.0
70.0
80.0
90.0
100.0
110.0
120.0
130.0
140.0
Std. Dev = 19.75
Mean = 12.6
N = 400.00
MEAN99

Statistics

		MEAN91	MEAN92	MEAN93	MEAN95	MEAN94	MEAN96	MEAN97	MEAN98	MEAN99
N	Valid	400	400	399	397	400	399	399	399	400
	Missing	0	0	1	3	0	1	1	1	0
Mean		10.9347	10.2387	8.3530	10.4483	9.4E+00	9.5E+00	1.4E+01	7.8E+00	1.3E+01
Median		4.7204	4.7868	3.7081	6.8535	3.8E+00	4.5E+00	6.4E+00	2.8E+00	5.8E+00
Std. Deviation		17.4363	16.8171	15.3031	11.9190	1.6E+01	1.3E+01	2.2E+01	1.7E+01	2.0E+01
Percentiles	95	37.3653	37.4242	37.0502	30.0466	3.4E+01	3.4E+01	5.4E+01	3.1E+01	4.4E+01

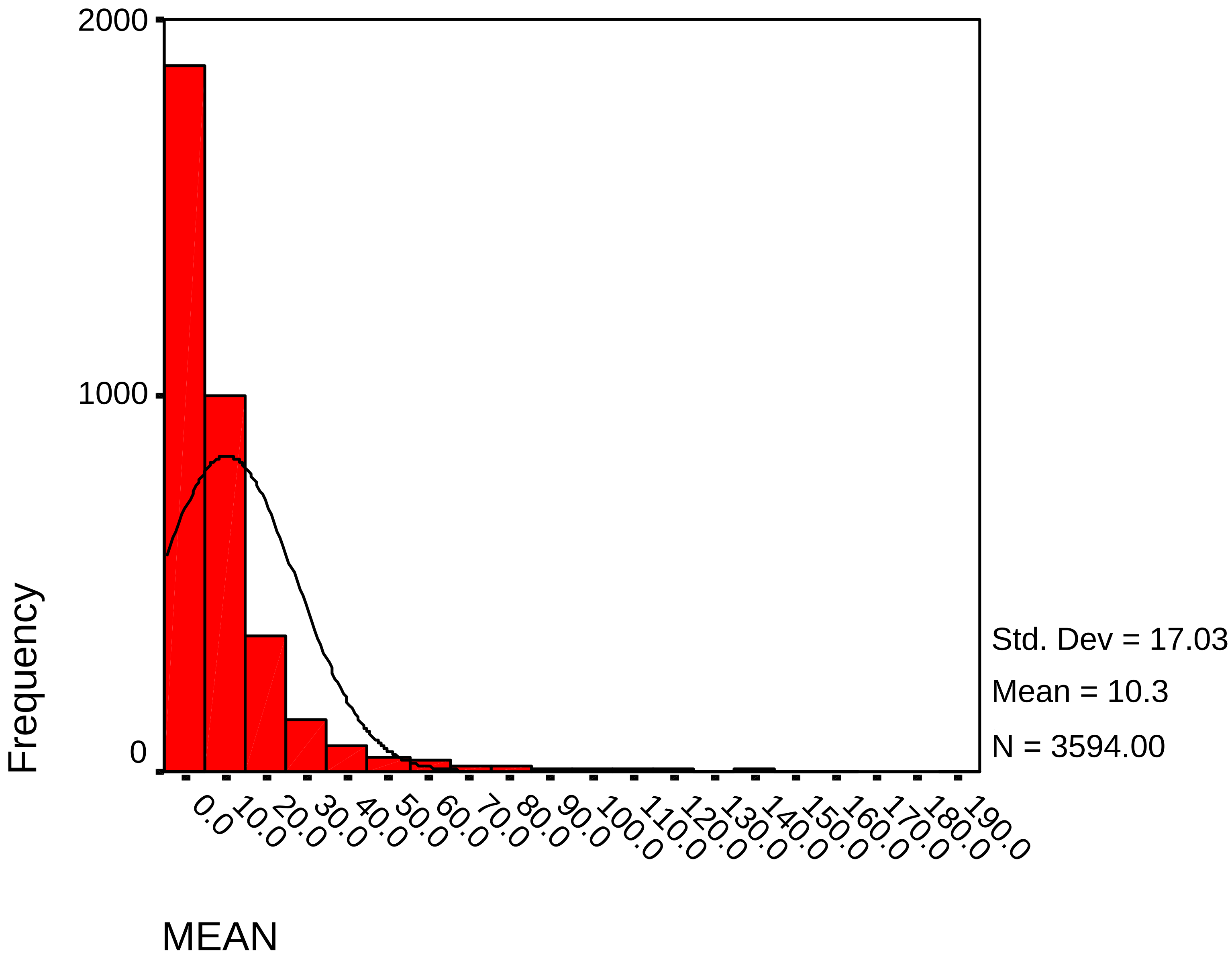
CUM98


200
100
0
Frequency
0.0
50.0
100.0
150.0
200.0
250.0
300.0
350.0
400.0
450.0
500.0
550.0
600.0
650.0
700.0
750.0
Std. Dev = 76.30
Mean = 39.5
N = 400.00
CUM98

Statistics

		CUM91	CUM92	CUM93	CUM95	CUM94	CUM96	CUM97	CUM98	CUM99
N	Valid	400	400	400	400	400	400	400	400	400
	Missing	0	0	0	0	0	0	0	0	0
Mean		48.3618	48.5969	42.7326	60.9681	45.3938	44.2318	47.3311	39.5317	48.8087
Median		21.7500	19.2871	15.0135	29.4479	15.4070	19.2834	19.9159	13.5710	20.0184
Std. Deviation		77.4229	82.8973	79.5638	97.5102	81.7065	75.7687	76.5822	76.3040	78.4001
Percentiles	95	220.1441	219.5115	194.2454	250.0938	197.5893	175.1612	176.2242	161.1253	185.9967

MEAN


2000
1000
0
Frequency
0.0
10.0
20.0
30.0
40.0
50.0
60.0
70.0
80.0
90.0
100.0
110.0
120.0
130.0
140.0
150.0
160.0
170.0
180.0
190.0
Std. Dev = 17.03
Mean = 10.3
N = 3594.00
MEAN

Statistics

		FIRST	MEAN
N	Valid	3600	3594
	Missing	0	6
Mean		21.2751	10.3235
Median		7.4855	4.6426
Std. Deviation		37.1303	17.0296
Percentiles	90	56.7620	24.6235
	95	107.8850	38.0882

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.186[a]	.035	.032	37.1592
2	.247[b]	.061	.056	36.6922
3	.281[c]	.079	.072	36.3904
4	.297[d]	.088	.079	36.2511

a. Predictors: (Constant), KD

b. Predictors: (Constant), KD, JUNE

c. Predictors: (Constant), KD, JUNE, APP

d. Predictors: (Constant), KD, JUNE, APP, DLAKED

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.213[a]	.045	.043	36.7045
2	.276[b]	.076	.072	36.1467
3	.314[c]	.099	.092	35.7505
4	.328[d]	.108	.099	35.6175

a. Predictors: (Constant), KD

b. Predictors: (Constant), KD, JUNE

c. Predictors: (Constant), KD, JUNE, APP

d. Predictors: (Constant), KD, JUNE, APP, IRATE

Stepwise regression of 20 factors of uncertainty										
FIRST	1991	1992	1993	1994	1995	1996	1997	1998	1999	Mean
Covmax	-	+	-	-	-	-	-	-	-	-
June	+	+	+	+	+	+	+	+	+	+
July	-	-	-	-	-	-	+	+	+	-
Aug.	+	+	+	+	+	+	+	-	+	+
DLAKED	+	0	0	0	+	0	0	0	+	0
SEEP	0	0	0	0	0	0	0	0	0	0
DR8Max	0	0	0	0	0	0	0	0	0	0
IRATE	0	0	0	0	0	0	0	0	+	0
DACT	0	+	+	0	0	0	0	0	0	0
WP	-	-	-	+	+	-	-	+	+	+
BD	0	0	0	0	0	0	0	0	0	0
App date	-	-	-	-	-	-	-	-	-	-
APP	+	+	+	+	+	+	+	+	+	+
APPEF	-	-	-	-	-	-	-	-	-	-
Kw	0	0	0	0	0	0	0	0	0	0
KS	+	+	0	0	+	0	+	0	0	+
KF	-	0	0	0	0	0	0	0	0	0
W0	0	0	0	0	0	0	0	0	0	0
Kd	-	-	-	-	-	-	-	-	-	-
VBIND	0	0	-	-	-	0	0	-	-	-

Stepwise regression of 20 factors of uncertainty										
Cum 21	1991	1992	1993	1994	1995	1996	1997	1998	1999	Mean
Covmax	-	-	-	-	-	-	-	-	-	-
June	+	+	+	+	+	+	+	+	+	+
July	+	+	+	+	+	+	+	+	+	+
Aug	+	+	+	+	+	+	+	+	+	+
DLAKED	0	0	0	0	0	0	0	0	0	0
SEEP	0	0	0	0	0	0	0	0	0	0
DR8Max	0	0	0	0	0	0	0	0	0	0
IRATE	0	0	0	0	0	0	0	0	+	0
DACT	0	0	0	0	0	0	0	0	0	0
WP	+	+	-	+	-	-	+	+	+	+
BD	0	0	0	0	0	0	0	0	0	0
App date	-	-	-	-	-	-	-	-	-	-
APP	+	+	+	+	+	+	+	+	+	+
APPEF	+	-	-	-	-	-	-	-	-	-
Kw	0	0	0	0	0	0	0	0	0	0
KS	+	+	+	+	+	+	+	+	+	+
KF	-	-	0	0	-	0	0	0	-	-
W0	0	0	0	0	+	0	0	0	0	0
Kd	-	-	-	-	-	-	-	-	-	-
VBIND	-	-	-	-	-	-	-	-	-	-

Stepwise regression of 20 factors of uncertainty										
Mean 21	1991	1992	1993	1994	1995	1996	1997	1998	1999	Mean
Covmax	-	-	-	+	-	-	-	+	-	-
June	+	+	-	+	+	+	+	-	+	+
July	-	-	-	-	-	-	-	-	+	-
Aug	+	+	-	-	-	+	+	-	+	-
DLAKED	0	0	0	0	0	0	+	0	0	0
SEEP	0	+	0	0	0	0	0	0	0	0
DR8Max	0	0	0	0	0	0	0	0	0	0
IRATE	0	0	0	0	0	0	0	0	0	0
DACT	0	0	0	0	0	0	0	0	0	0
WP	+	-	-	+	-	+	-	+	+	-
BD	0	0	0	0	0	0	0	0	0	0
App date	-	-	-	-	-	-	-	-	-	-
APP	+	0	+	+	+	+	+	+	+	+
APPEF	-	-	+	-	-	-	+	-	-	-
Kw	0	0	0	0	-	0	0	0	0	0
KS	0	0	0	0	0	0	0	0	0	0
KF	-	-	0	0	-	-	0	0	-	-
W0	+	+	0	0	+	+	0	0	+	+
Kd	-	-	-	-	-	-	-	-	-	-
VBIND	-	-	-	-	-	-	-	-	-	-

RESULTS

Frequencies distribution seems lognormal.

Parameters important are:

Kd (Koc and organic carbon)

mixing depth of sediment

date of application

application rate

max crop coverage

water management behaviour as depth of paddy

UPSCALING

How perform upscaling ?

Our idea was to found a metamodel useful for extend the results.

Difficulties due:

- low correlation between outputs and input data
- the variables correlated are often not spatial distributed
- and some of these are empirical

CONCLUSION

- stochastic approach allows to carry out more realistic risk assessment
- stochastic approach allows to identify crucial variable in the model
- it is difficult to upscale results in paddy area using RICEWQ model