Review of Current Pesticide Risk Assessment Models and Development of a PURE Model

Minghua Zhang and Yu Zhan
Dept. of Land, Air and Water Resources
University of California Davis




Partial References

Acronym	Model	Year	Location	Citation
Relative Scoring Method				
EIQ	Environmental Impact Quotient	1992	USA	(Kovach et al. 1992)
SSRP	Site Specific Pesticide Recommendations	1992	USA	(Hornsby 1992)
PI	Pesticide Index	1994	Australia	(Penrose et al. 1994)
CHEMS-1	Chemical Hazard Evaluation for Management Strategies 1	1996	USA	(Swanson et al. 1997)
EHP	Environmental Health Policy Programme Ranking System	1996	USA	(Pease et al. 1996)
PERI	Pesticide Environmental Risk Indicators	1999	Sweden	(Nilsson 1999)
MATF	Multi-Attribute Toxicity Factor	2002	USA	(Benbrook et al. 2002)
Win-PST	Windows Pesticide Screening Tool	2005	USA	http://www.wsi.nrcs.usda.gov/products/W2Q/pest/winpst.html
Risk Ratio Method				
EYP	Environmental Yardstick for Pesticides	1994	Netherlands	(Levitan 1997)
SYNOPS-1.1	Synoptisches Bewertungsmodell fur Pflanzenschutzmittel 1.1	1997	Germany	(Gutsche et al. 1997)
SYNOPS-2	Synoptisches Bewertungsmodell fur Pflanzenschutzmittel 2	1999	Germany	http://www.aftresearch.org/ipm/risk/
SYPEP	System for Predicting the Environmental Impact of Pesticides	1999	Belgium	http://www.aftresearch.org/ipm/risk/
EcoRR	Ecological Relative Risk	2002	Australia	(Sanchez-Bayo, 2002)
pEMA	Pesticide- Environmental Management for Agriculture	2002	UK	(Brown et al. 2003, Hart et al. 2003, Lewis et al. 2003)
POCER	Pesticide Occupational and Environmental Risk	2002	Belgium	(Vercruysse et al. 2002)
EPRIP	Environmental Potential Risk Indicator for Pesticides	2004	Italy	(Padovani et al. 2004)
PRoMPT	Pesticide Risk Management and Profiling Tool	2005	Australia	(Whelan et al. 2005)
HAPERITIF	Harmonized Pesticide Risk Trend Indicator for Food	2006	Italy	(Calliera et al. 2006)
PIRI	Pesticide Impact Rating Index	2006	Australia	http://www.clw.csiro.au/research/biogeochemistry/assessment/projects/piri.html
Fuzzy Logic Expert Method				
IPEST	Ipest	1997	France	(van der Werf et al. 1998)
IPEST-B	Ipest (B stands for Brittany)	2000	France	(Roussel et al. 2000)
Rpest	Risk of Pesticide	2007	France	(Tixier et al. 2007)

Model Comparisons

Models	Study Purpose	Risk Components	Use Suitability	Advantages	Disadvantage/Limitations	Source(s)	Scale	Methodology Used	Country Developed	Time
CHEMS	As a screening tool to provide a relative assessment of chemical hazards to human health and the environment	(acute, chronic human health), (terrestrial acute, aquatic acute, aquatic chronic environmental effects)	Selecting priority chemicals for safer substitutes assessment	Presenting a good way to describe the hazard of pesticides	The fate of metals after release is not completely accounted for; BOD and chemicals already exist in the environment is hard to decided at farm level.	Swanson, M., Davis, 1997. A screening method for ranking and scoring chemicals by potential human health and environmental impacts. Environmental Toxicology and Chemistry 16 (2), 372-383.	Pesticide, Crop, Farm, Regional	Relative scoring tables	USA	1996
EEP	To quantify the exposure of the environment to pesticides, based on molecular-chemical properties of the pesticides	air, water, soil	Providing a rational basis for targeted improvement.	Including air compartment.	Only estimating the exposure, no toxicity was included.	Wijnands, F.G. 1997. Integrated crop protection and environment exposure to pesticides: methods to reduce use and impact of pesticides in arable farming. European Journal of Agronomy 7:251-260.	Pesticide, crop, farm	Not defined, like part of risk ratios	The Netherlands	1997
EIQ	To organize the published environmental impact information of pesticide into a usable form to help Growers, other IPM practioners make more environmentally sound pesticide choice	(Applicator, picker), (consumer exposure, groundwater), (fish birds, bees, beneficial arthropods)	Making more environmental sound pesticide choices; measuring the environmental impact of different pest management and pesticide programs	Simple to use; including many risk components.	The pesticide operators and workers of the EIQ is only based on toxicity data for rabbits/rats, no exposure calculations are included.	Kovach, J., 1992. Amethod to measure the environmental impact of pesticides. New York's Food and Life Sciences Bulletin 139, 1-8	Pesticide, Regional	Relative scoring tables	USA	1992

Model Categories

1. Relative Scoring
   - EIQ, SSRP, PI, CHEMS-1, EHP, PERI, MATF, Win-PST
2. Risk Ratio
   - EYP, SYNOPS-1.1, SYNOPS-2, SYPEP, EcoRR, pEMA, POCER, EPRIP, PRoMPT, HAPERITIF, PIRI
3. Fuzzy Logic Expert System
   - Ipest, Ipest-B, Rpest
4. Other categories
   - EEP, PERPEST, PestLCI

1. Relative Scoring

- Input parameters:
  - Values of inputs are transformed into ranks, and then condensed into one or more risk indicators.
- Advantage:
  - Data likely to be available
  - Easy to use
- Disadvantage:
  - Heavily relying on pesticide toxicity data
  - Information largely condensed and simplified

Relative Scoring Example 1,EIQ

- Acute Dermal LD_{50} Rats/Rabbits (DT)

DT Rank	**LD_{50}**
1	> 2000 mg/kg
3	200 – 2000 mg/kg
5	0 – 200 mg/kg

$$EIQ = \frac{[C \times (DT \times 5 + DT \times P)] + [C \times \frac{S+P}{2} \times SY + L] + [F \times R + D \times \frac{S+P}{2} \times 3 + Z \times P \times 3 + B \times P \times 5]}{3}$$

Farm worker **Consumer** **Ecological**

EIQ model

- Quantitative values, separate and aggregated risks

Pesticides A.I.	EIQ INDEX	FARM WORKER	CONSUMER	ECOLOGICAL
Abamectin	0.32	18	3	59
Azinphos-methyl	47.14	30	2	73
Bifenazate	7.83	18	3	61
Carbaryl	39.67	54	6	42
Chlorpyrifos	56.56	18	3	76
Clofentezine	3.69	18	7	48
Diazinon	44.25	7	2	99
Dicofol	44.86	18	7	67
Diflubenzuron	8.01	8	3	83
Fenbutatin oxide	27.33	21	4	117
Hexythiazox	7.99	30	13	107
Lambda Cyhalothrin	1.49	62	5	92
Malathion	149.19	54	4	68

Relative Scoring Example 2,
Win-PST model (qualitative ranks)

Pesticide A.I.	Fish			Human	
	IARP	ILP	ISRP	ILP	ISRP
Abamectin	H	X	X	H	H
Azinphos methyl	I	X	X	I	I
Bifenazate	L	I	I	H	H
Carbaryl	L	I	I	I	I
Chlorpyrifos	L	X	X	I	I
Clofentezine	L	I	H	I	H
Diazinon	H	X	X	X	X
Dicofol	L	I	H	H	X
Diflubenzuron	L	H	H	V	V
Fenbutatin oxide	I	X	X	V	L
Hexythiazox	L	I	I	I	I
Lambda Cyhalothrin	L	H	X	I	H
Malathion	I	X	X	I	I

IARP: Soil / Pesticides Interaction Adsorbed Runoff Potential

ILP: Soil / Pesticides Interaction Leaching Potential

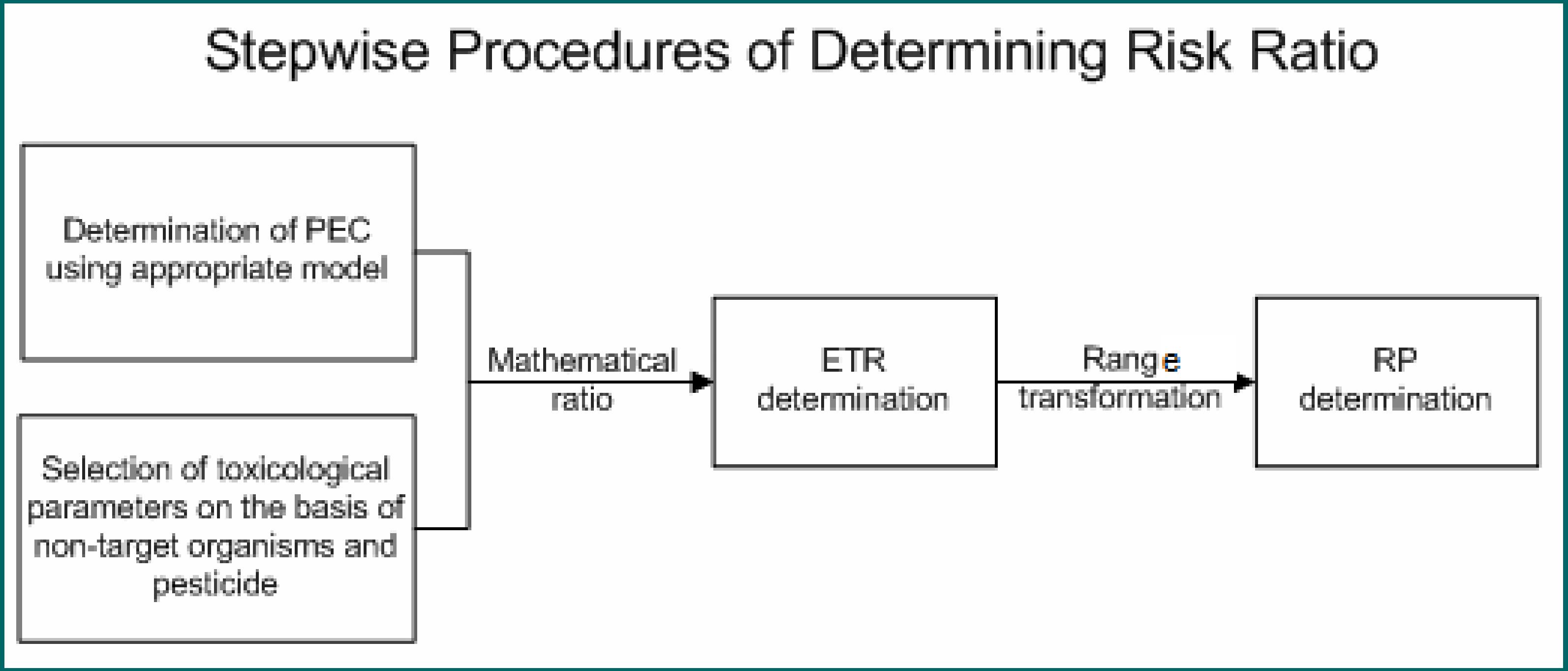
ISRP: Soil / Pesticides Interaction Solution Runoff Potential

X: extra high; H: high; **I**: intermediate; **L**: low; V: very low

2. Risk Ratio

- Definition:
  - Represent risk as a ratio between exposure and toxicity, usually using exposure simulation sub-models.
- Advantage:
  – Simulate pesticide exposures of non-target organisms
- Disadvantage:
  – Exposure simulation can be complex or the results may not match well with the reality
  – More data are usually required

Risk Ratio Flow Chart



PEC: Predicted Environmental Concentration

ETR: Exposure Toxicity Ratio = PEC / Toxicity

RP: Risk Point

Risk Ratio Example 1, EPRIP model

Pesticides A.I.	Aggregated	Groundwater	Surface Water	Soil	Air
Abamectin	29	1	4	1	1
Azinphos-methyl	60	1	5	2	1
Bifenazate	60	1	5	2	1
Carbaryl	65	1	5	3	1
Chlorpyrifos	60	1	5	2	1
Clofentezine	3	1	3	1	1
Diazinon	60	1	5	2	1
Dicofol	33	1	4	2	1
Diflubenzuron	29	1	4	1	1
Fenbutatin oxide	3	1	3	1	1
Hexythiazox	3	1	3	1	1
Lambda Cyhalothrin	55	1	5	1	1
Malathion	60	1	5	2	1

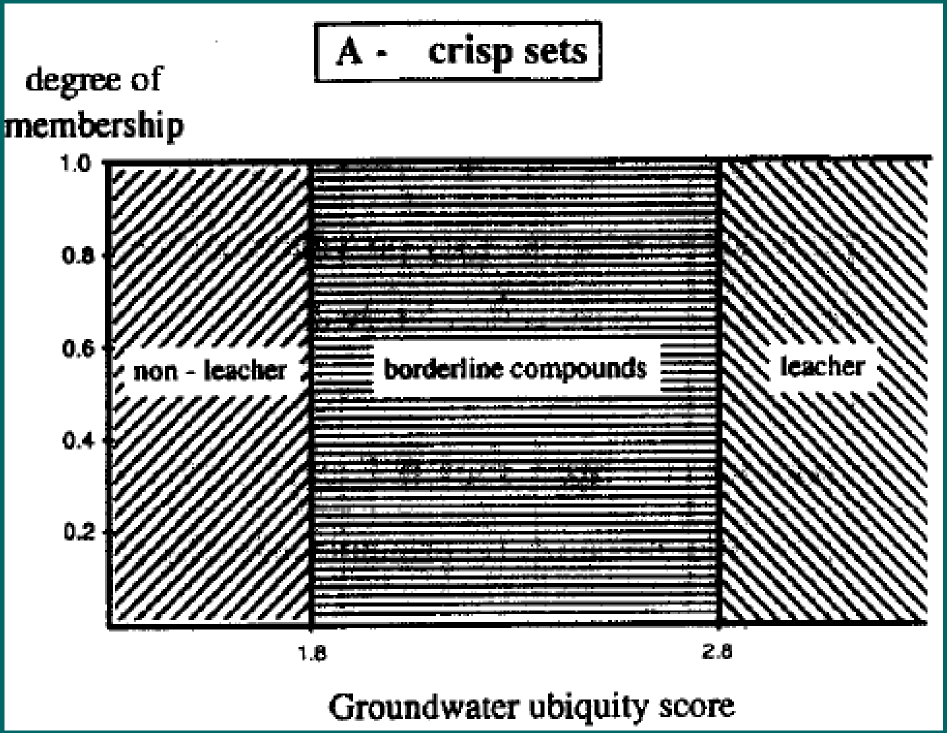
EPRIP evaluated all the pesticides risk to groundwater and air to be 1 (minimum risk) due to its insensitivity to these two compartments.

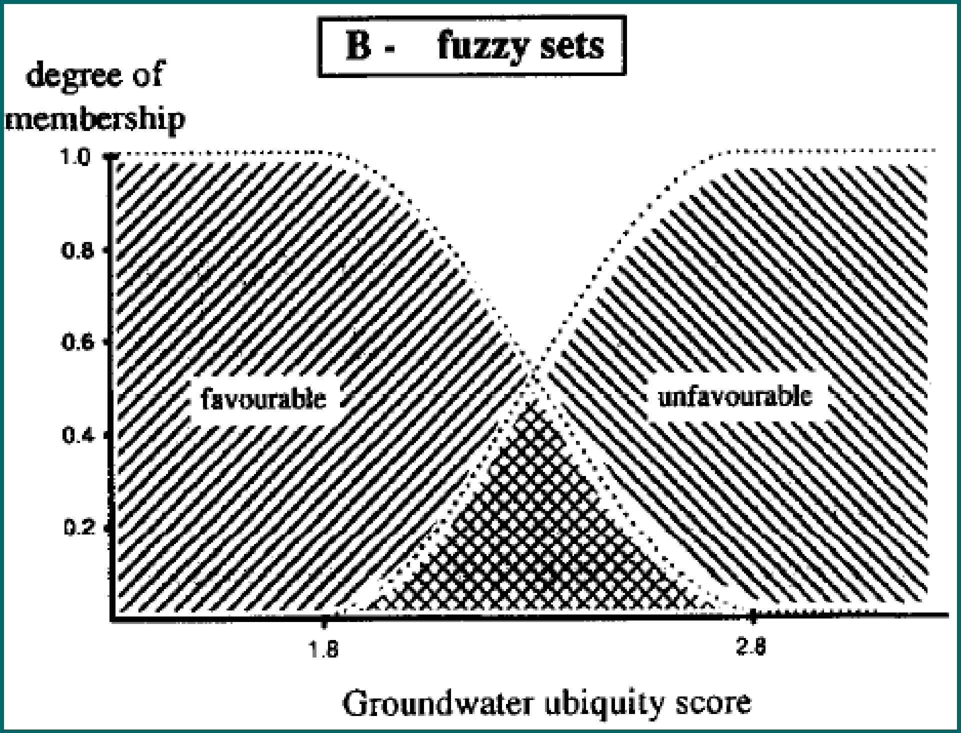
3. Fuzzy Logic Expert System (1)

- Input parameters:
  Input data are assigned values based on their degree of membership to extreme classifications of complete impact or no impact, then use expert opinions based on decision-rules to generate risk points.
- Advantages:
  - Use expert opinions instead of exposure simulation models
- Disadvantages:
  - (Subjective) expert opinion relied

Fuzzy Logic Expert System (2)

1. Fuzzy:

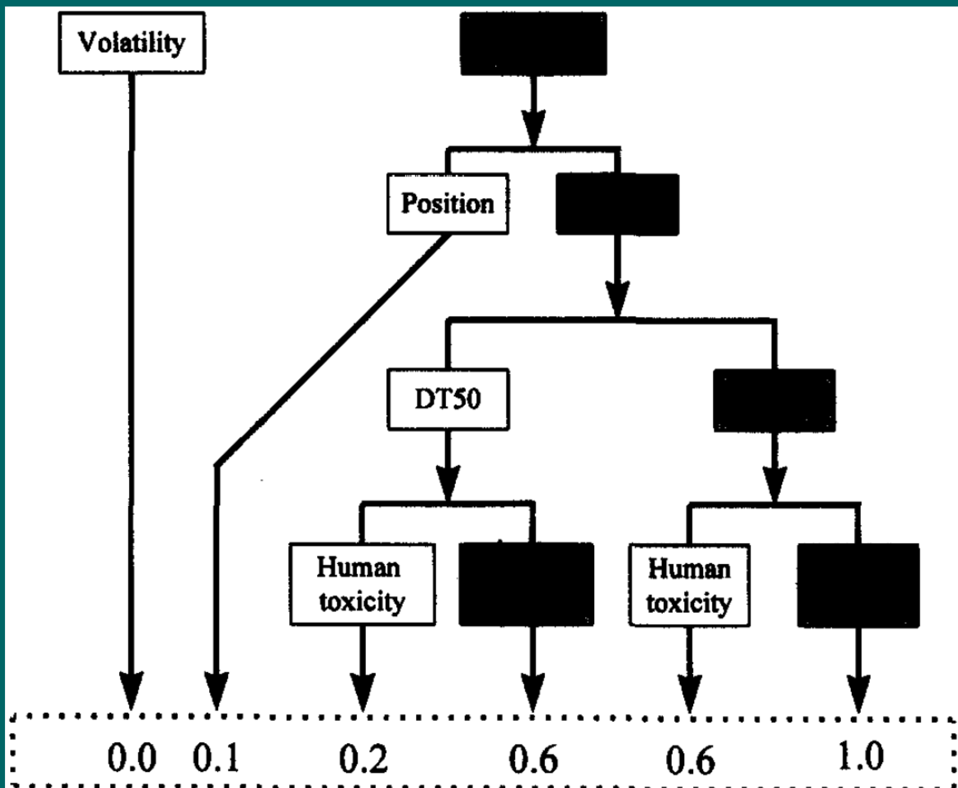




2. Logic:

- If x_1 is A_{11} and x_2 is A_{12}, then y is B_1
- If x_1 is A_{21} and x_2 is A_{22}, then y is B_2

Fuzzy Logic Expert System Example, Ipest (Air risk)



The effect of the input variables Volatility, Position of application, Field half-life and Human toxicity on the value of the conclusions of the decision rules for the indicator module Rair (Risk of air contamination) according to their membership to the fuzzy sets Favorable (non-shaded boxes) and Unfavourable (shaded boxes).

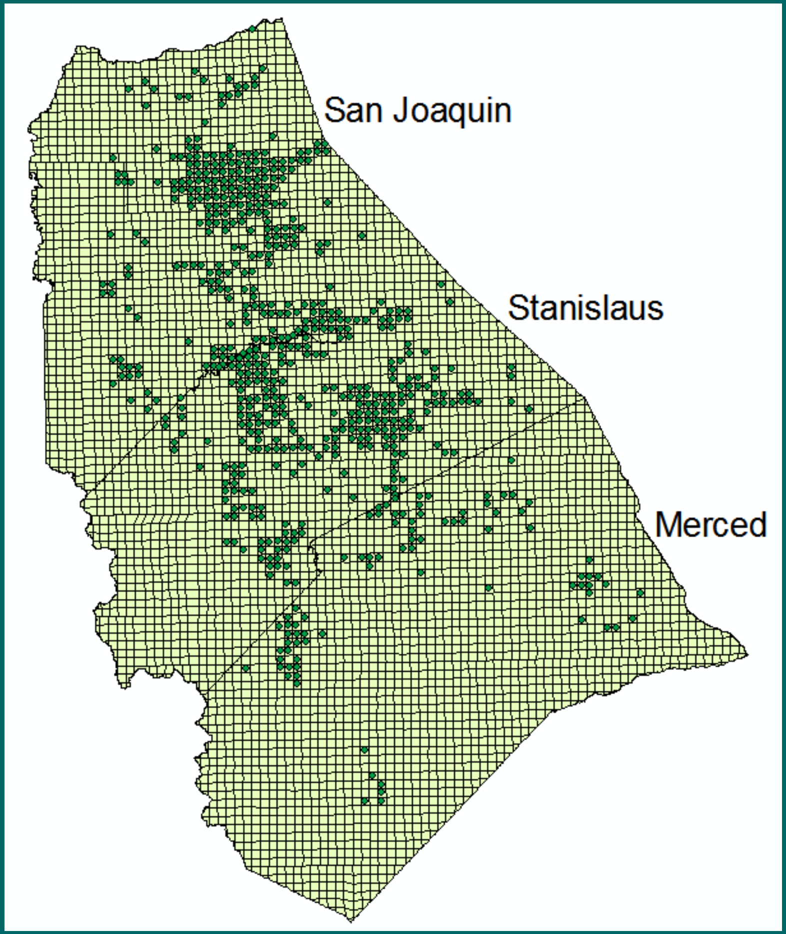
	Volatility/lg(Kh)	Position	DT50	Human Toxicity/lg(ADI)
F	< lg2.65E-6	100% of the pesticide in the soil	< 1 day	> lg(1 mg/kg)
U	> lg2.65E-4	0% of the pesticide in the soil	> 30 days	< lg(0.0001 mg/kg)

Fuzzy Logic Expert System Example, Ipest model

Chemical Name	Aggregated	Presence	Groundwater	Surface Water	Air
Abamectin	0.30	0.00	0.00	1.00	0.00
Azinphos-methyl	0.70	0.81	0.00	1.00	0.00
Bifenazate	0.59	0.48	0.00	1.00	0.44
Carbaryl	0.68	0.78	0.09	1.00	0.00
Chlorpyrifos	0.73	0.85	0.00	1.00	0.45
Clofentezine	0.43	0.34	0.00	0.88	0.07
Diazinon	0.68	0.79	0.00	1.00	0.20
Dicofol	0.58	0.82	0.00	0.87	0.15
Diflubenzuron	0.53	0.45	0.00	1.00	0.00
Fenbutatin oxide	0.56	0.64	0.00	0.92	0.10
Hexythiazox	0.39	0.35	0.00	0.82	0.04
Lambda Cyhalothrin	0.36	0.05	0.00	1.00	0.11
Malathion	0.77	0.95	0.00	1.00	0.00

Case Study – walnut insecticides

- Studied area:
  San Joaquin, Stanislaus, and Merced counties
- Studied orchard: Walnut
- Studied period:
  2002 - 2004



Main Data Sources

- Chemical, physical and toxic properties of A.I.
  - MeisterPro Crop Protection eHandbook 2007
  - FPPD (FOOTPRINT Pesticide Properties Database)
  - PAN (Pesticide Action Network)
  - Biobest
- Application rate & pesticides product info
  - PUR database (Pesticide Use Reporting)
  - EP database (Emission Potential)
- Soil properties of San Joaquin Valley
  - SSURGO (Soil Survey Geographic)
- Meteorological data of San Joaquin Valley
  - CIMIS (California Irrigation Management Information System)
  - USGS (U.S. Geological Survey)

Model Comparison Method

- Spearman Correlation method
  used to test the similarity between models due to the non-normality distribution.

- Model output comparisons for
  - aggregated final values
  - separate risk components
    - Groundwater, surface water, soil, air, bee, beneficial, bird, human.

Models Comparison Results

Chemical Name	EIQ	Ipest	CHEMS1	EPRIP	PERI	POCER
Abamectin	0.32	0.30	0.63	29	0.02	1.66
Azinphos-methyl	47.14	0.70	86.05	60	3.29	3.11
Bifenazate	7.83	0.59	13.12	60	2.04	2.15
Carbaryl	39.67	0.68	59.31	65	5.19	2.59
Chlorpyrifos	56.56	0.73	113.28	60	6.74	2.73
Clofentezine	3.69	0.43	6.89	3	0.29	0.00
Diazinon	44.25	0.68	54.38	60	5.25	3.23
Dicofol	44.86	0.58	147.74	33	5.15	0.39
Diflubenzuron	8.01	0.53	5.83	29	0.74	0.15
Esfenvalerate	1.73	0.35	2.31	55	0.17	2.18
Fenbutatin oxide	27.33	0.56	31.71	3	2.19	2.47
Hexythiazox	7.99	0.39	7.17	3	0.51	0.03
Lambda Cyhalothrin	1.49	0.36	1.74	55	0.08	1.88
Malathion	149.19	0.77	186.57	60	7.46	3.00
Methidathion	80.59	0.68	68.87	65	3.73	2.84
Methomyl	6.23	0.54	16.47	33	0.96	1.72
Methoxyfenozide	6.97	0.44	7.40	1	0.89	0.84
Methyl Parathion	22.09	0.65	51.19	33	2.58	1.08
Naled	29.36	0.67	64.50	55	6.40	2.91
Permethrin	13.48	0.53	9.07	29	0.41	1.94
Phosmet	87.48	0.76	158.02	60	7.10	2.86
Propargite	89.79	0.61	119.63	33	5.35	0.69
Pyridaben	4.25	0.55	8.06	55	0.63	1.47
Pyriproxyfen	1.37	0.33	2.19	2	0.14	0.11
Spinosad	0.21	0.22	0.44	2	0.02	1.17
Tebufenozide	4.18	0.46	9.04	2	1.16	1.32

Good correlations between the models.

Red: the AIs with the 5 highest risk ranks

Green: the AIs with the 5 lowest risk ranks

Correlation Analysis

Averaged Application Rate (AR) Used

	EIQ	Ipest	CHEMS1	EPRIP	PERI	POCER
Ipest	0.91**					
CHEMS1	0.94**	0.93**				
EPRIP	0.61**	0.76**	0.61**			
PERI	0.92**	0.94**	0.95**	0.62**		
POCER	0.51**	0.67**	0.53**	0.76**	0.56**	
AR	0.96**	0.94**	0.97**	0.61**	0.97**	0.50**

All the Application Rate is set to 1 kg/ha

	EIQ	Ipest	CHEMS1	EPRIP	PERI
Ipest	-0.20				
CHEMS1	0.28	-0.44*			
EPRIP	0.14	0.74**	-0.40*		
PERI	0.06	0.03	0.13	-0.14	
POCER	-0.12	-0.05	0.07	0.02	-0.33

**: $p<0.01$; *: $p<0.05$

Model Comparisons on Surface Water Risk

Chemical	EIQ	EPRIP	EYP	Ipest	POCER	SYNOPS1
Abamectin	0.30	4	2622	0.01	0.85	0.00
Azinphos-methyl	33.81	5	81976	1.35	26.64	0.25
Bifenazate	7.13	5	126756	0.29	41.20	0.01
Carbaryl	10.53	5	13002	1.17	4.23	0.60
Chlorpyrifos	43.93	5	68914	1.76	22.40	4.88
Clofentezine	3.80	3	675	0.13	0.22	0.63
Diazinon	18.30	5	81347	1.22	26.44	0.25
Dicofol	36.75	4	1307	1.28	0.42	3.84
Diflubenzuron	1.28	4	2401	0.26	0.78	0.00
Esfenvalerate	1.06	5	28400	0.04	9.23	8.74
Fenbutatin oxide	14.42	3	769	0.53	0.25	0.06
Hexythiazox	3.99	3	266	0.13	0.09	0.45
Lambda Cyhalothrin	0.70	5	8889	0.03	2.89	0.12
Malathion	88.80	5	338295	3.55	109.95	0.36
Methidathion	27.13	5	11304	1.09	3.67	0.07
Methomyl	3.26	4	1907	0.22	0.62	0.00
Methoxyfenozide	0.51	1	3	0.13	0.00	0.06
Methyl Parathion	11.60	4	7066	0.77	2.30	0.34
Naled	24.74	5	188533	0.99	61.27	6.77
Permethrin	4.14	4	1842	0.17	0.60	17.69
Phosmet	73.97	5	98623	2.96	32.05	17.15
Propargite	50.20	4	1363	1.78	0.44	2.48
Pyridaben	3.97	5	17932	0.16	5.83	2.12
Pyriproxyfen	1.51	2	72	0.05	0.02	0.20
Spinosad	0.07	2	11	0.01	0.00	0.00
Tebufenozide	0.62	2	22	0.16	0.01	0.07

Red:

high risk A.I.

Green:

low risk A.I.

Correlation among models for surface water risks

	AR	EIQ	EPRIP	EYP	Ipest	POCER
EIQ	0.92**					
EPRIP	0.45*	0.53**				
EYP	0.51**	0.57**	0.94**			
Ipest	0.99**	0.94**	0.50**	0.55**		
POCER	0.51**	0.57**	0.94**	1.00**	0.55**	
SYNOPS1	0.36	0.53**	0.38	0.33	0.39*	0.33

**: $p<0.01$; *: $p<0.05$.

Summary for Model Comparisons

- The results of most models are highly correlated with application rate (A.I.).

- When the effect of application rate is excluded from the models calculation, the results generated by all the models are poorly correlated.

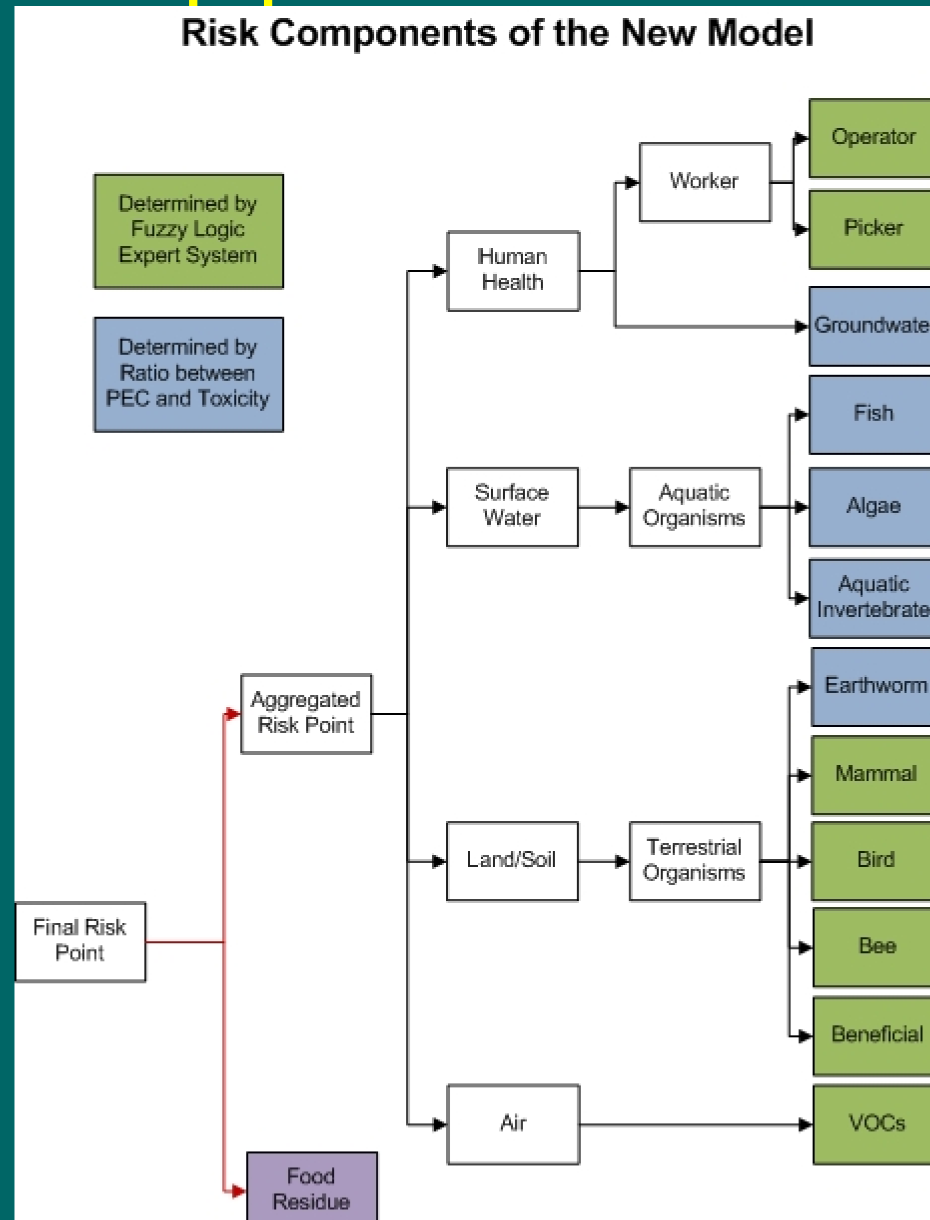
- In evaluating several risk components, some models use the similar algorithms, even the same algorithms.

- Different algorithms may result in similar results.

- We will review more models…

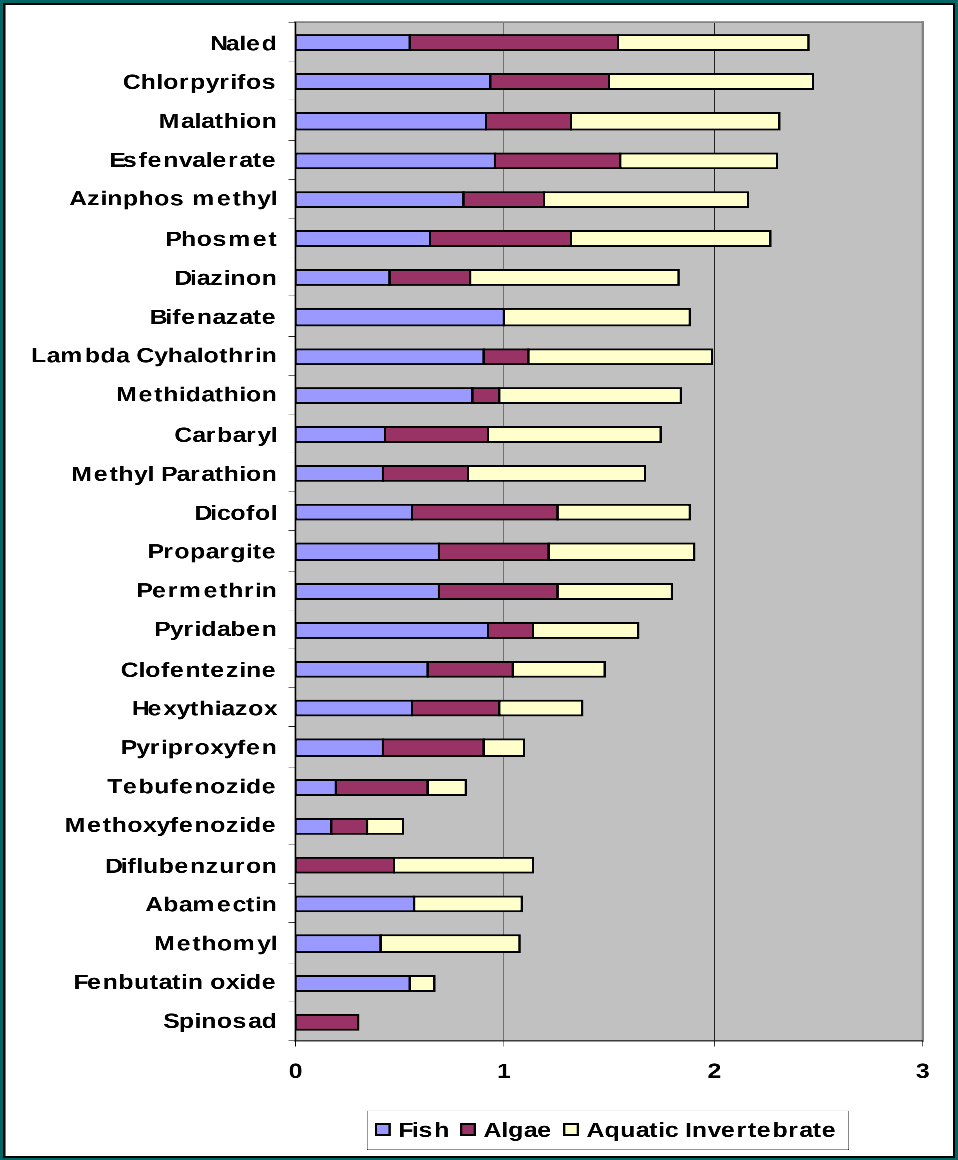
Pesticide Use Risk Evaluation (PURE)

- Major methodologies
  - Fuzzy logic expert system
  - Risk ratio method
- The RP (Risk Point) of each risk component ranges from 0 to 1 (RP↑ ↔ Risk↑), and aggregated by fuzzy logic expert system.
- The “Food Residue” component is independent of application rate.
- The Air risk component is calculated in product level by using EP (Emission Potential).

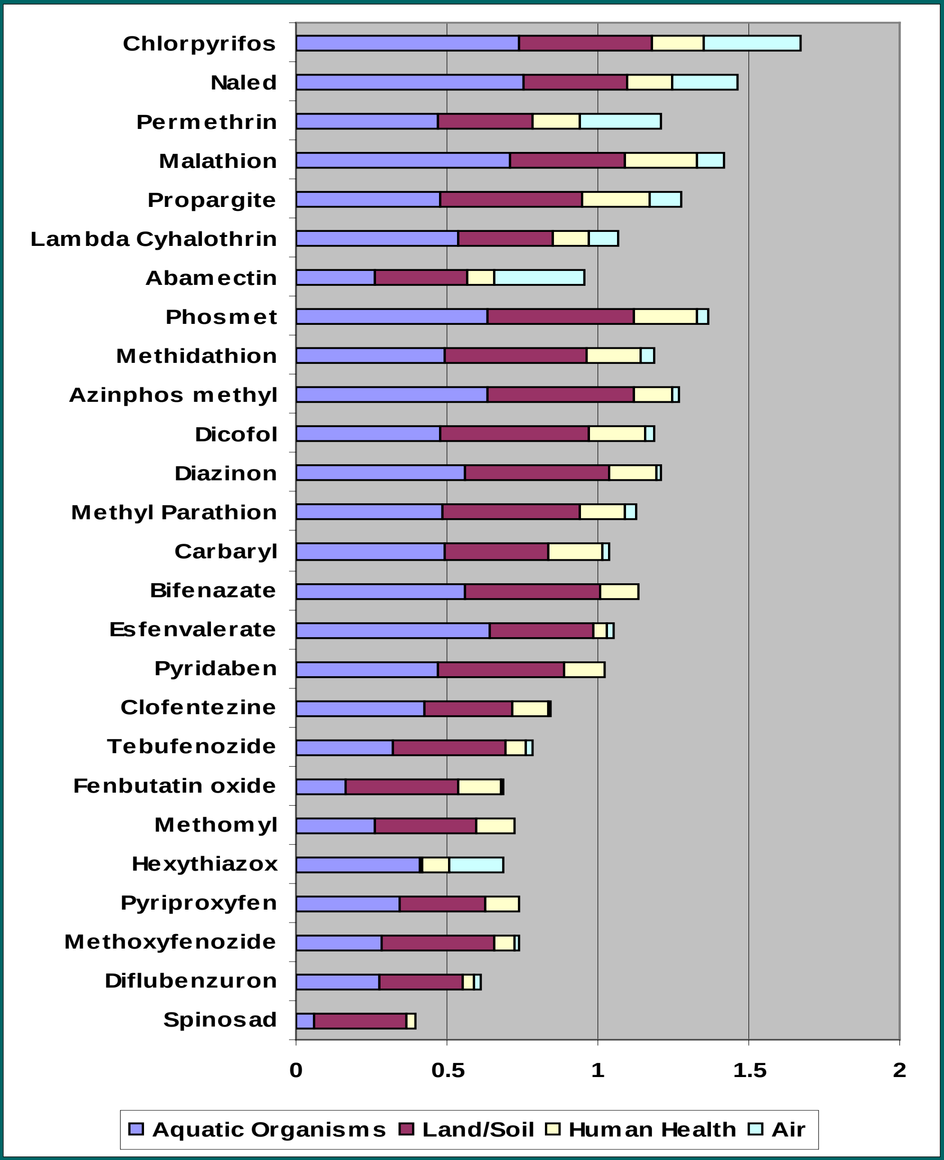


Samples Results

a) Surface Water



b) Aggregated Risk Points



PURE Model Summary

- Features
  - **Transparent:** all equations and data will be public available.
  - **Flexible:** fuzzy logic expert system decision rules can be modified according to expert opinions; both for separate and aggregated risk points.
  - **Extendable**: as the new model is well organized with separate “modules”, they can be modified or improved, even new modules can be imported (such as efficacy and economics).

- Ongoing Work
  - Incorporate farm activities as coefficients into the new model.
    - Irrigation efficiency
    - Application methods
    - Application timing
    - Other farm activities affecting pesticide use risks (e.g. BMP)
  - Perform calibration, sensitivity test, and validation
  - Develop a website

Thank you !

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