Pesticide Behaviour in Soil, Water and Air

Development of Groundwater Exposure Simulation Tool for Pesticides Used in Rice Paddy in China

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Outline

1. Introduction
2. Establishment of exposure scenarios
3. Construction of exposure simulation tool
4. Application of simulation tool
5. Conclusions

1. Introduction

- China is a big country in rice production, rice planting area accounts for about 20% of the world's rice planting area, rice is also the largest food crop in China;

- In rice cultivation, pesticides are used in large amounts and in high frequency to control serious diseases, pests and weeds. Typically, standing water in rice paddies is required for a long time over the growing season;

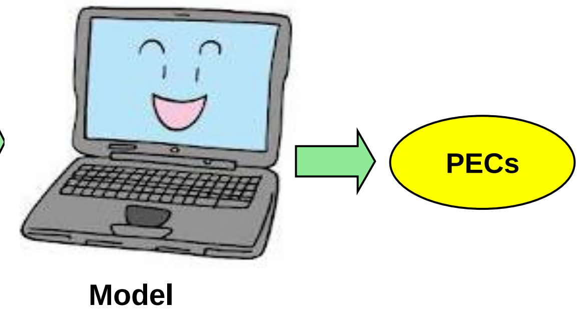
- The special aquatic cultivation practices and high requirement for crop protection products can lead to the potential risk of pesticides contamination in groundwater which may receive recharge from paddy;

- It is important to conduct groundwater risk assessment to provide scientific bases for pesticides registration and management.

2. Establishment of rice—ground water exposure scenario

(1) Definition of scenario

Physi-chemical properties of pesticide
Application: rate, number, timing and etc.
Environmental fate: degradation, sorption and etc.
Meteorological: daily precipitation, temperature and etc.
Hydrology: watershed, water body
Soil: type, texture
Crop: agricultural practices



Exposure Scenario

A set of fixed input parameters in a pesticide fate model i.e. soil parameters, climate etc (FOCUS).

Standard Exposure Scenario

Represents "the realistic worst case" in an area. The realistic worst case means conditions most vulnerable for pesticide pollution but realistically exist and are integration of climate, soil, hydrology, crop and agricultural practice information (FOCUS).

(2) Principles for establishing rice-groundwater scenario

General principle – "realistic worst case"

Principles for selecting scenario sites and establishing scenario:

- ◆ Major rice growing area;
- ◆ Annual average precipitation: large (vulnerable to leaching);
- ◆ Soil type: sandy loam or sand (vulnerable to leaching);
- ◆ Organic matter: low (invulnerable to degradation);
- ◆ Main agricultural practices(single/double cropping, direct seeding/transplanting).

(3) Procedure of exposure scenario establishment

① Dividing scenario zones

Divide scenario zones using GIS, according to rice cultivation and climate data.

② Selecting scenario sites

Select one or more scenario sites from each zone basing on “realistic worst case” principle.

③ Collecting data of scenarios

Collect scenario information, e.g., weather, soil, crop, hydrology data and so on.

④ Generating scenario files

Write scenario files based on different types of information.

① Division of scenario zones

❶ Getting rice Paddy distribution in China

Make the rice paddy distribution map using GIS according to the latest land-use dataset.

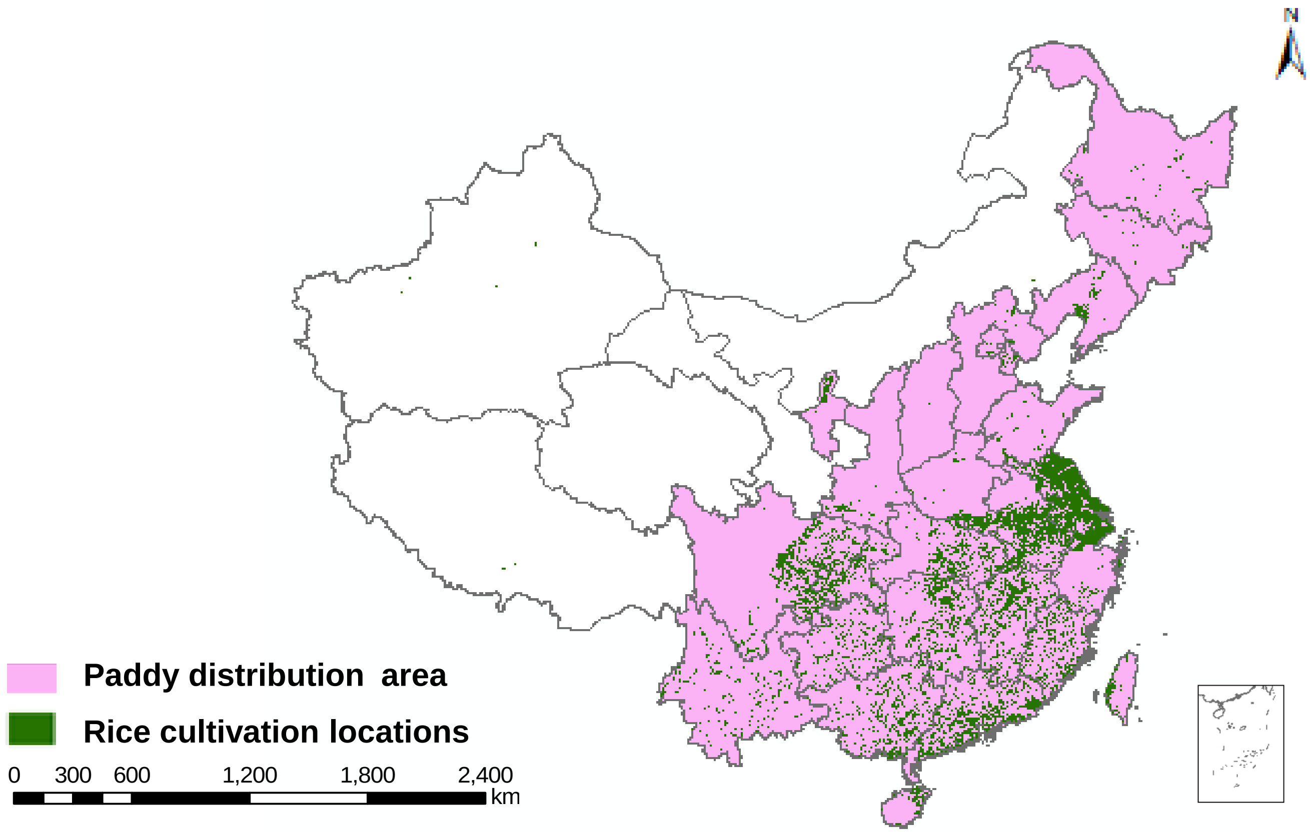


Fig 1. Rice paddy distribution map of China

① Division of scenario zones

❷ Climate zoning of rice Paddy distribution area

Collect annual average precipitation and annual average temperature from 498 meteorological stations for a 30-year period in rice paddy distribution area, then use GIS Interpolation to make division map of precipitation and temperature.

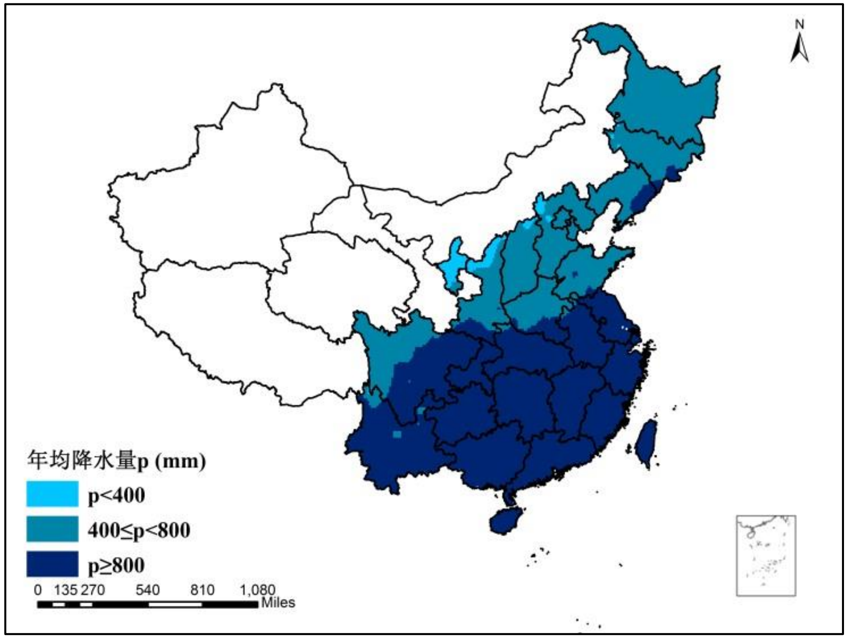


Fig 2. Division map of annual average precipitation

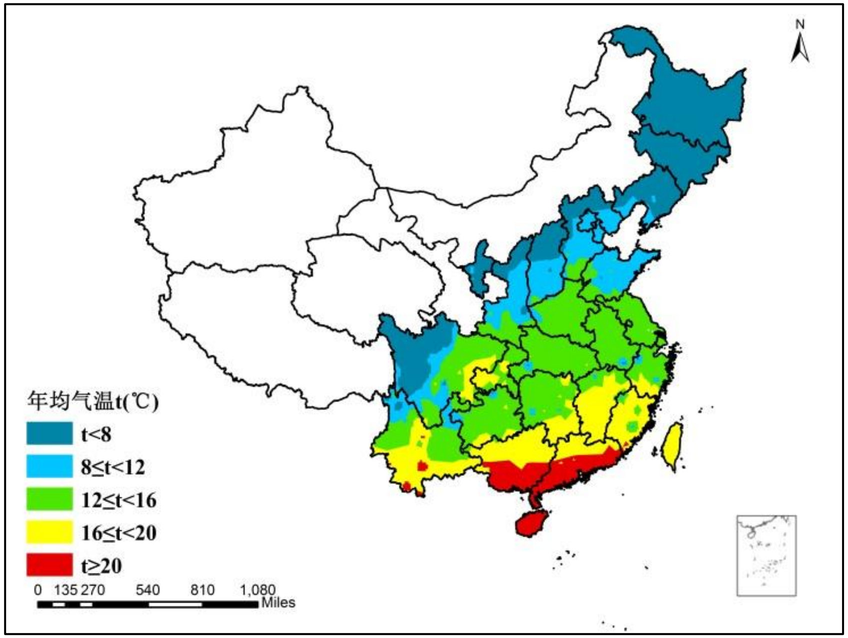


Fig 3. Division map of annual average temperature

① Division of scenario zones

❷ Climate zoning of rice Paddy distribution area

Overlay the two maps of precipitation zone map and temperature zone map to obtain 9 climate zones.

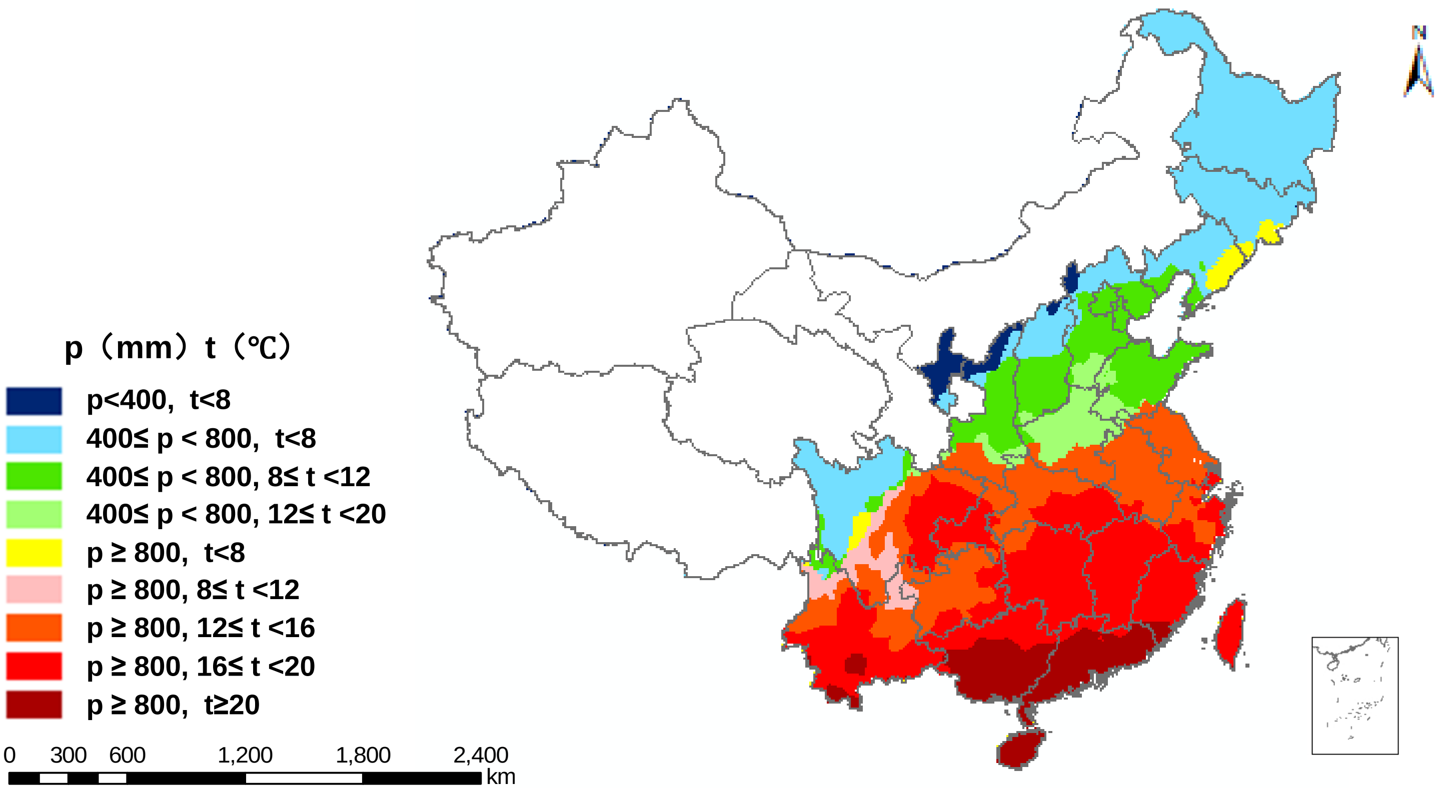


Fig 4. Climate zone map

① Division of scenario zones

❸ Determining scenario zones

Merge the 9 climate zones into 4 scenario zones.

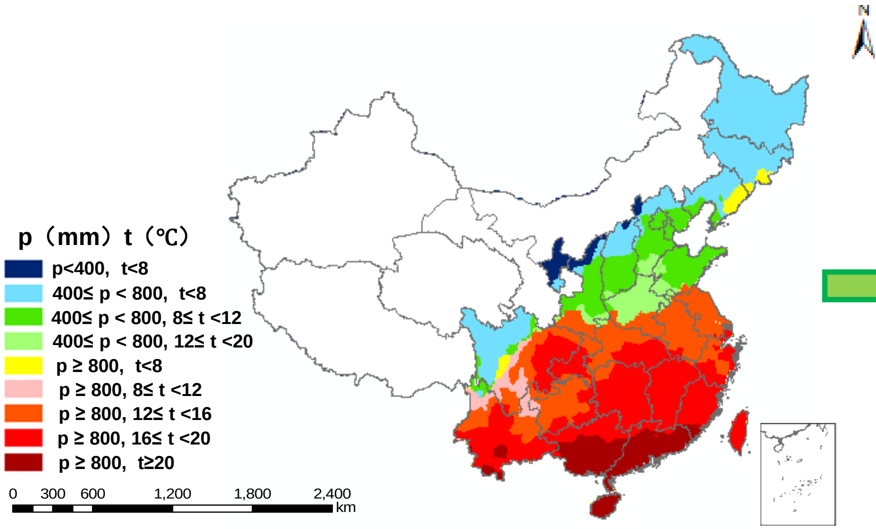


Fig 5. Climate zones map

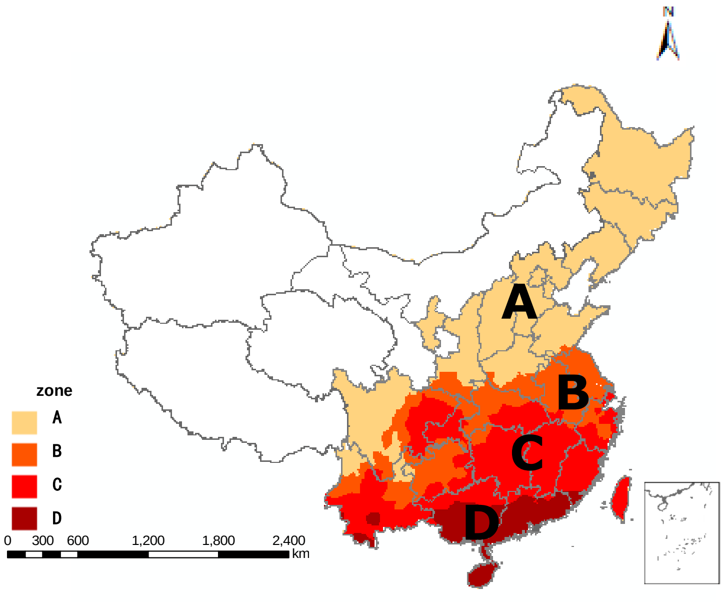


Fig 6. Scenario zones map

① Division of scenario zones

❹ Information of scenario zones

Table 1　Scenario zones information

Scenario Zones	Geographical range	Rice type	Temperature（℃）	Precipitation（mm）
A	Northeast, North, Southwest	single-season rice	t<20	p<800
B	East, Middle, small area of Southwest	single, double-season rice	12≤t<16	p≥800
C	Middle, East, some area of Southwest	single, double-season rice	16≤t<20	p≥800
D	South, small area of East	double-season rice	t≥20	p≥800

② Selection of scenario site in each scenario zone

Protection goal: to protect 95% situations

↓

The selected scenario site should represent about 95% protection level of the scenario zone.

The overall 95th percentile could be best approximated by using a 80th percentile value for weather and a 80th percentile value for soil. The 80th percentile for weather was determined using multi-year precipitation data. The 80th percentile for soil was determined using soil organic matter content data.

② Selection of scenario site

❶ Data collection of each county

Collect the weather data (annual average precipitation), soil data (soil species, soil texture, organic matter, etc) and rice cultivation data of all the 2067 counties in scenario zones.

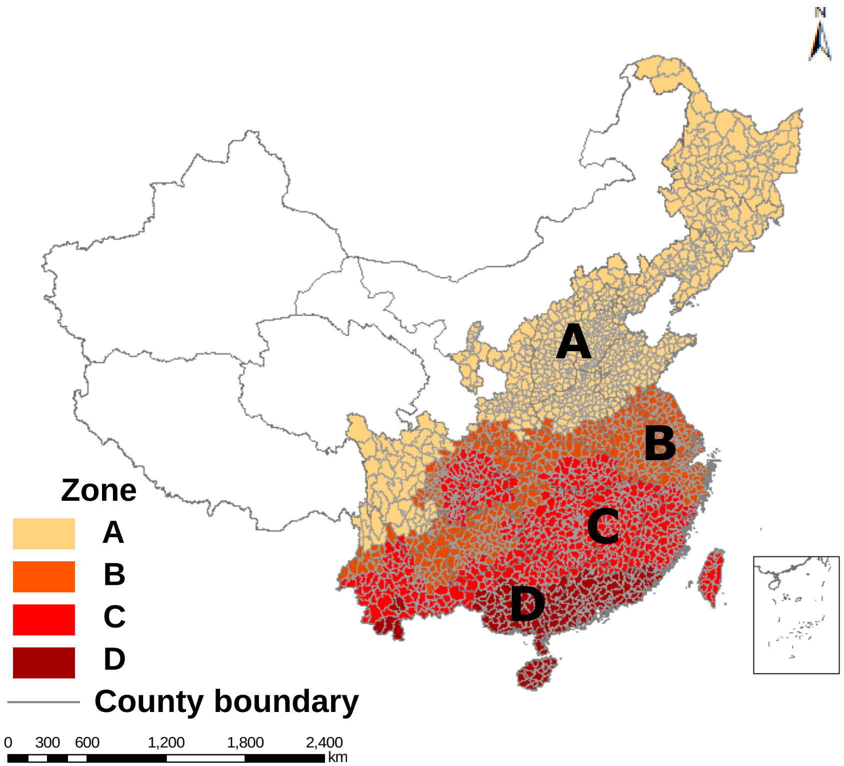


Fig 7. County area map of scenario zones

② Selection of scenario site in each scenario zone

❷ Determination of scenario site

Calculate the 80th percentile value of annual average precipitation of each scenario zone.

Calculate the 20th percentile value of soil organic matter content of each scenario zone.

screen out alternative scenario sites of each scenario zone

determine the final scenario sites in each scenario zone

Overall consideration of specific conditions of rice cultivation, soil texture, soil species area and protection level.

❸ Location and information of final scenario sites

Table 2 Basic information of determined scenario sites

No.	Province	City	County	Soil species	Soil subtypes	Soil texture	Soil organic matter（%）	Precipitation（mm）	Protection level (th)
1	L.Ning	P.Jin	Dawa	轻水碱田	盐渍水稻土	CL	1.66	656	0.924
2	J.Su	W.Xi	Yixing	白土头	漂洗水稻土	SiCL	1.89	1290	0.933
3	A.Hui	X.Cheng	Langxi	棕红泥田	潴育水稻土	LC	1.93	1220	0.909
4	Z.Jiang	S.Xing	Zhuji	水南泥砂田	渗育水稻土	SL	1.89	1392	0.953
5	F.Jian	N.Ping	Jianyang	黄底灰泥田	潴育水稻土	SL	1.65	1665	0.964
6	J.Xi	N.Chang	Nanchang	巴邱黄泥田	淹育水稻土	SiCL	1.85	1615	0.940
7	G.Xi	Y.Lin	Bobai	砾质泥砂田	潴育水稻土	SL	1.42	1786	0.953
8	H.Nan	D.zhou	Danzhou	浅砂泥土田	淹育水稻土	SL	1.31	1838	0.970

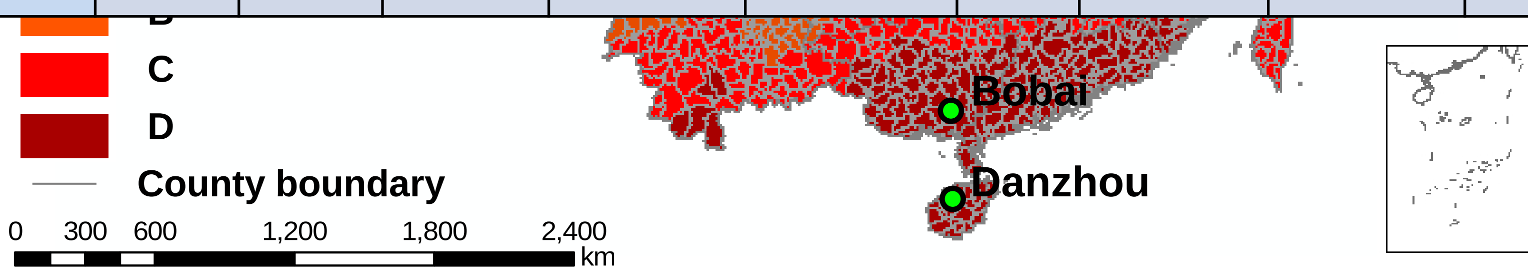


Fig 8. Scenario sites location map

Table 3 16 rice — groundwater standard exposure scenarios

No.	Scenario sites	scenarios
1	Liaoning Dawa	Single cropping —Transplanting
2	Jiangsu Yixing	Single cropping — Direct seeding
3	Anhui Langxi	Single cropping — Direct seeding
		Single cropping — Transplanting
4	Zhejiang Zhuji	Single cropping — Direct seeding
		Single cropping — Transplanting
		Double cropping — Direct seeding
		Double cropping — Transplanting
5	Fujian Jianyang	Double cropping — Transplanting
6	Jiangxi Nanchang	Single cropping — Direct seeding
		Single cropping — Transplanting
		Double cropping — Direct seeding
		Double cropping — Transplanting
7	Guangxi Bobai	Double cropping — Transplanting
8	Hainan Danzhou	Single cropping — Transplanting
		Double cropping —Transplanting

③ Data collection of scenarios

Collect 4 types of data for each scenario, including:

Weather data

- Daily precipitation
- daily temperature
- daily wind speed at 10m
- Cloud coverage
- Daily pan-evaporation

……

(30 years data)

Soil data

- Soil profile depth
- Horizon
- Texture
- Percent sand
- Percent clay
- pH-H_2O
- Percent OM
- Bulk density
- Field capacity
- Wilting point

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Crop data

- Maximum rooting depth
- Maximum canopy height at maturation date
- Typical date of crop planting, emergence, maturity and harvest
- Deposition of plant matter after harvest
- Date to irrigate and drainage

……

Ground water data

- Bulk density of sediment
- Organic carbon content of sediment
- Depth to ground water
- Aquifer thickness (dilution zone)
- Porosity of aquifer

……

Field investigation of the scenario sites

Scenario 1

Scenario site: **Jiangxi Nanchang**

Location: **Zhugang farm**

Time: **September 23, 2015**

The rice planting system: **Single cropping rice (30%) , double cropping rice (70%)**

Field investigation of scenario sites

Scenario 2

Scenario site: Fujian Sanming

Location: Xiamao county

Time: September 24, 2015

The rice planting system: Single cropping rice (80%)， double cropping rice (20%)

④ Generation of scenario files

Write specific scenario files according to different kinds of data to provide for model call.

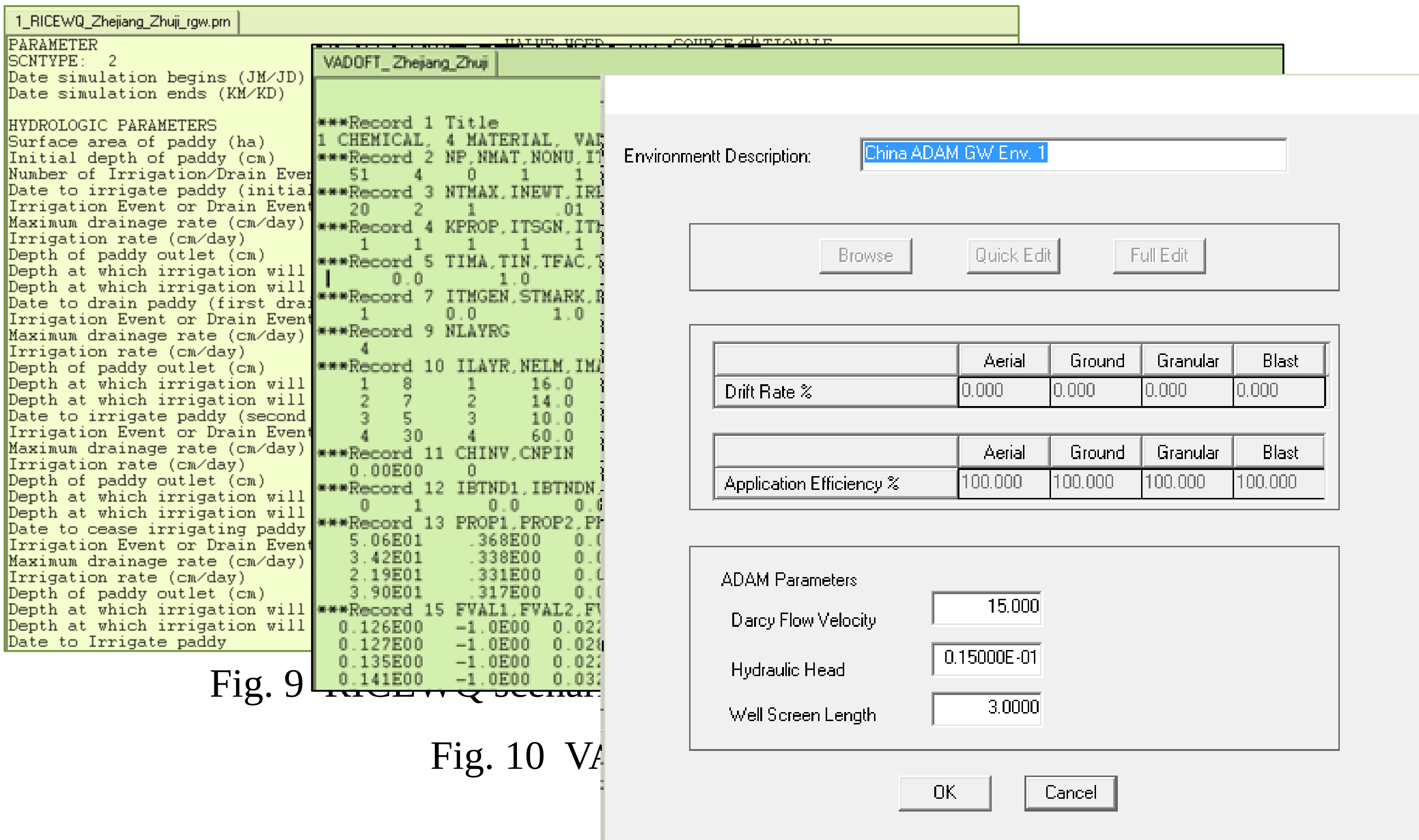


Fig. 9 RICEWQ scenar

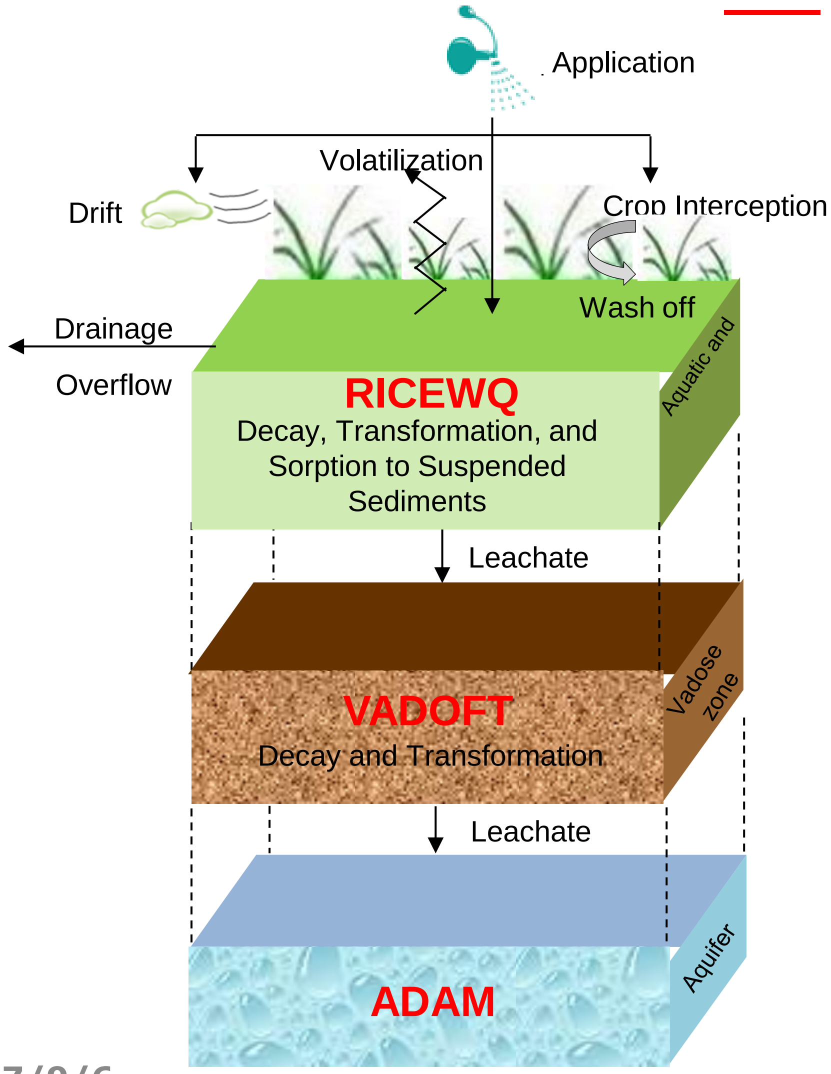
Fig. 10 VA

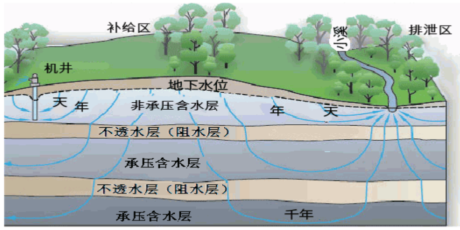
Fig. 11 ADAM scenario file

3. Construction of exposure simulation tool

(1) Construction of exposure simulation module

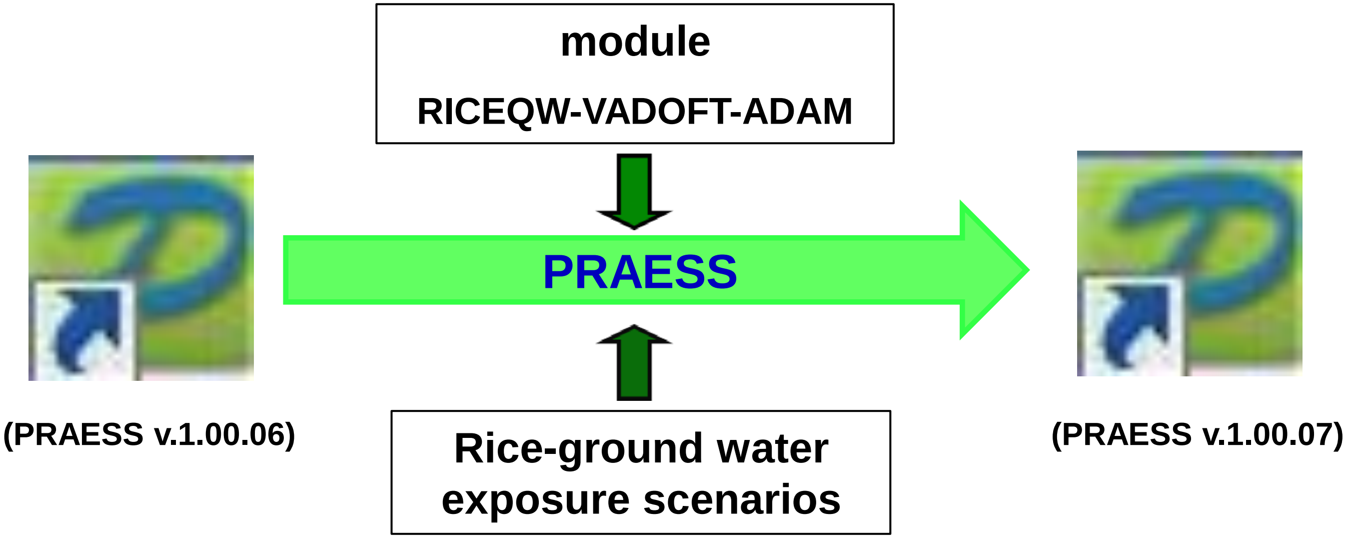
—— coupling RICEQW-VADOFT-ADAM





3. Construction of exposure simulation tool

(2) Construction of simulation tool

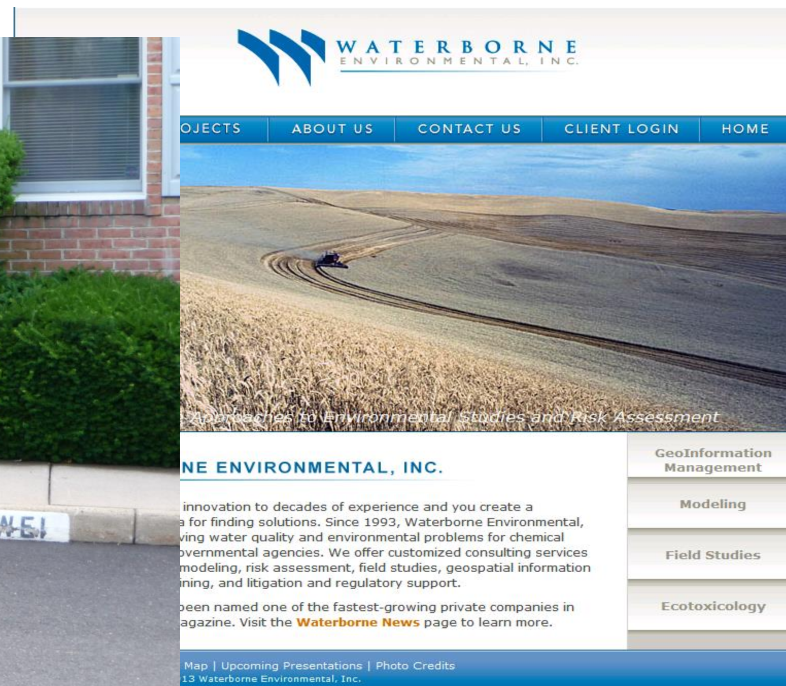


(3) Introduction of PRAESS

PRAESS (Pesticide Risk Assessment Exposure Simulation Shell) , is a tier II modeling tool developed for China to predict exposure concentrations of pesticides in surface water, ground water and soil;

— Method： Integrate several models (PRZM, EXAMS, RICEWQ, VADOFT, ADAM) and Chinese scenarios into one platform.

— Constructing: The tool was constructed by NIES and WEI jointly.



(3) Introduction of PRAESS

Contains four sets of model systems

- PRZM-EXAMS
- RICEWQ-EXAMS
- PRZM-ADAM
- RICEWQ-VADOFT-ADAM

Can simulate four types of scenarios

- Upland crop—Surface water
- Rice paddy—Surface water
- Upland crop—ground water
- Rice paddy—ground water

4. Application of simulation tool

—— groundwater risk assessment for pesticides used in rice paddy

Guideline: Guidance on environmental risk assessment for pesticide registration

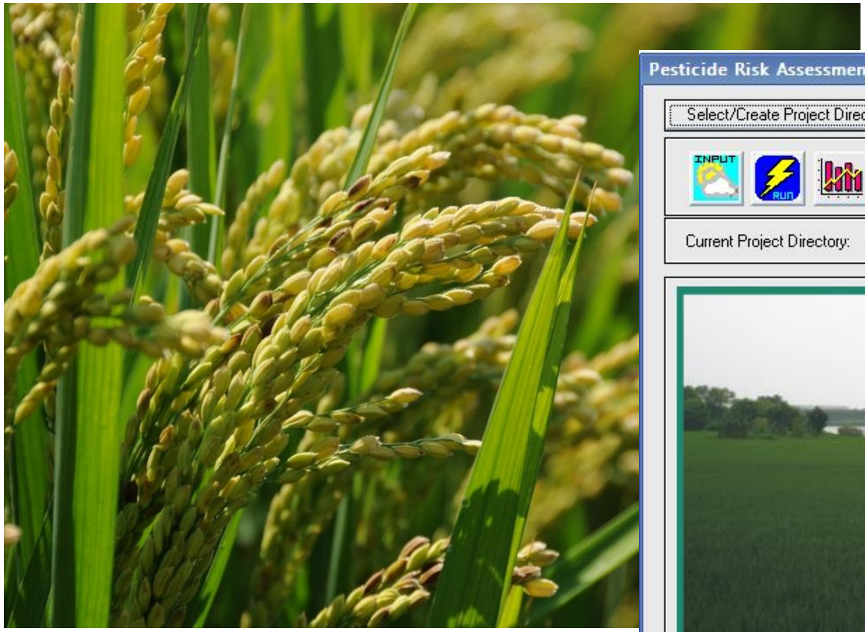
—Part 6: Groundwater (NY/T 2882.6—2016)

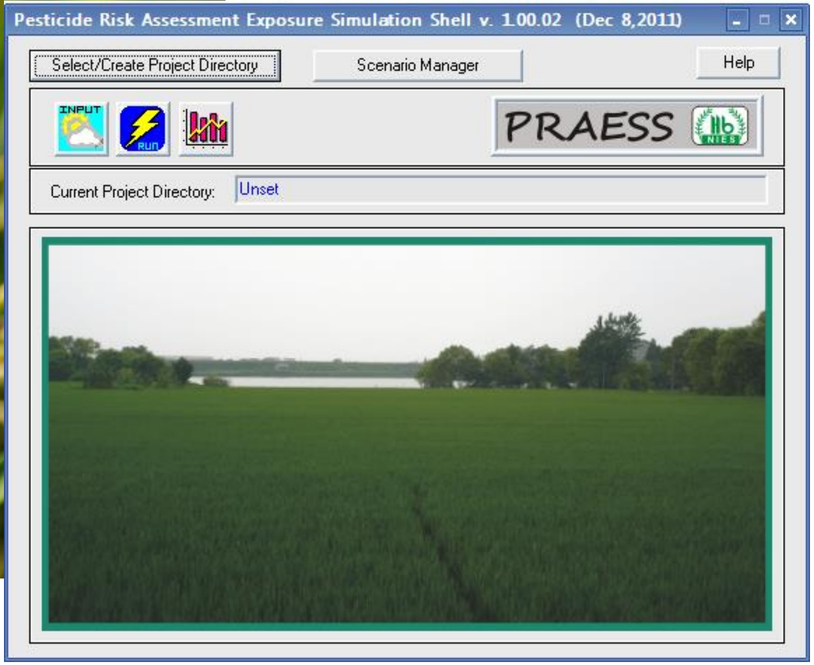
Tool: PRAESS

Module: RICEQW-VADOFT-ADAM

Scenarios: 16 rice-groundwater scenarios

Pesticides: 38 pesticides commonly used in rice paddy in China





4. Application of simulation tool

—— groundwater risk assessment for pesticides used in rice paddy

Exposure assessment

Collecting environmental behavior parameters of pesticides, inputting them into PRAESS, selecting the 16 rice — groundwater scenarios and running the RICEWQ-VADOFT-ADAM model system to obtain the predicted concentrations of 38 pesticides in groundwater. The results are as follows:

序号	登记名称	福建建阳		广西博白		海南儋州			
		单季稻/移栽		双季稻/移栽		单季稻/移栽		双季稻/移栽	
		峰值	年均值	峰值	年均值	峰值	年均值	峰值	年均值
1	阿维菌素	9.4E-20	5.8E-20	0.0	0.0	1.9E-20	8.8E-21	1.2E-20	6.6E-21
2	苯醚甲环唑	1.0E-02	7.2E-03	1.4E-04	8.2E-05	2.8E-04	1.7E-04	4.1E-04	2.4E-04
3	苯噻酰草胺	8.6E-02	6.3E-02	4.6E-04	3.0E-04	9.1E-03	5.6E-03	6.5E-03	3.9E-03
4	吡虫啉	8.8E-01	5.6E-01	4.8E-01	3.2E-01	3.3E-01	2.0E-01	5.7E-01	3.8E-01
5	吡嘧磺隆	5.2E-01	3.6E-01	5.7E-02	3.5E-02	6.1E-01	3.9E-01	6.2E-01	3.7E-01
6	吡蚜酮	2.5E-07	1.7E-07	4.4E-13	2.2E-13	1.7E-09	9.4E-10	7.4E-10	4.1E-10
7	苄嘧磺隆	9.2E-06	5.2E-06	2.1E-09	9.0E-10	7.7E-07	3.5E-07	3.5E-07	1.5E-07
8	丙环唑	1.2E-01	6.8E-02	2.5E-02	1.1E-02	4.5E-02	1.8E-02	4.3E-02	1.7E-02
9	丙溴磷	2.5E-01	1.8E-01	5.7E-04	3.5E-04	5.6E-02	3.5E-02	3.8E-02	2.3E-02
10	丁草胺	3.7E-05	1.8E-05	7.2E-09	2.9E-09	3.0E-07	1.4E-07	1.2E-07	6.6E-08
11	丁硫克百威	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
12	毒死蜱	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
13	二氯喹啉酸	9.7	5.4	2.4	1.3	14.5	8.8	15.7	9.1
14	呋虫胺	2.9E-01	1.5E-01	2.4E-01	9.9E-02	2.3E-01	1.4E-01	2.9E-01	1.7E-01
15	氟苯虫酰胺	2.8E-03	2.0E-03	4.1E-05	2.7E-05	1.7E-04	1.0E-04	1.3E-04	7.4E-05
16	氟环唑	1.5E-05	1.0E-05	8.8E-09	4.4E-09	7.7E-08	4.4E-08	5.1E-08	2.8E-08
17	己唑醇	1.9E-01	1.2E-01	1.2E-01	6.0E-02	1.3E-01	7.8E-02	1.3E-01	7.2E-02
18	甲磺隆	9.6E-01	5.5E-01	1.7E-01	9.6E-02	1.1	6.3E-01	1.1	6.4E-01
19	氯虫苯甲酰胺	3.1E-02	2.1E-02	6.0E-03	4.0E-03	7.5E-03	4.6E-03	4.7E-03	3.1E-03
20	马拉硫磷	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
21	咪鲜胺	3.0E-01	2.1E-01	1.3E-01	7.9E-02	2.8E-01	1.7E-01	2.4E-01	1.5E-01
22	醚菊酯	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
23	嘧菌酯	1.2	7.6E-01	1.1	5.9E-01	1.7	9.4E-01	1.6	9.8E-01
24	氰氟草酯	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
25	噻虫啉	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
26	噻虫嗪	2.4E-03	1.2E-03	1.1E-03	4.1E-04	9.9E-04	5.2E-04	1.1E-03	6.6E-04
27	噻呋酰胺	2.4E-01	1.7E-01	8.1E-02	5.3E-02	1.4E-01	8.6E-02	1.2E-01	7.4E-02
28	噻嗪酮	1.0E-02	6.2E-03	4.0E-03	1.6E-03	7.6E-02	3.7E-03	7.0E-03	3.7E-03
29	三环唑	6.4	4.2	6.2	4.0	3.8	2.5	3.9	2.3
30	三唑磷	2.4E-04	7.4E-05	1.5E-07	7.4E-08	2.4E-06	8.7E-07	3.0E-06	1.1E-06
31	双草醚	1.2E-05	4.7E-06	6.7E-10	2.5E-10	1.1E-06	4.5E-07	4.3E-07	1.9E-07
32	肟菌酯	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
33	五氟磺草胺	8.2E-01	5.5E-01	2.0E-01	1.2E-01	1.3	7.2E-01	1.2	7.3E-01
34	戊唑醇	7.3E-01	5.3E-01	2.6E-01	1.5E-01	5.0E-01	3.0E-01	4.2E-01	2.5E-01
35	西草净	3.5	2.5	4.6	2.9	16.9	10.8	17.2	10.0
36	烯啶虫胺	2.2	1.5	3.8E-01	2.4E-01	3.8	2.2	3.7	2.2
37	乙草胺	2.5E-06	1.3E-06	1.4E-08	5.7E-09	6.8E-07	2.8E-07	8.5E-07	4.3E-07
38	茚虫威	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Effect assessment

Predicted no effect concentration (PNEC)：

(1) According to Chinese guidance on environmental risk assessment for pesticide —Part 6: Groundwater (NY/T 2882.6—2016)

PNEC can be calculated using Equation(refer to WHO's GV calculation) as follow:

$$PNEC = \frac{ADI \times bw \times P}{C}$$

Where,

ADI — Acceptable daily intake ($mg/kg_{body\ weight}$);

bw — Body weight (kg), and its default value is 63 kg;

P — The proportion of pesticides from drinking water in *ADI* (%), and its default value is 20%;

C — Daily water consumption (L), and its default value is 2L.

(2) The EU groundwater cutoff criterion 0.1 ppb was used as a comparison.

Risk characterization

The pesticide risk to groundwater can be described by risk quotient (RQ). RQ can be calculated as follow:

$$RQ = \frac{PEC}{PNEC}$$

If the RQ≤1, the risk can be accepted; if the RQ>1, the risk cannot be accepted.

Results showed

- Based on the guidance of NY/T 2882.6—2016 or WHO's GV, of all the 38 pesticides, only one pesticide's risk was unacceptable;
- Based on EU groundwater cutoff criterion, of all the 38 pesticides, 16 pesticides' risk were unacceptable.

In risk assessment, what kind of PNEC value is selected has great influence on management decision.

5. conclusions

- 8 rice-groundwater exposure scenario sites and 16 scenarios were established for China;
- Exposure simulation tool for rice-groundwater were constructed through integrate the module — RICEWQ-VADOFT-ADAM and the above 16 scenarios into the simulation shell — PRAESS;
- PRAESS has four sets of model systems and 30 scenarios which could represent the typical agricultural conditions of rice, maize, wheat, cotton, cabbage and apple in China.
- The modules and scenarios in PRAESS have been validated by some monitoring data from the scenario sites. Validation results showed that the predicting results and the monitoring results matched well.
- More scenarios need to be established to meet the requirements of pesticides registration managements, further validation need to be done.

Acknowledgement

The project has received a lot of support, thanks…

- **MEP**
- **Waterborne Environmental Inc.**
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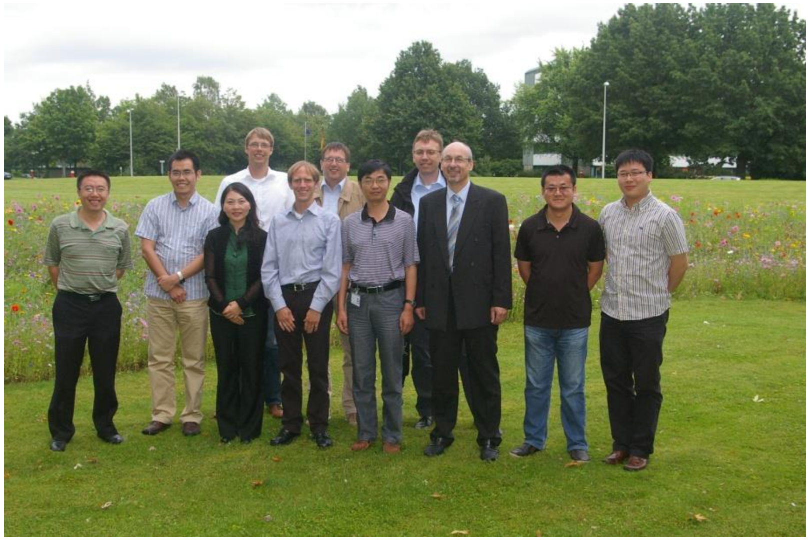
- **Bayer CropScience**
- **Project group**




Thank you for your
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