



II Simposio Nacional de Ingeniería Hortícola  
Automatización y TICs en agricultura  
Almería, 10-12 de febrero de 2016



# Ponencia la aplicación de las TICs en la agricultura China

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Beijing, China

# ***1 Introduction***

# Agenda

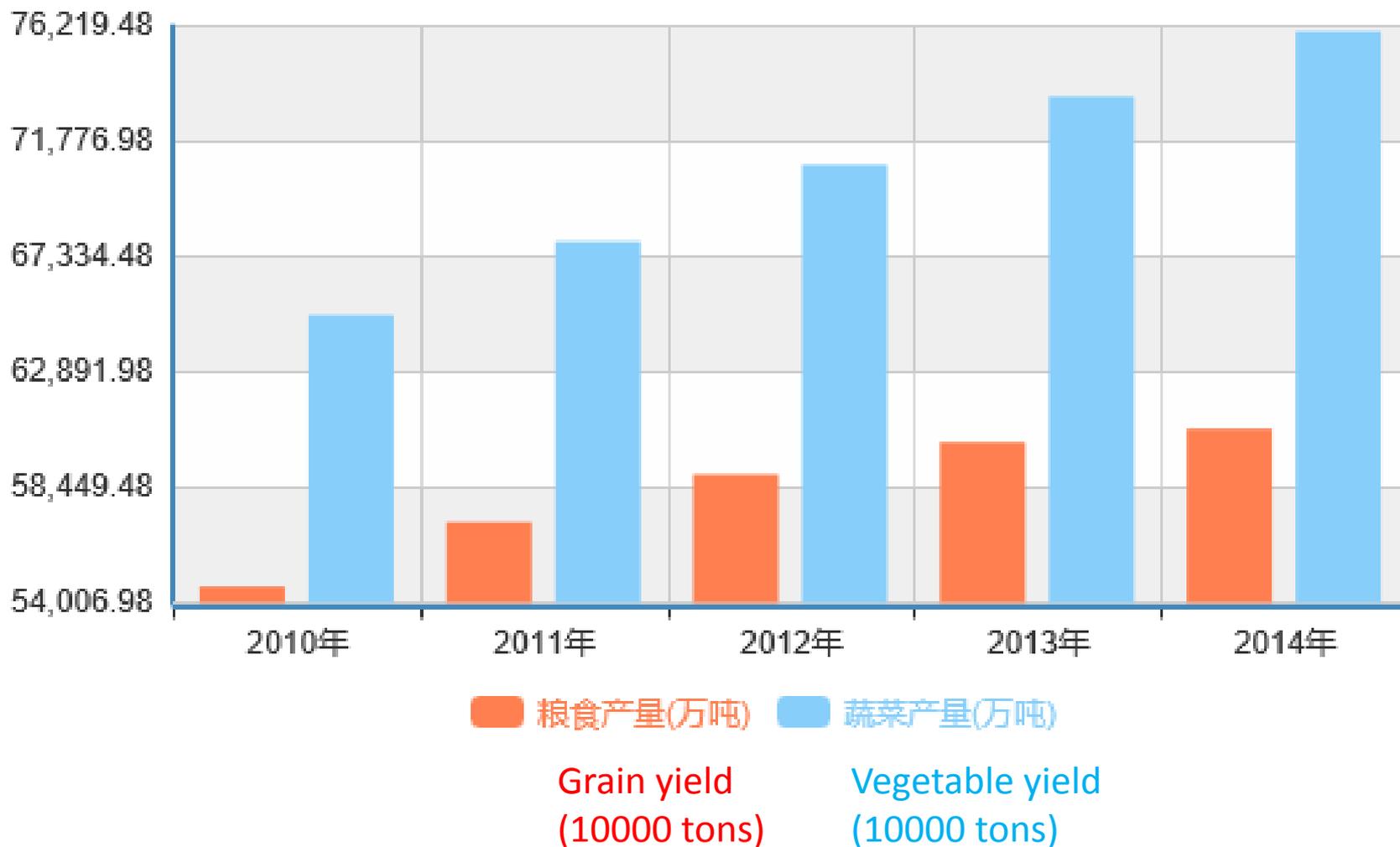
- 1 Introduction
- 2. Breeding
- 3. Production
- 4. Logistics and traceability
- 5. Application
- 6. Cooperation with Spain

# Horticulture: rapid development

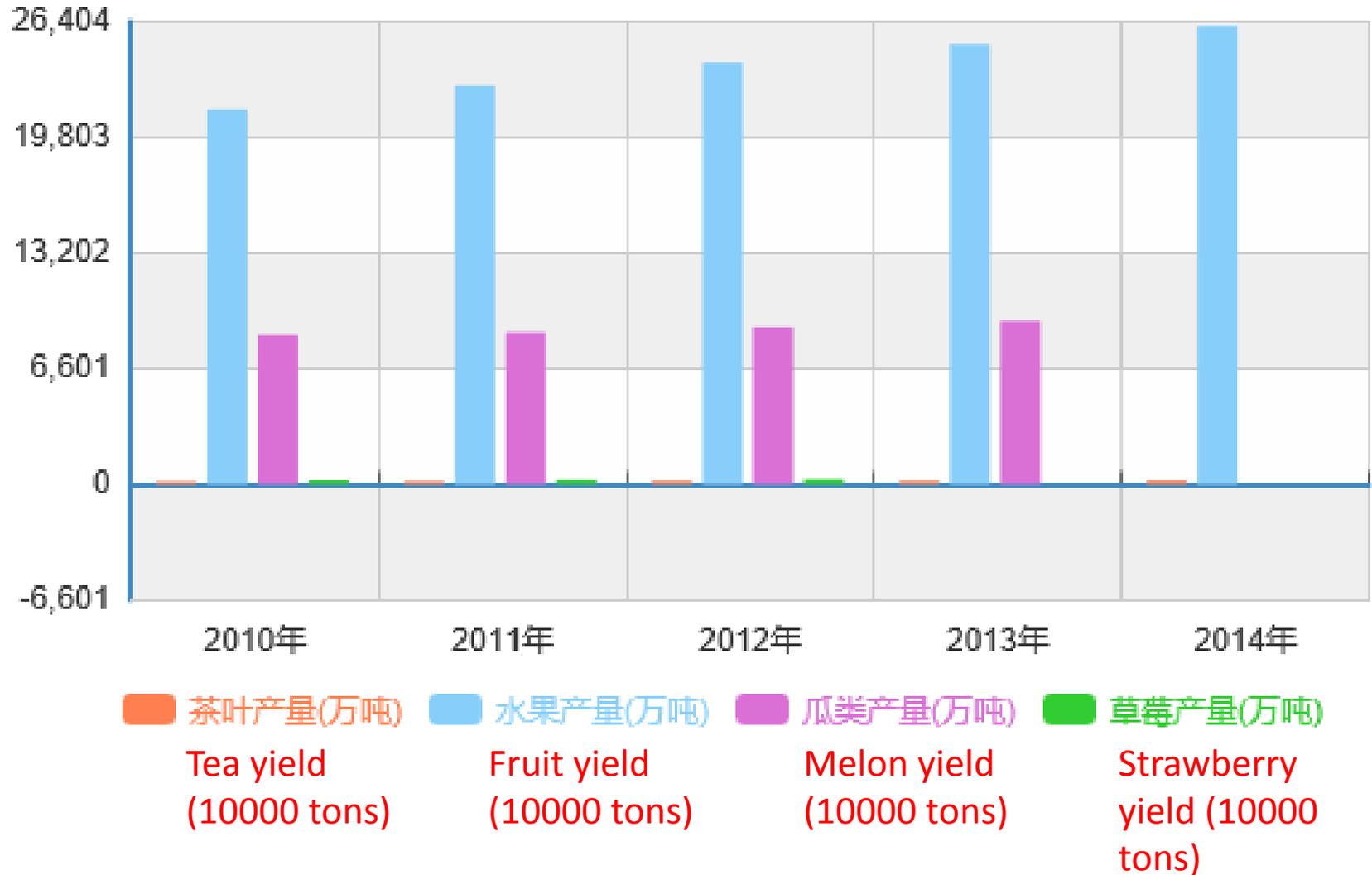
- The rapid rise of the middle class and rising per capita income in emerging economies are leading to increasing demand for healthy, safe and sustainably produced horticultural products. (China has about 300 million population with middle class level)



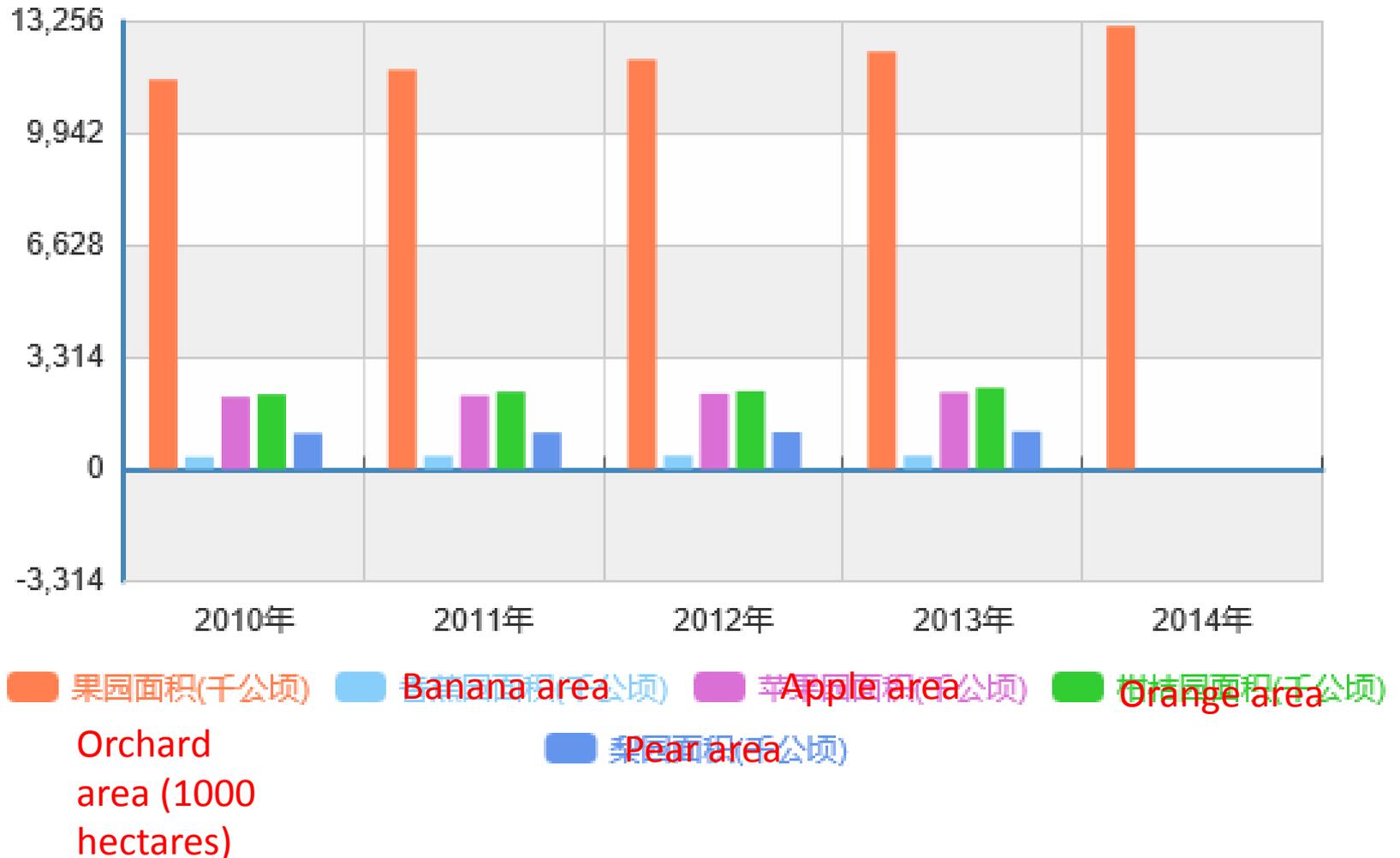
# 1.1 General view of China's horticulture



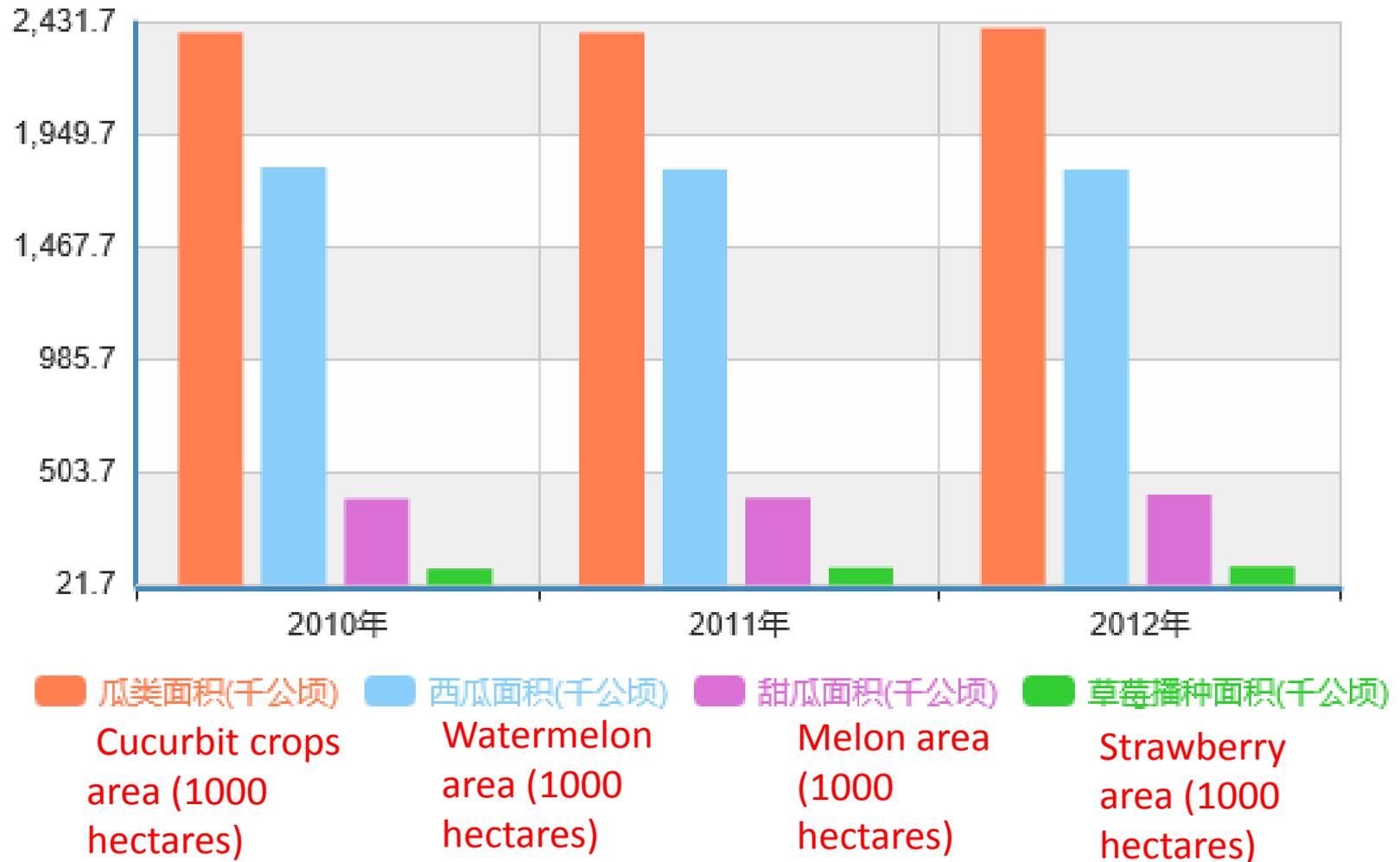
# Horticultural yield in China



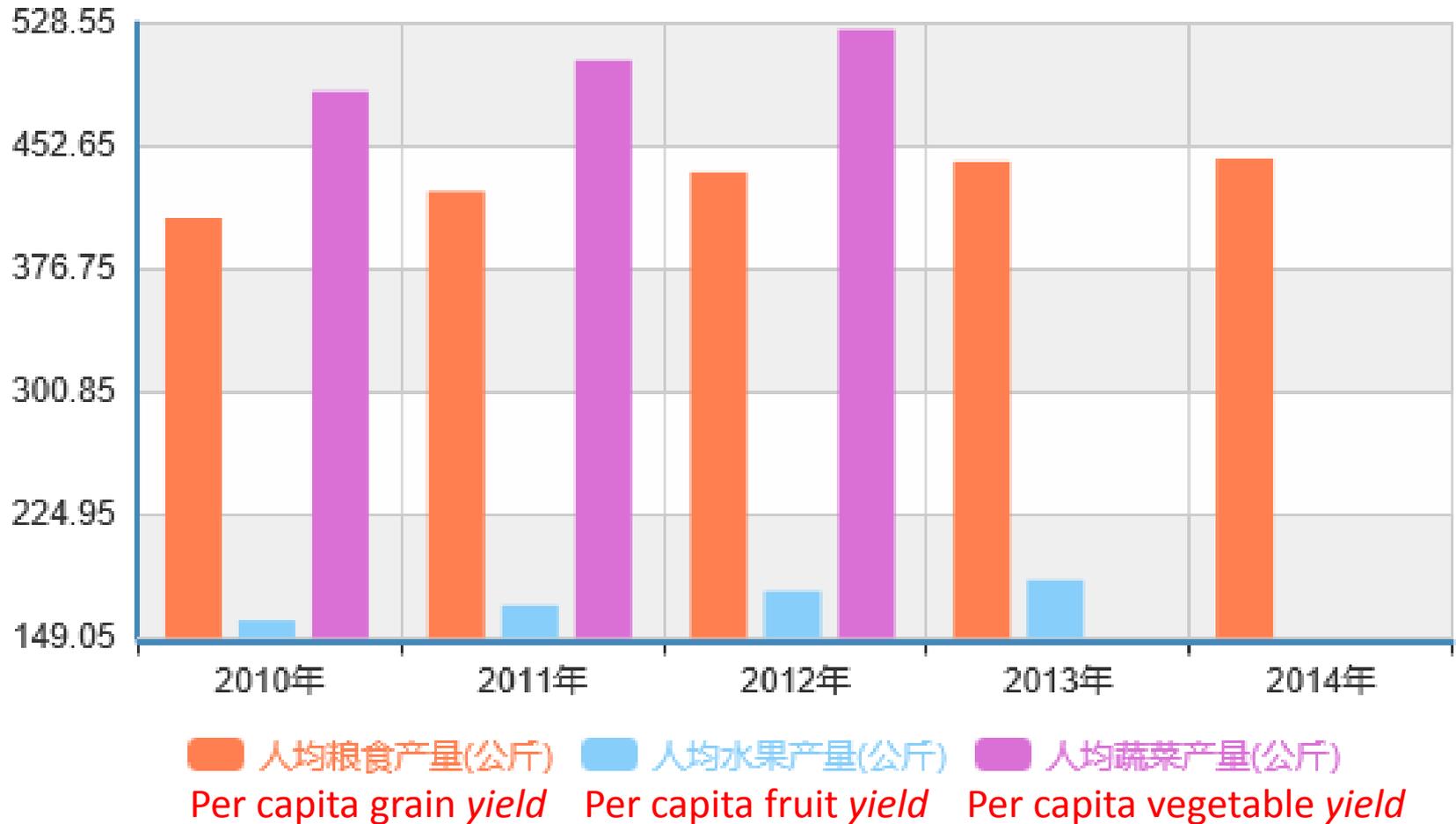
# Orchard area



# Cucurbit crop area

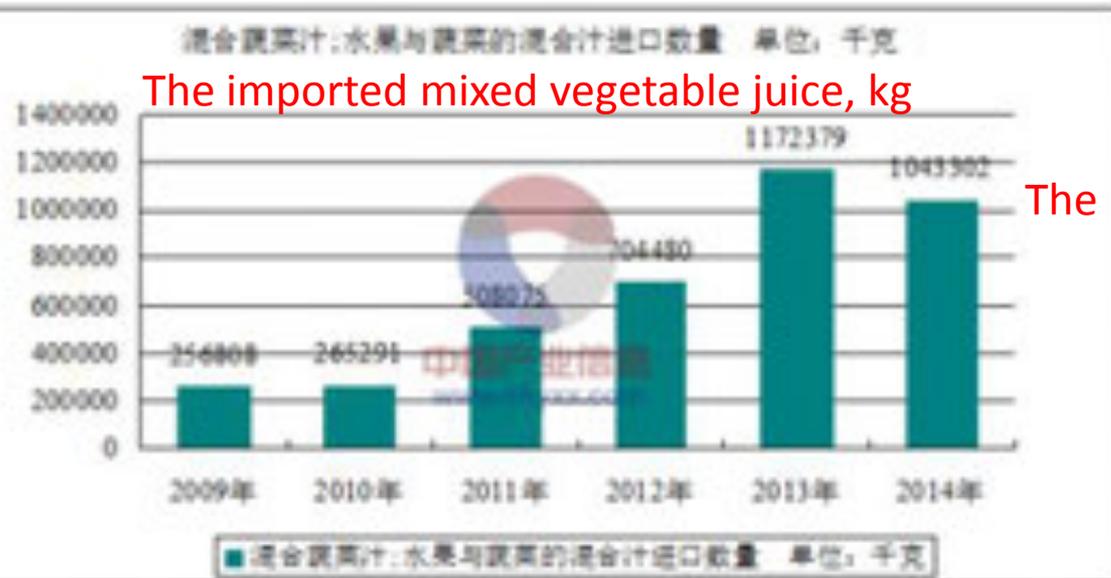


# Per capita yield



# Higher demand for imported food

- 2015, China imported more than 4 million tons of fruits



The imported mixed vegetable juice, 1000\$



# Global importers

## Exhibitors

137 International Exhibitors

270%

Growth from 2013

90 Chinese Exhibitors

Nations  
&  
Regions



## 2014 Top 15 Imported Fruit

Variety	Total (Tons)	Variety	Total (Tons)
Longan	128,790.37	Kivi	6,896.94
Banana	114,475.49	Citrus	6,759.75
Watermelon	72,423.74	Apple	2,513.74
Dragon Fruit	67,764.12	Pear	1,661.63
Grape	36,508.86	Mango	639.27
Durian	17,307.64	Papaya	107.09
Mangosteen	11,090.95	Leeche	0.05
Pineapple	6,921.40		

Data from China  
World Fruit &  
Vegetable Trade  
Fair, 2015

# S&T demand for horticulture



Fresh, Frozen & Dehydrated  
Produce Products



Nuts & Processed  
Produce Products



Juice, Drinks & Winery



Herbs & Spices



Organic & Healthy Food



Produce Packaging  
Machinery & Technology



After Harvest Machinery &  
Technology



Logistics & Cold Chain



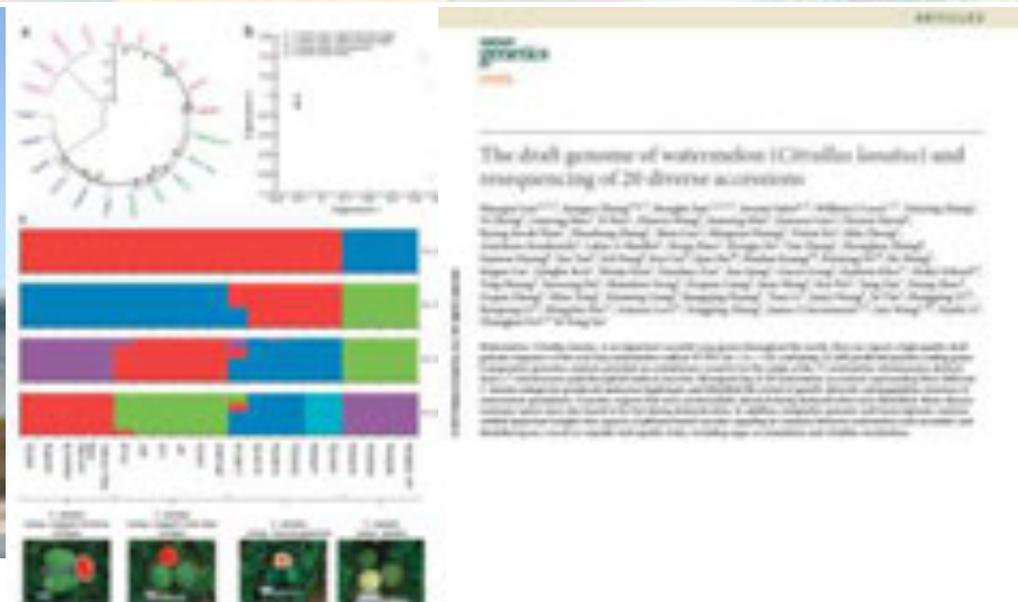
Breeding & Seedling  
Technology



Marketing, Research, Consulting &  
Financial Solutions

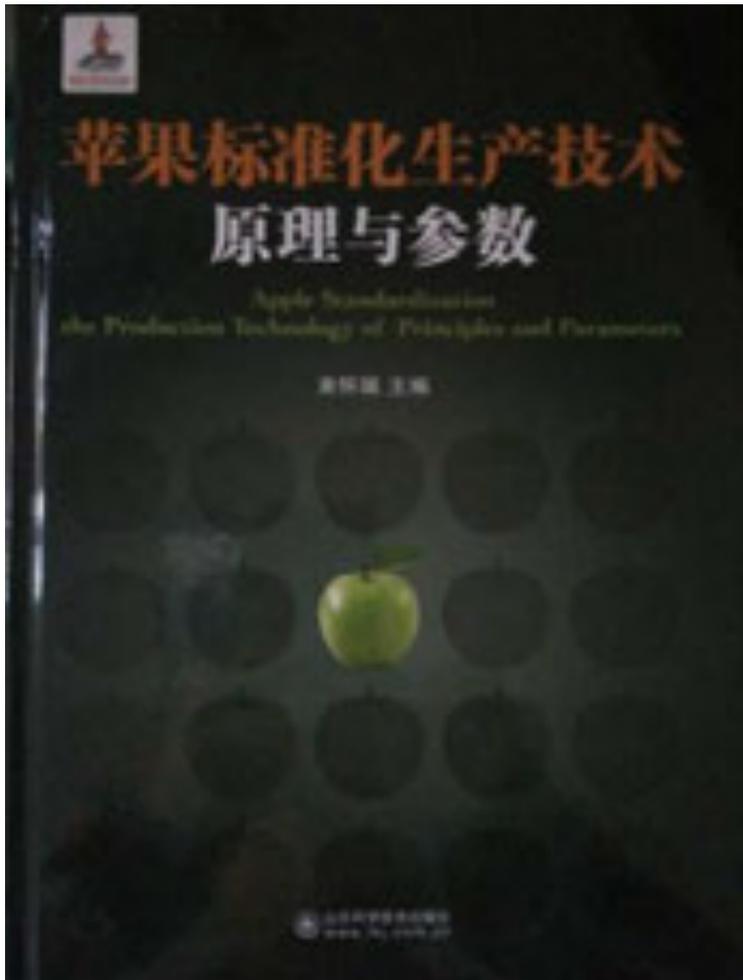
# 2. Breeding

- Mining the variety resources



## 2. Breeding

- Establish the variety resource standard



# 2. Breeding

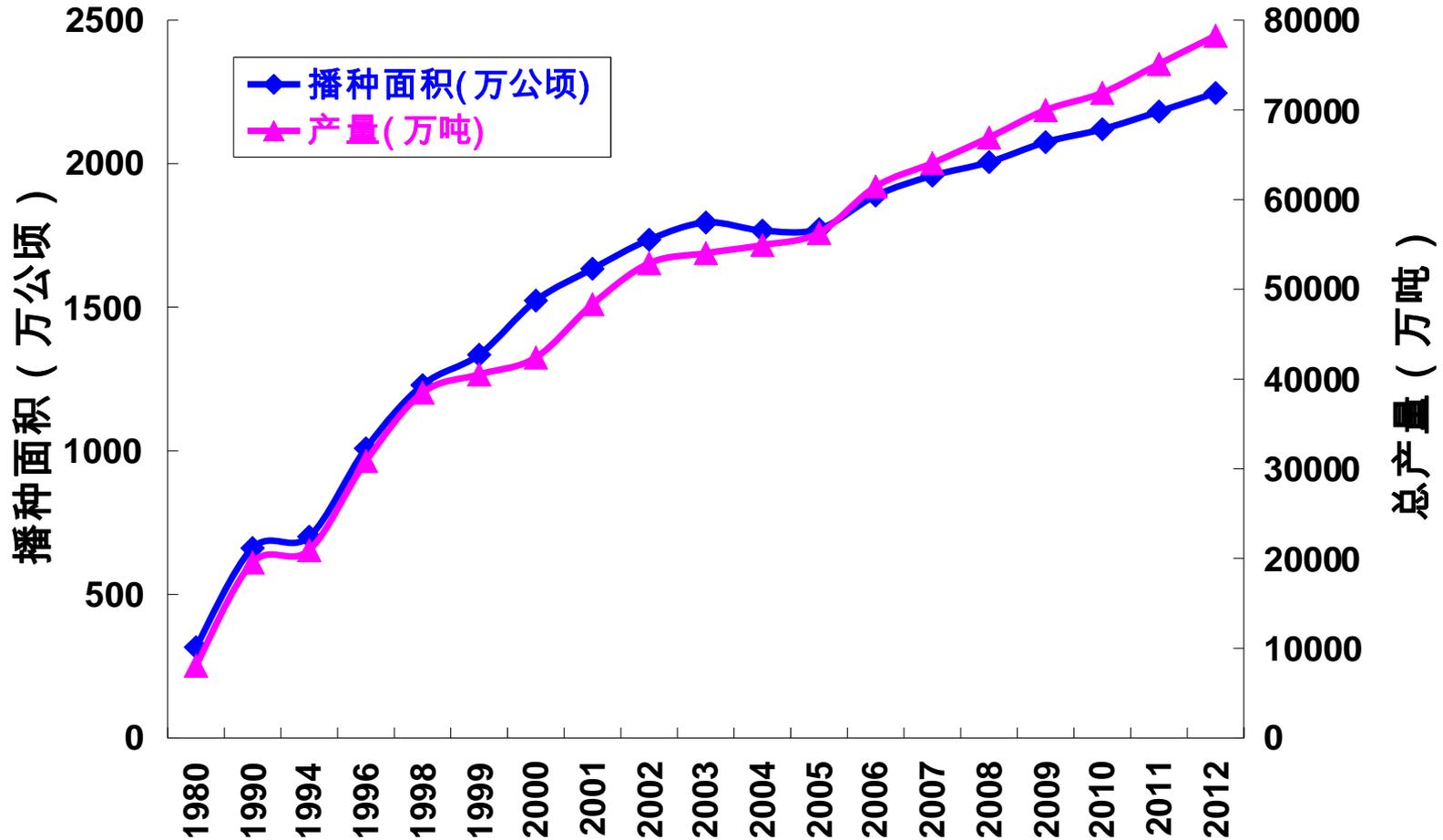
- Golden seed breeding platform



# 3. Production

- 3.1 Problem
- 3.2 Monitor
- 3.3 Model
- 3.4 Decision and conduction

# Fast increase of horticultural production in China

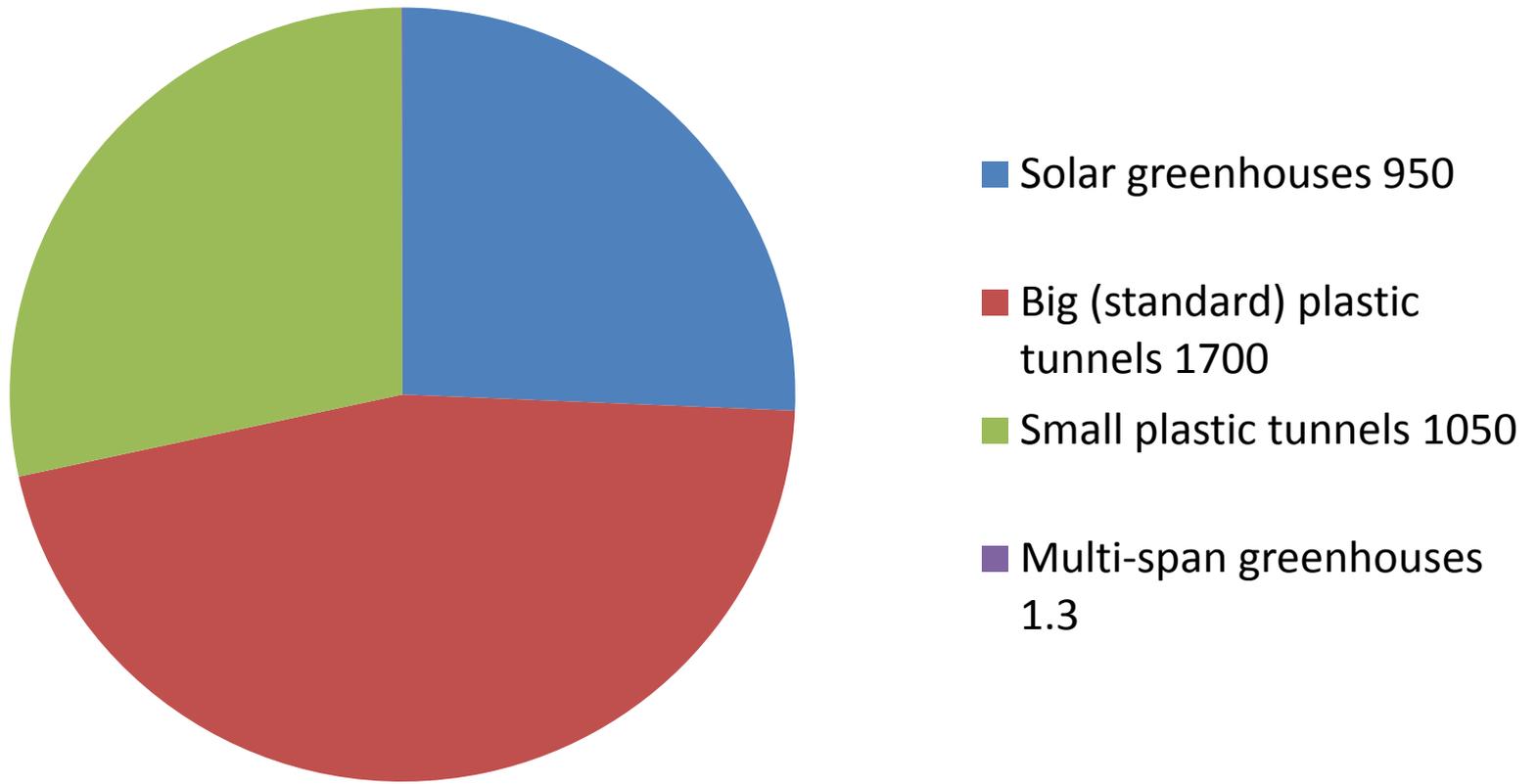


Annual planting area and yield for vegetables in China

Li Baoju, 2013

# 3.1 Problem

China greenhouse Area(1000 ha)



# Low cost, simple facilities in agriculture



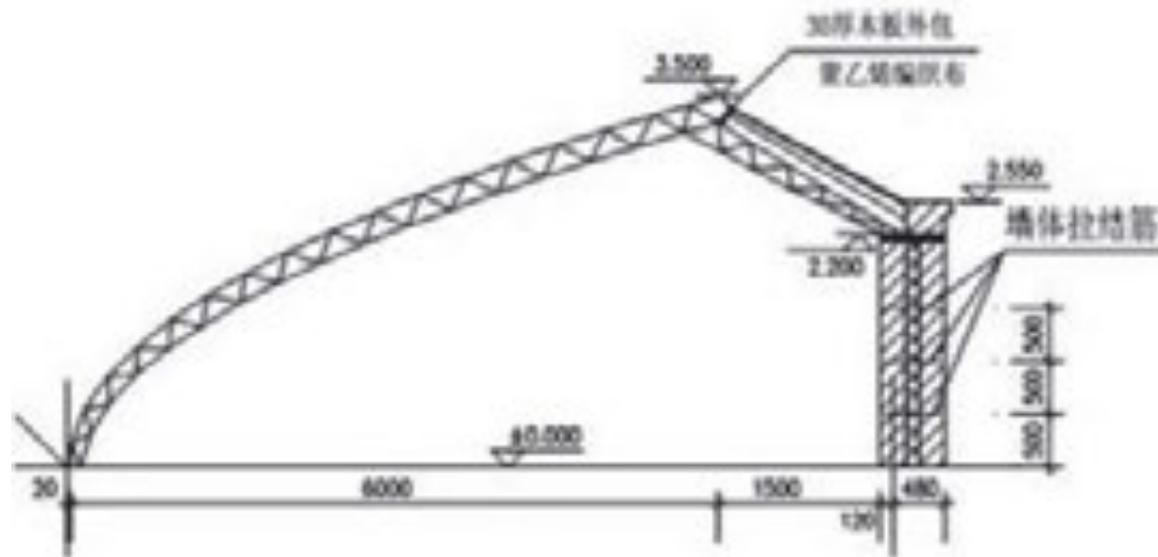
2016-5-3

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Zhang Zhenhe, 2009

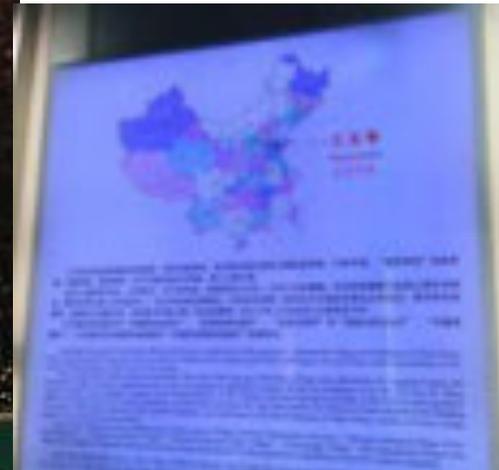
# Solar greenhouse creation

- 1985, Farmers in Haicheng and Wafangdian, Liaoning province, China invented solar greenhouses to produce fruit vegetables, in the external weather of  $-20^{\circ}\text{C}$ .



辽沈 I 型日光温室断面示意图

# Solar greenhouse extension



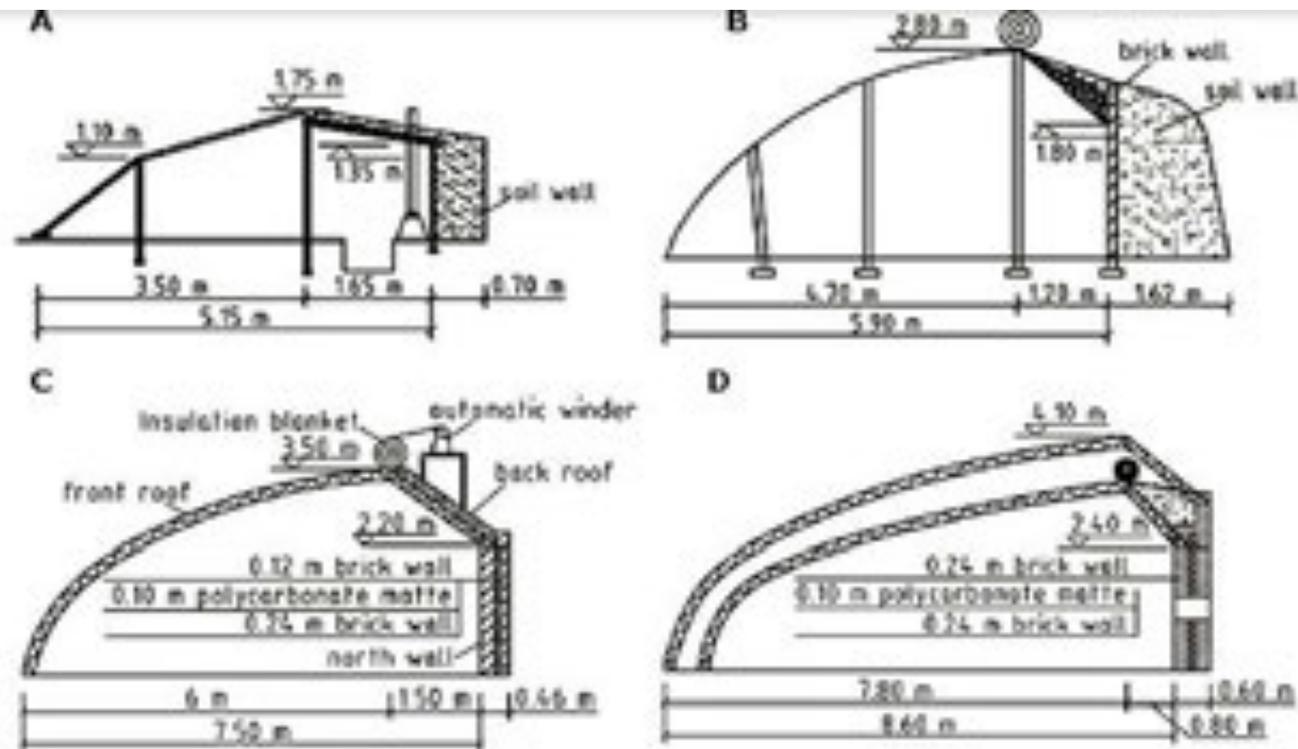


Fig. 1. Models, structure parameters, and evolution of solar greenhouse structure in China. (A) The primary solar greenhouse (before 1985): spans = 5.5 to 6.5 m, wall thickness = 0.5 to 0.7 m, arch height = 2.1 to 2.4 m; steel frames and two to three pillars inside the greenhouse, no insulating blanket, the roof is glass. (B) Modified solar greenhouse (1986–95): spans = 6.0 to 8.0 m, arch height = 3.0 to 4.0 m; frames are bamboo, steel, or a mixture of both, with two to three pillars inside; soil wall thickness = 0.8 to 1.1 m with heterogeneous double layer; transparent coverage materials polyethylene (PE) or polyvinyl chloride (PVC) with insulating blanket on it. (C) Modern solar greenhouse (1996–present): spans = 8.0 to 14.0 m, arch height = 3.8 to 5.5 m, walls of air-entrained brick, polystyrene slates, and perlite at 0.8 m; non-pillar, zinc-coated steel frame. The rolling up and down of the insulation blanket and ventilation vents are all automatic. The east and west walls have a wet curtain cooling system. (D) Double-arch solar greenhouse (2007–present): structure parameters are the same as (C) except the double-arch frames; 1 m = 3.2808 ft.



Fig. 2. Photos of a single-slope solar greenhouse: (A) exterior, (B) interior, (C) upper side of the double-arch solar greenhouse, and (D) a group of solar greenhouses. (Photos A through C were provided by M. Qu and Z. Zhang, respectively; photo D is courtesy of Beijing Agricultural Bureau).

# Greenhouses in different latitudes

Table 1. The main structural parameters of the solar greenhouse located at different degrees of latitude (Zhang, 2001).

Latitude	Greenhouse types <sup>x</sup>	Span (m) <sup>y</sup>	Ridge ht (m)	Back wall ht (m)	Back roof horizontal shadow length (m)
43°N	1	7.0	3.5–3.8	2.3–2.5	1.5–1.6
	2	6.5	3.3–3.6	2.2–2.3	1.4–1.5
	3	6.0	3.0–3.4	2.0–2.2	1.3–1.4
41°N–42°N	1	7.5	3.6–3.9	2.3–2.6	1.5–1.6
	2	7.0	3.4–3.7	2.1–2.4	1.4–1.5
	3	6.5	3.2–3.5	2.0–2.3	1.3–1.4
38°N–40°N	1	8.0	3.7–4.0	2.4–2.6	1.4–1.5
	2	7.5	3.5–3.7	2.2–2.5	1.3–1.4
	3	7.0	3.3–3.5	2.2–2.5	1.2–1.3

<sup>x</sup>Greenhouse types are divided by the span and the ridge height.

<sup>y</sup>1 m = 3.2808 ft.

# Solar greenhouse cost and benefit

Table 2. Input and output of different styles of greenhouses for growing cucumber and tomato in Beijing, China.

Projects	Solar greenhouse		Gutter-connected heated greenhouse	
	Modified bamboo-steel frame	Modern zinc-coated steel frame	Polycarbonate mat	Glass greenhouse
Construction cost (yuan/m <sup>2</sup> ) <sup>a</sup>	40–60	150–200	650–750	850–950
Depreciated value				
Duration (years)	5–10	15–20	20–30	20–30
Value/year (yuan/m <sup>2</sup> )	4–12	7.5–13.3	21.7–37.5	28.3–47.5
Annual production material input (yuan/m <sup>2</sup> )	4.8	4.8	5.5	5.5
Labor input (yuan/m <sup>2</sup> )	7.2	7.2	6.5	6.5
Production cost				
Heating energy input (yuan/m <sup>2</sup> ) <sup>b</sup>	0	0	89.6	89.6
Wet-curtain cooling cost (yuan/m <sup>2</sup> ) <sup>c</sup>	0	0	4.0	4.0
Production cost (yuan/m <sup>2</sup> )	12	12	105.6	105.6
Vegetable productivity				
Annual vegetable income (yuan/m <sup>2</sup> ) <sup>d</sup>	45	45	60	60
Net income (yuan/m <sup>2</sup> )	21–29	19.5–25.5	-67.3 to -83.1	-73.9 to -93.1
Ratio of annual input/output	1:1.88	1:1.76	1:0.44	1:0.42

<sup>a</sup>1 yuan/m<sup>2</sup> = \$0.1465/m<sup>2</sup> = \$0.0136/ft<sup>2</sup>.

<sup>b</sup>Heating cost was calculated by assuming that the gutter-connected greenhouse needs to be heated 100 d in winter, and needs burn 1.12 kg m<sup>-2</sup> (0.229 lb/ft<sup>2</sup>) of coal per day at unit price of 0.80 yuan/kg (\$0.1172/kg, \$0.0532/lb).

<sup>c</sup>Cooling cost was calculated by assuming that the gutter-connected greenhouse needs to be cooled 100 d in summer, and needs consume 0.4 kW m<sup>-2</sup> (0.037 kW/ft<sup>2</sup>) of electricity per day at unit price of 0.80 yuan/kW (\$0.1172/kW).

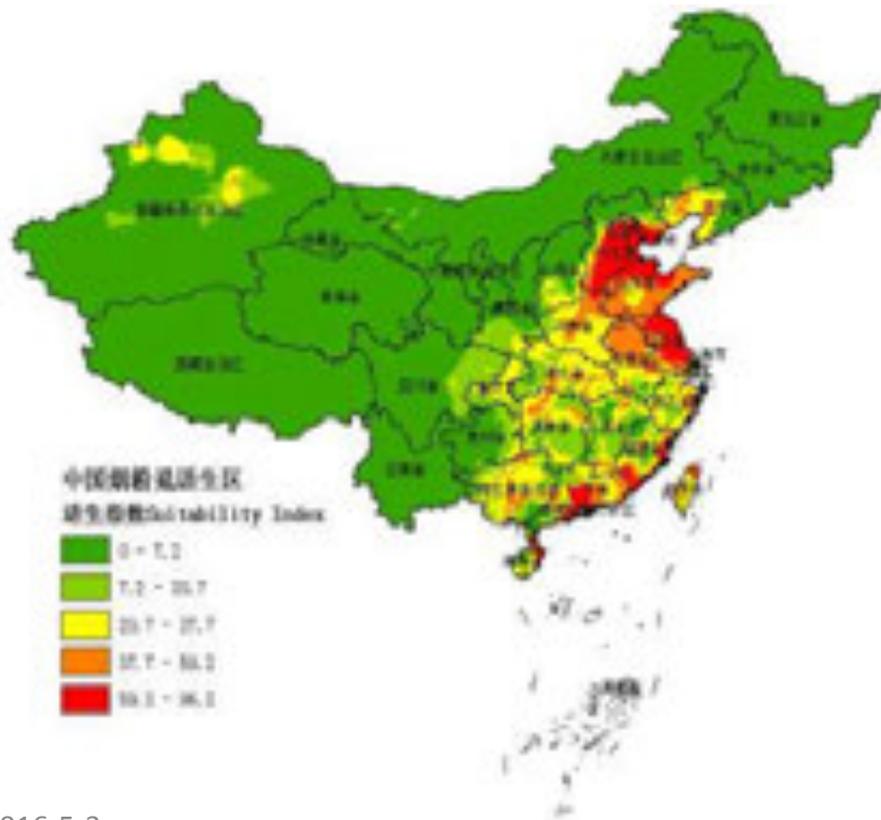
<sup>d</sup>Annual vegetable income was calculated by assuming vegetable price is 2.0 yuan/kg (\$0.2930/kg, \$0.1329/lb) and annual average yield of solar greenhouse and gutter-connected greenhouse in 3 years was 22.5 and 30.0 kg m<sup>-2</sup> (4.61 and 6.14 lb/ft<sup>2</sup>), respectively.

# Some problems

- Lack of unified plan and strategy
- Less ability of environment control
- Heavy soil continuous cropping obstacles, and diseases and pests
- Lower efficiency of production

# Diseases and insect pests are the major limitation for agricultural production

- The usual loss for horticultural crops is more than 20% due to pests, and the improper control may result in loss of 50-60%, especially no harvest when the heavy situation occurs.



# The improper control for diseases and pests affect Agricultural product quality safety



# Traditional pathogen monitoring method



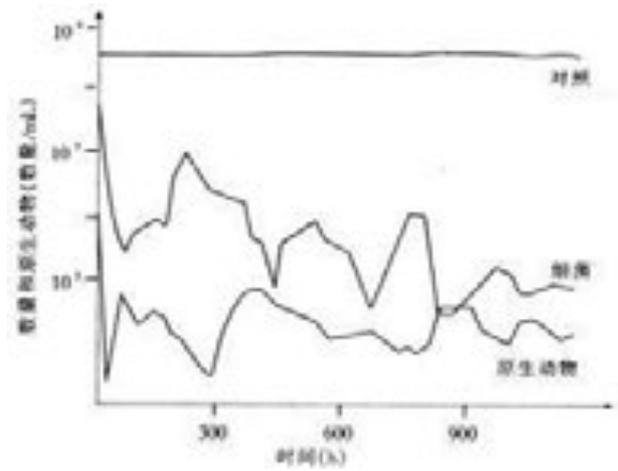
Spore traps



Collection by labor



Microscope testing



Spore analysis

# Traditional pest monitoring method



Field sample



Expert identify



On site testing



Statistic analysis

# Lower efficiency of usage on data



Paper



Computer



PDA

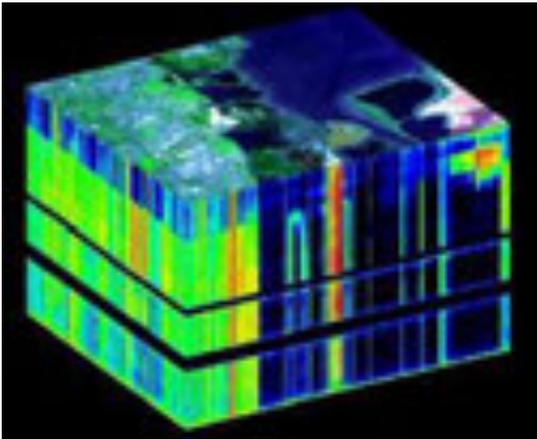


Cell phone

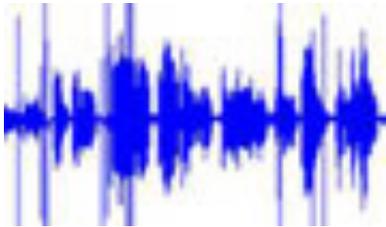


**Weather station data has not been well used**

# Urgent need of Intelligent, automatic tools



**Hyper spectrum**



**Voice**



**Infra red**



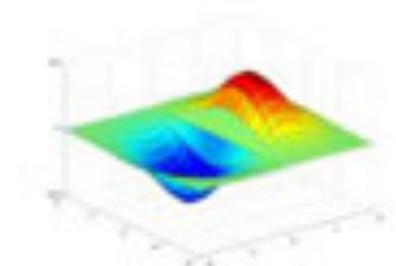
**Machine vision**



**IOT, Cloud computing, big data has great potential**

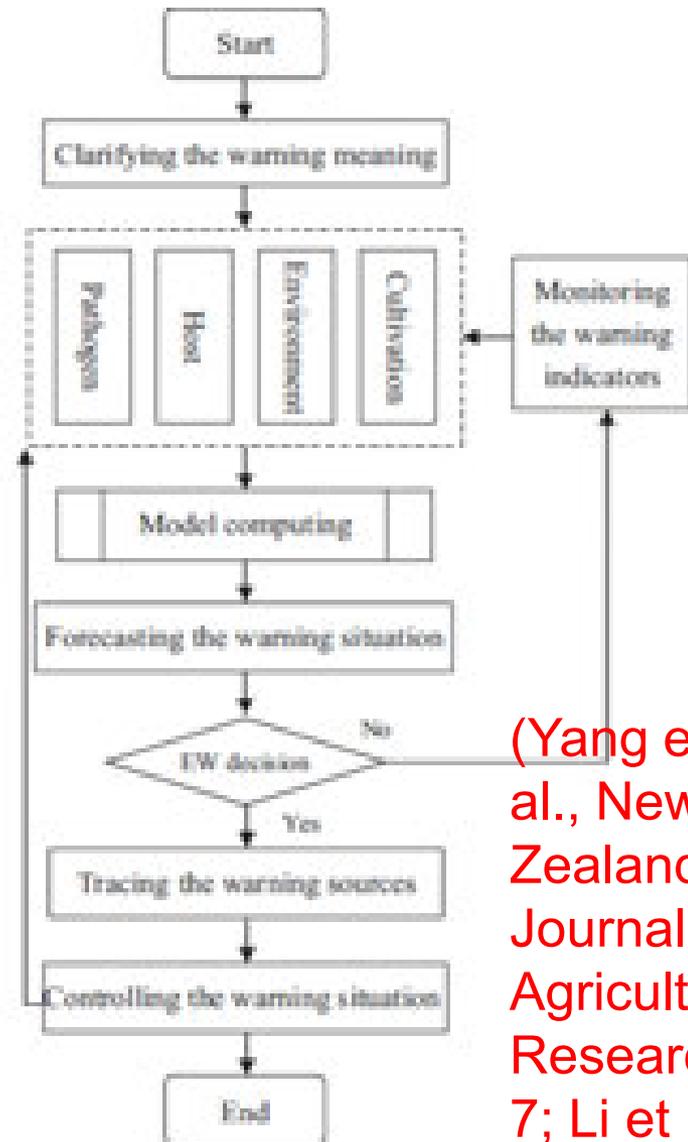
# Trends in Plant Protection Science

- **Thousands years ago: Experiment**
  - Field survey
  - Express the natural phenomenon
- **A hundred years before: Theory**
  - Disease epidemiology and insect ecology
  - Mathematical Model
- **Last several decades: Computing**
  - ICT application
  - Computer simulation
- **Nowadays: Big Data**
  - Data-intensive scientific discovery
  - Global pest forecast and control



# Our goal

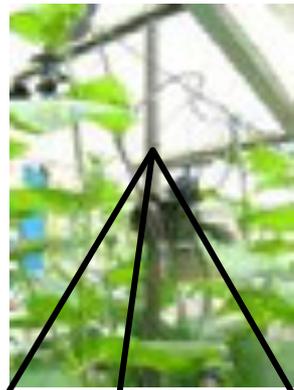
- Automatic monitoring
- Precision model
- Decision and control



(Yang et al., New Zealand Journal of Agricultural Research, 2007; Li et

# ***3.1 Monitoring the pest tetrahedron***

**Complex system of disease pyramid**

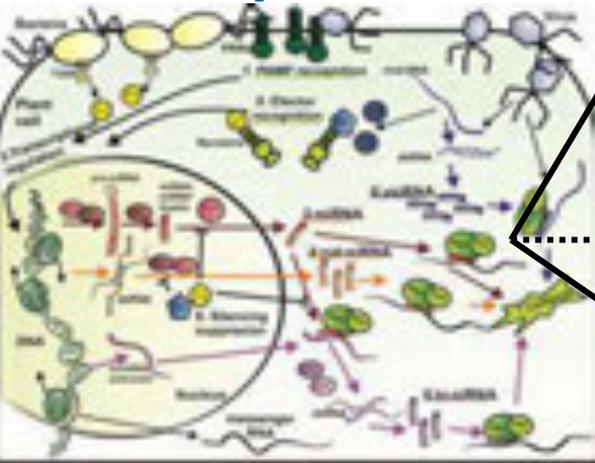


**Host phenotyping:  
Hyperspectral, High-throughput, online**

**Pest detection:  
from Molecular  
to Population**

**Plant disease and  
insect early  
warning model  
and system**

**Cultivation  
record: holistic,  
traceable,  
visible**

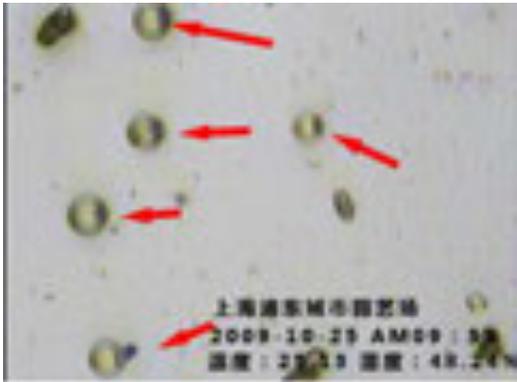


**Environment monitoring:  
integrated, dynamic and  
heterogeneous**

# (1) Pest monitoring equipment in fruits

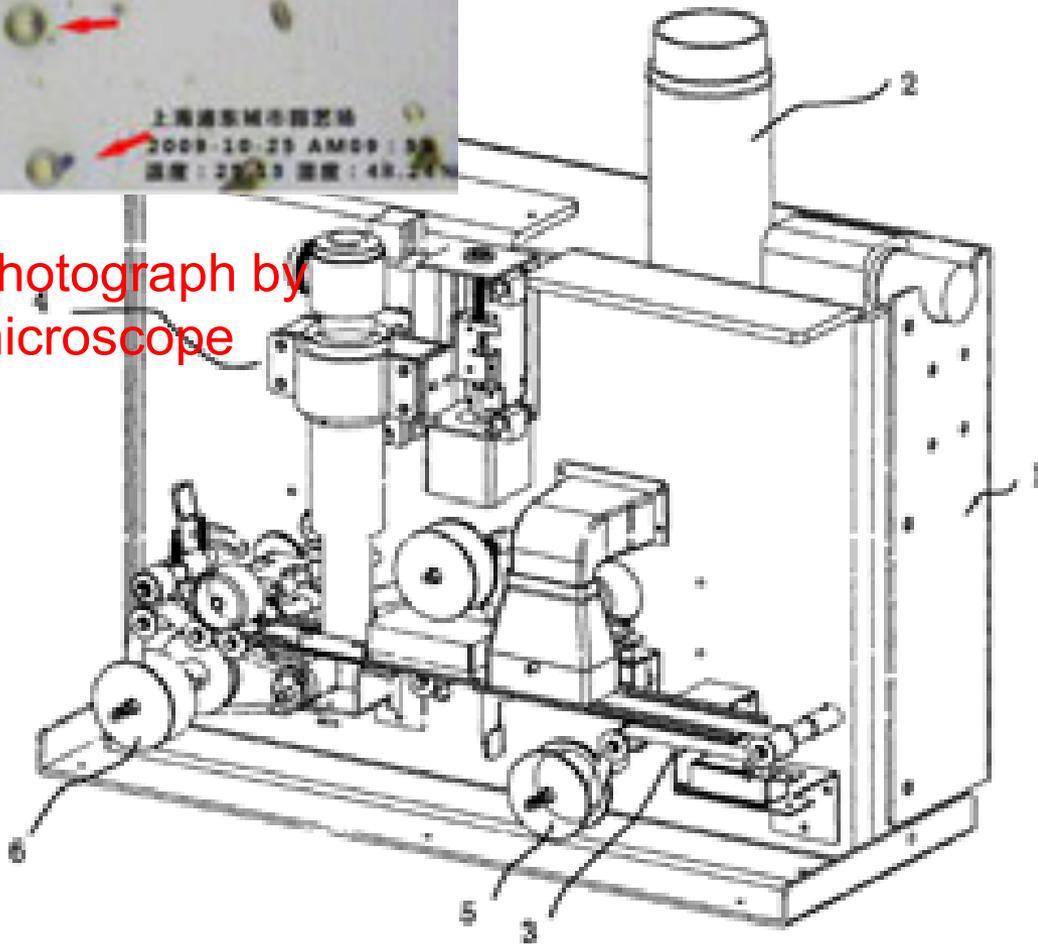


# Plant pathogen detection



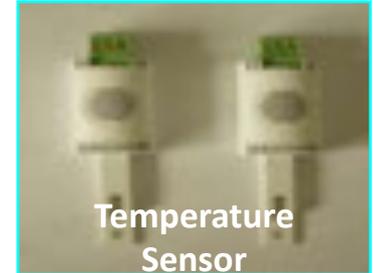
Micro spores collection

Photograph by microscope



Patent: ZL201010178307.2<sup>99</sup>

## (2) Monitoring inside and outside environment of the facilities



**NERCITA has developed ten types greenhouse sensors**

- **Technologies: drift suppressing, nonlinearity compensation**
- **Advantages: precision, stable, consistent**
- **Practical use: information acquisition in greenhouse**

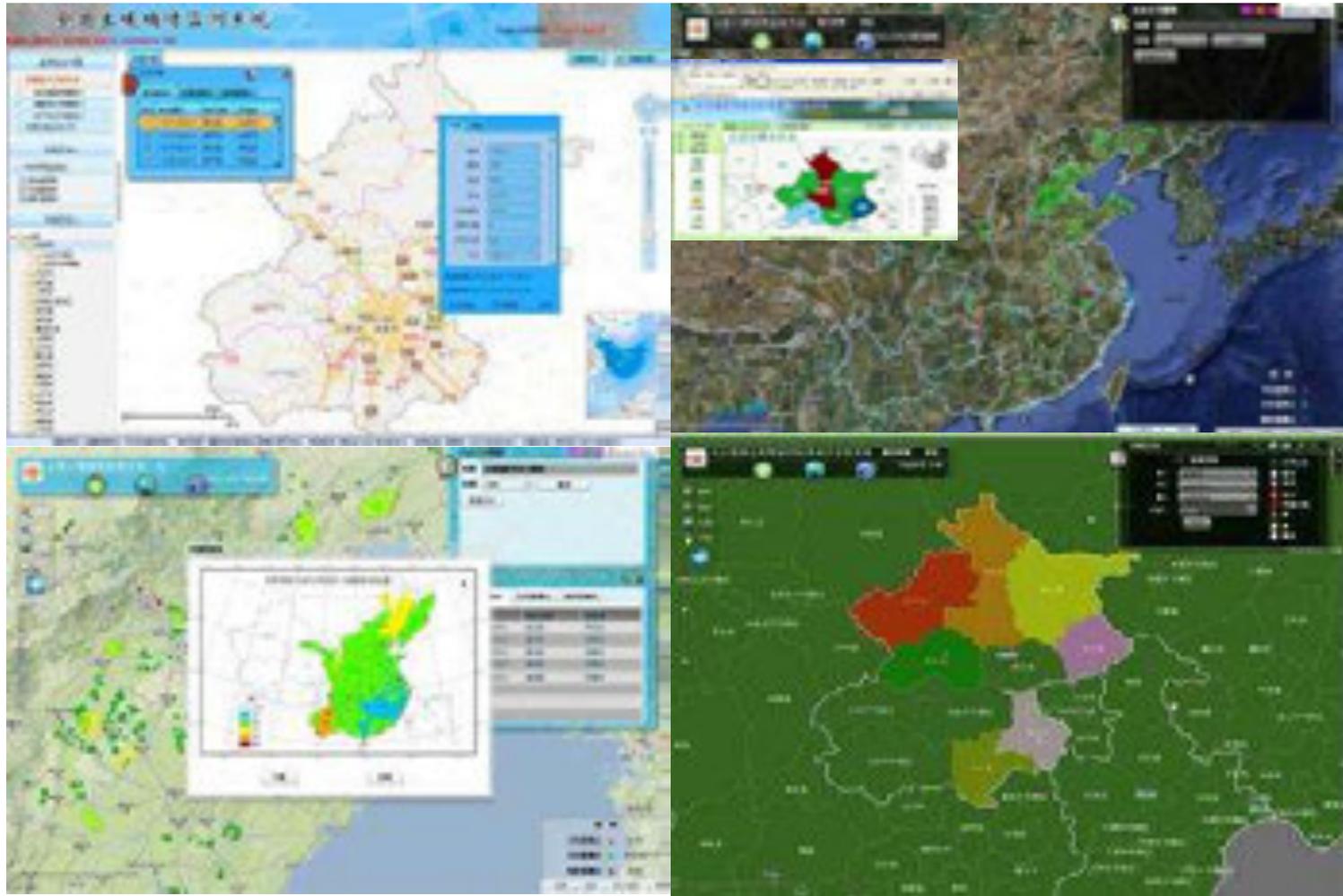
# Soil moisture monitoring

Integrated station

Indicators	Functions
Soil info	Four channel of soil temperature, soil moisture and eight channel for other sensors.
Weather parameters	Air temperature, relative humidity, wind velocity, wind direction, solar radiation, atmosphere, rainfall, ET
Display	LCD touch screen
Communication	GPRS, GSM, WAN
Protocol	Standard MODBUS
Data storage	20000 rows
Programming	Online programming
Transfer method	At different interval, called by cell phone



■ Web specific map and short message services



Agricultural soil moisture disclose and service software

# 农业部办公厅文件

农办农[2010]40号

## 农业部办公厅关于做好土壤墒情 监测工作的通知

各省、自治区、直辖市农业(畜牧)厅(委、局),新疆生产建设兵团农业局:

近年来,我国旱灾频发,旱灾面积不断扩大,干旱缺水已成为粮食稳定增产、农民持续增收的重要制约因素。开展土壤墒情监测,掌握墒情变化情况,是农业抗旱减灾、指导农民科学灌溉、应用先进节水技术的前提和基础。为进一步做好土壤墒情监测工作,更好地服务于农业生产,现将有关事项通知如下:

### 一、充分认识土壤墒情监测工作的重要意义

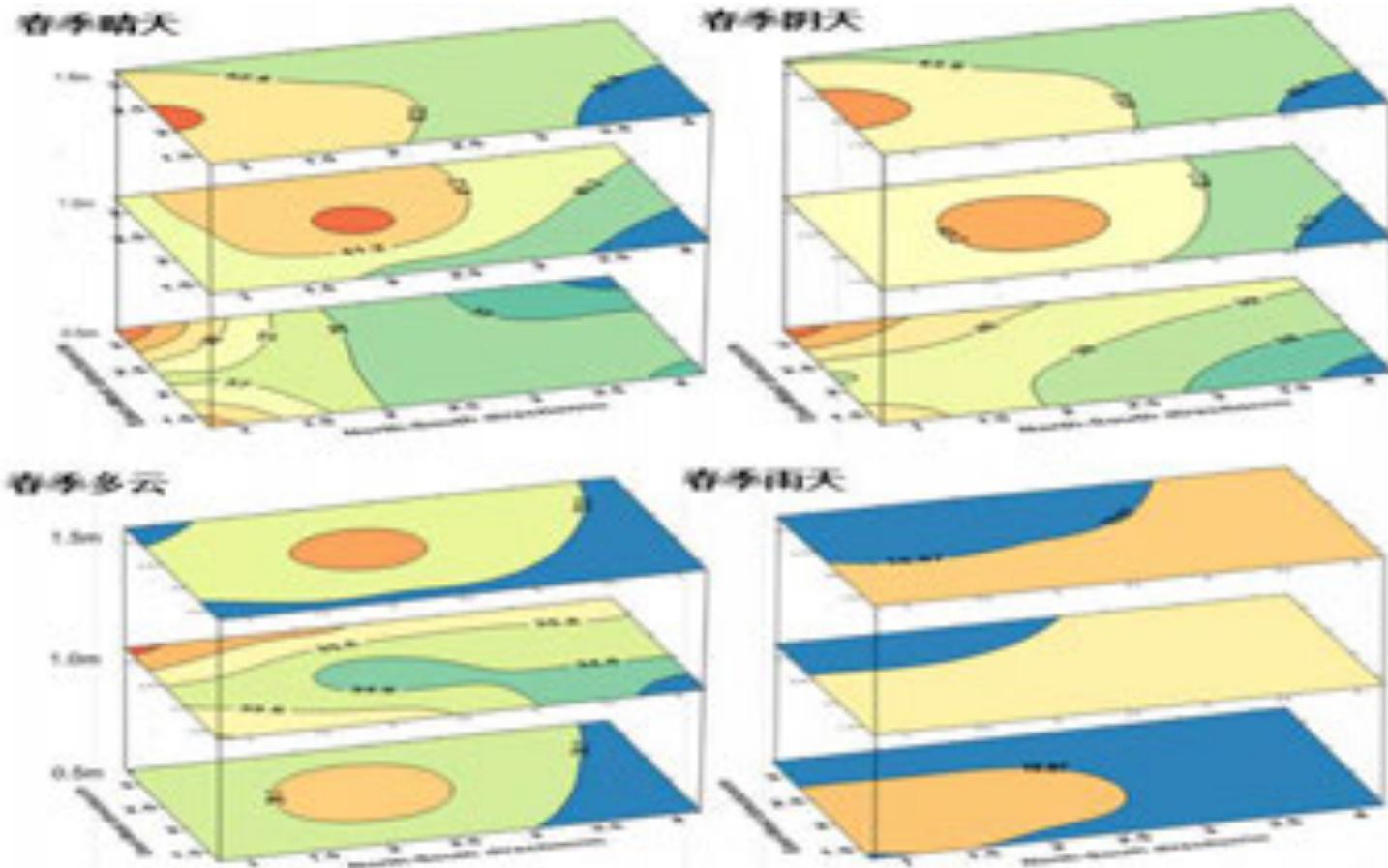
我国是世界上水资源最为紧缺的国家之一,人均水资源占有量 2000 立方米,仅为世界平均水平的 28%。建国以来,我国旱灾

— 1 —

The screenshot shows a web browser window displaying a page from the Ministry of Agriculture of China. The page features a red banner at the top with the text '第四届建设创新型国家大会农资分论坛' (4th National Conference on Building an Innovative Nation - Agricultural Inputs Sub-forum). Below the banner is the logo for '中国节水农业' (China Water-Saving Agriculture) and a navigation menu. The main content area is titled '农业部办公厅关于印发《全国土壤墒情监测工作方案》的通知' (Notice of the General Office of the Ministry of Agriculture on Issuing the 'National Soil Moisture Monitoring Work Plan'). The notice is dated '2010年4月16日' (April 16, 2010) and is signed by '王爱宝' (Wang Aibao). The text of the notice discusses the importance of soil moisture monitoring in the context of increasing droughts and the need for water-saving technologies. The browser's address bar shows the URL 'http://www.moa.gov.cn/'.

•The system has got the funding of 800 million RMB from MOA since 2012

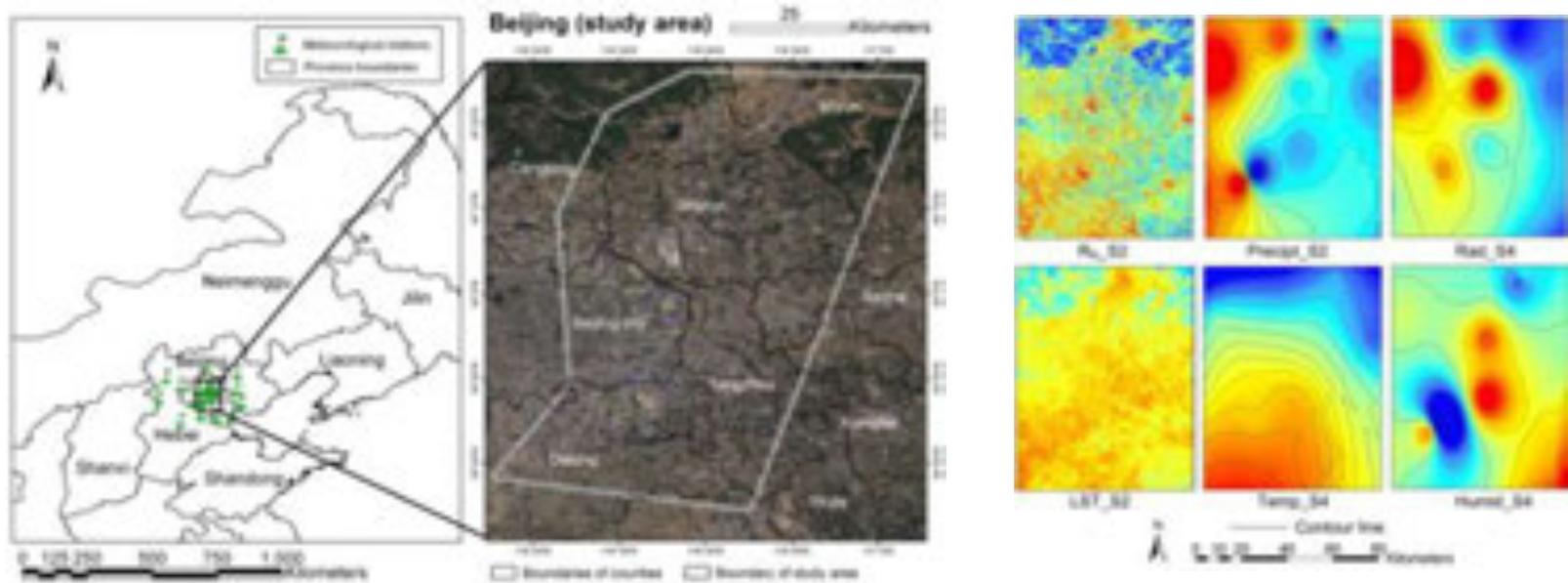
# Time-space distribution of greenhouse environment



春季不同天气温室内不同冠层高度空气温度时空分布

Fig.2-9 Temperature spatial and temporal distribution under different canopy height on different weather spring

# Environment monitoring combining remote sensing and meteorology information



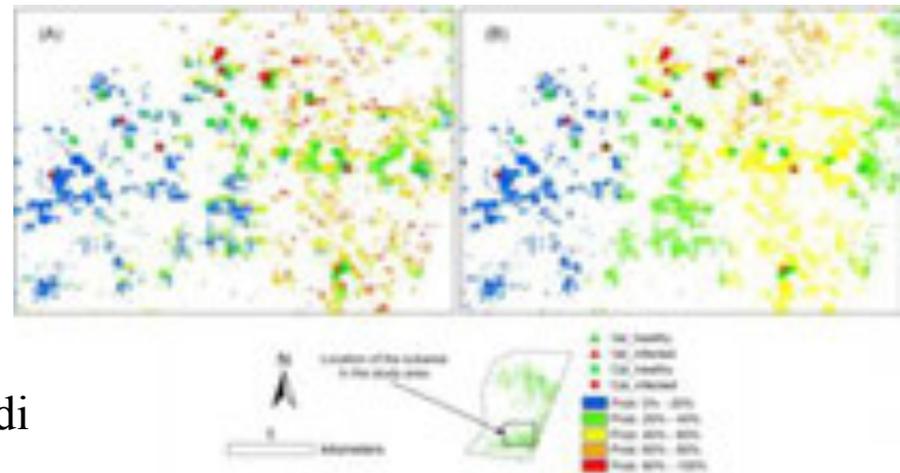
## ■ Vegetarian status variables:

TVI, SAVI, DSWI, SIWSI

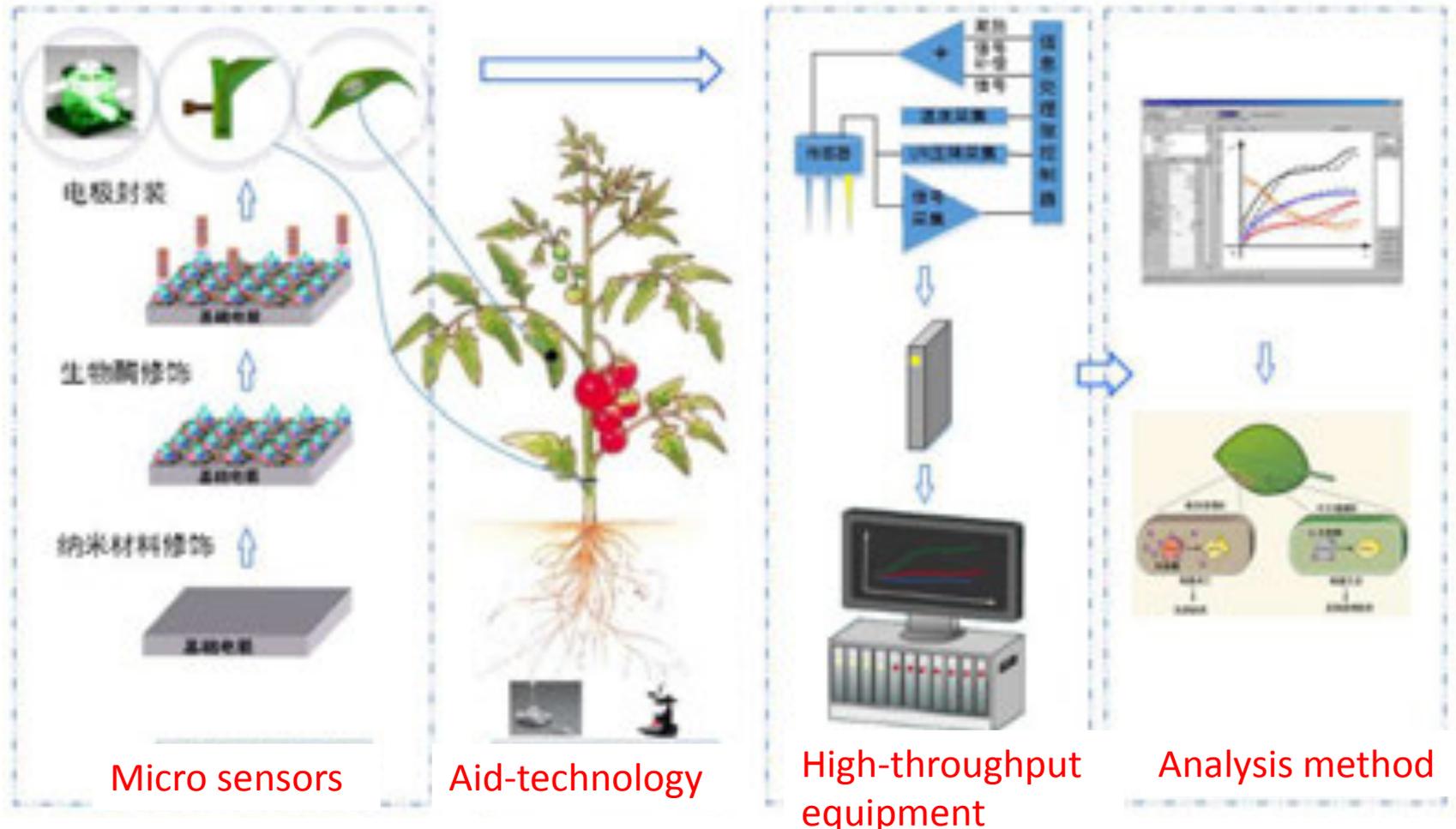
## ■ Farm environment variables:

Land surface temperature (LST)

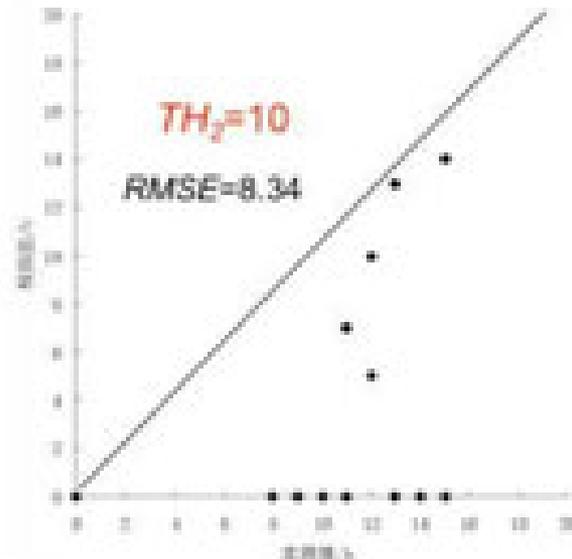
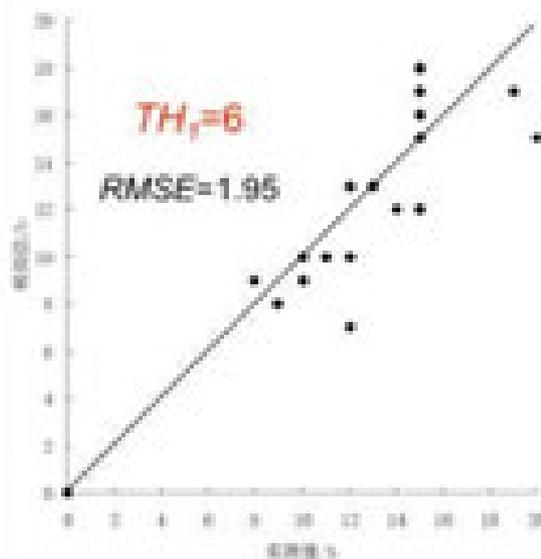
Temperature, rainfall, humidity, radiation



# (3) Host phenotyping: Hyperspectral, High- throughput, online



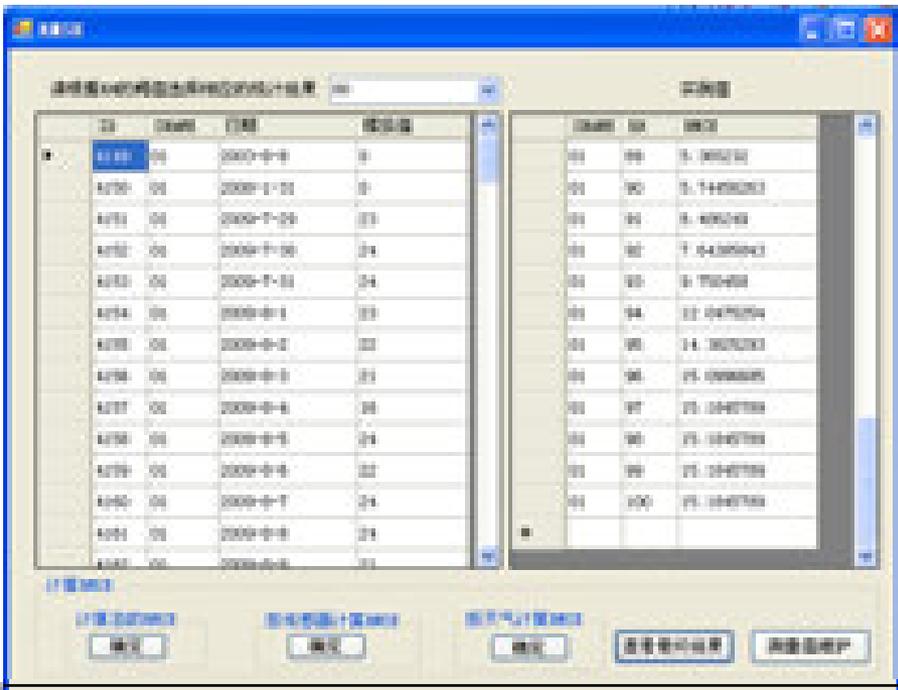
# The calibration method for leaf wetness sensors



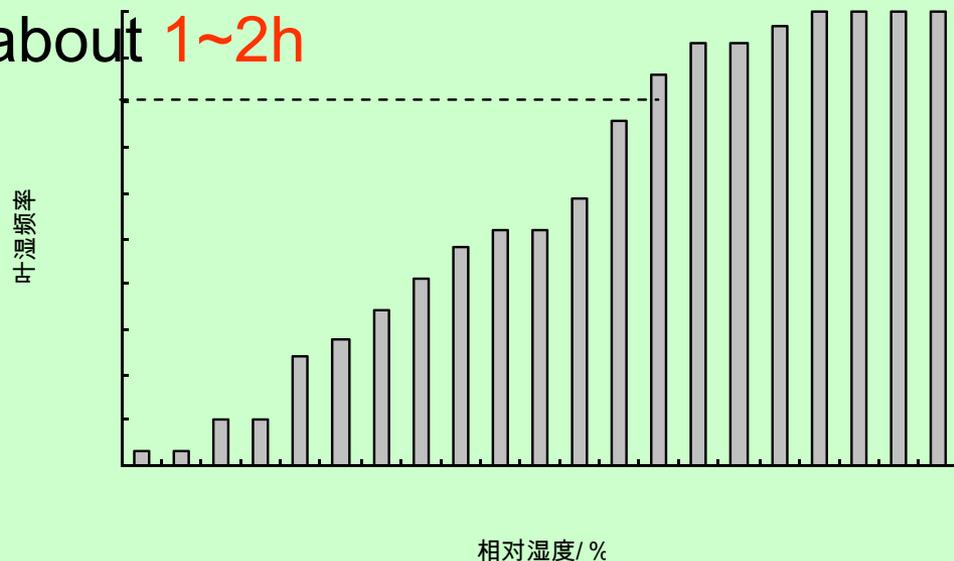
叶片部位	准确率 $F_c$	灵敏度 $C_{SI}$	误报率 $F_{AR}$	偏差率 $B_s$
左侧叶缘	0.75	0.25	0.36	0.46
右侧叶缘	0.79	0.23	0.16	0.29
叶尖	0.83	0.28	0.15	0.35
叶背面	0.63	0.13	0.48	0.29
叶片下方	0.70	0.12	0.08	0.14

(Li et al., Transaction of CSAE, 2010b)

# The estimation model based on RH



RH $\geq$ 89% or 90%, the errors are about 1~2h



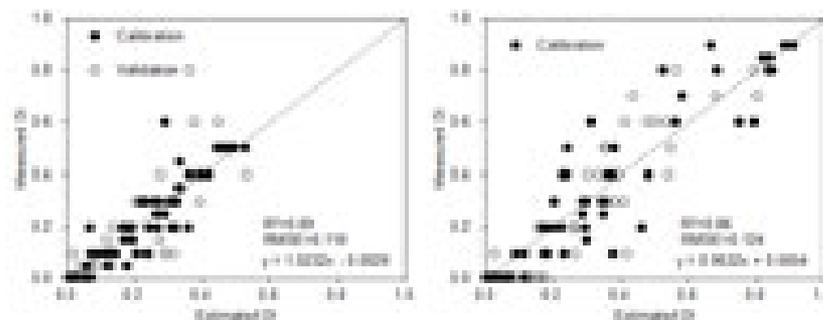
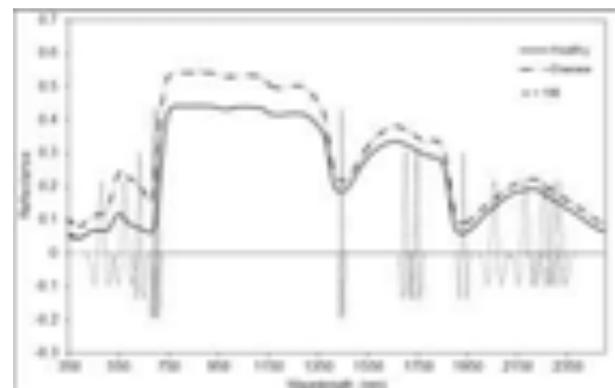
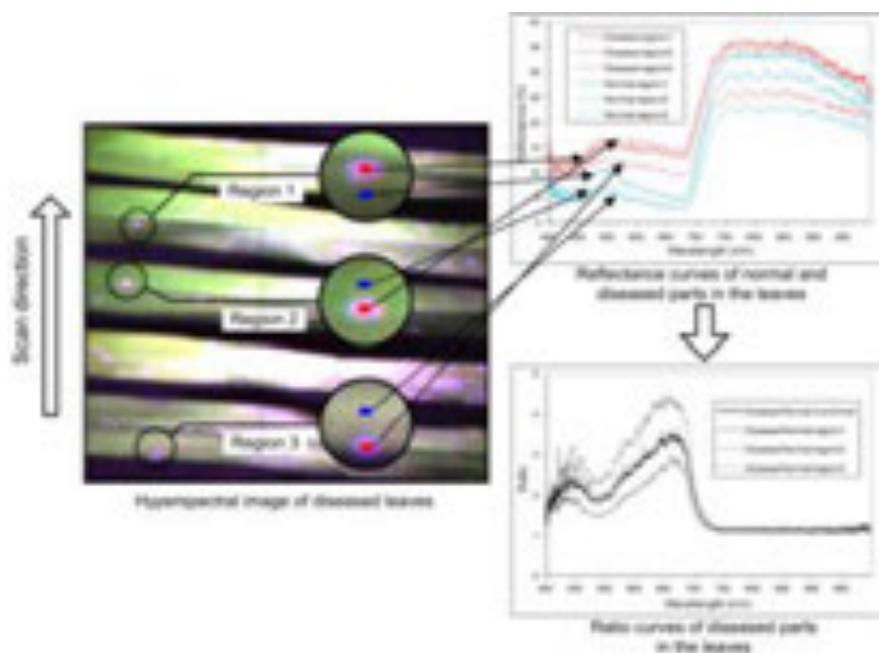
*a*      *b/h*      *R*<sup>2</sup>      *W*      *C*      *MAE/h*      *MBE/h*

试错法	1.22	-3.17	0.73	0.89	0.82	2.03	0.03
平均值法	1.25	-2.86	0.74	0.89	0.82	2.14	0.76
叶湿频率法	1.27	-6.58	0.62	0.78	0.69	3.55	-2.65

2016-5-3

(Li et al., Transaction of CSAE, 2010c)

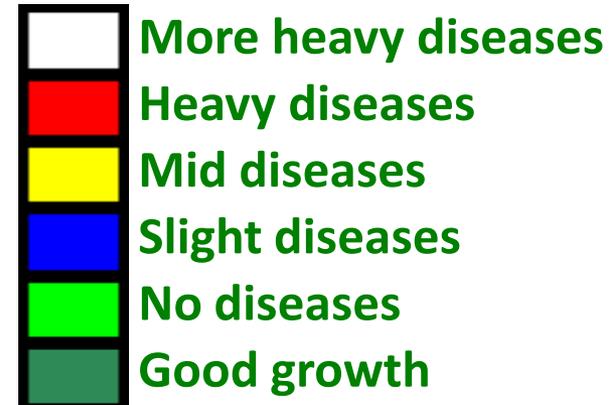
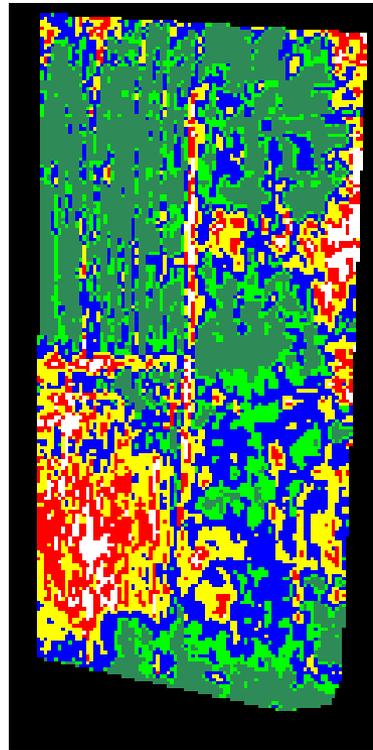
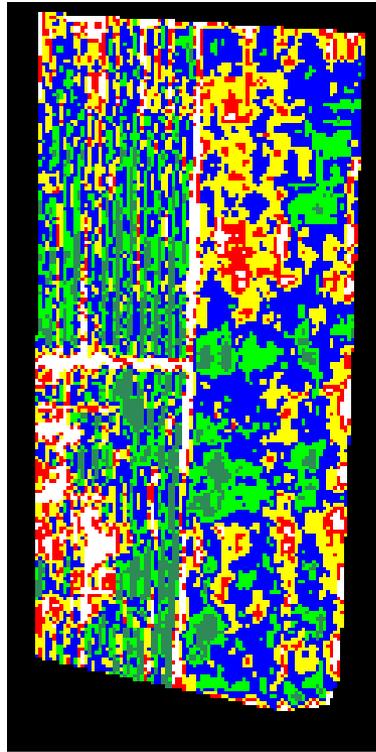
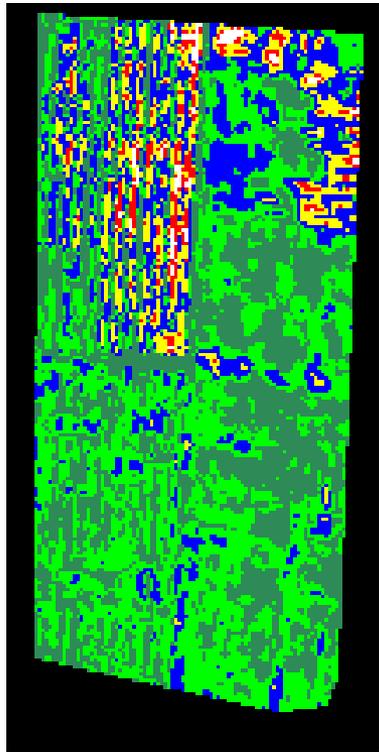
# Crop disease spectrum characteristics and info abstraction



Analysis and process  
of image spectrum  
information

# Crop disease monitoring

$$Disease\_index = \frac{R_{Disease} - R_{Normal}}{R_{Normal}} \times \frac{NIR_{Normal} - NIR_{Disease}}{NIR_{Normal}}$$



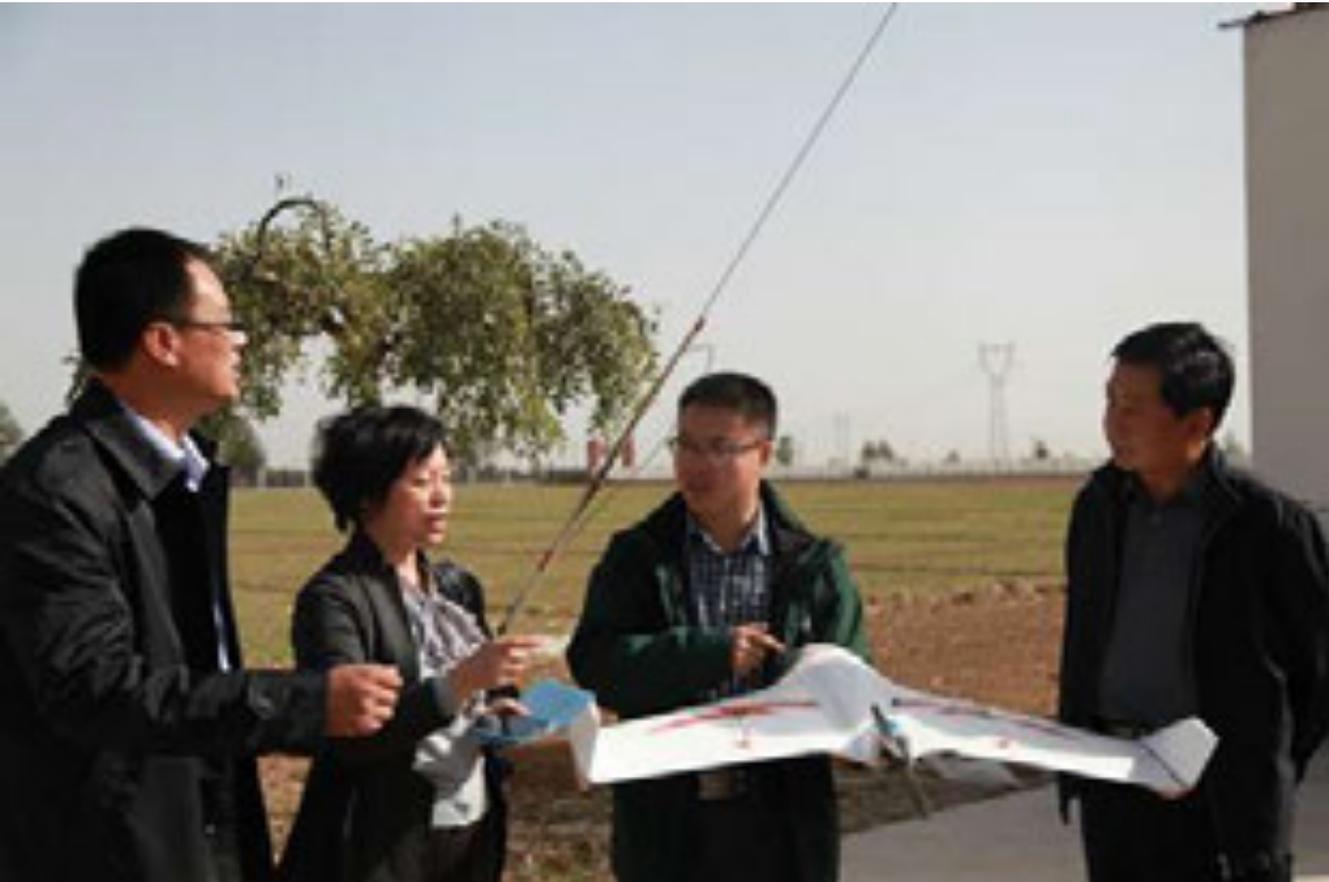
PHI image spectrum based disease index monitoring in different stages



## **NERCITA has developed five crop information analysis systems**

**With machine vision and Hyperspectral technologies, we have realized non-damage detection for greenhouse crop nutrition, growth diagnosis, main agricultural parameters.**

# UAV in application



# (4) Portable agricultural record keeping system



# Production record keeping system

The image displays three screenshots of a production record keeping system interface, showing data entry, a warning message, and a confirmation dialog.

**Screenshot 1: Disease\_early\_early Warning**  
Field ID: 003605  
Cultivar: Jingyan mini No.2  
Primary inoculum: Yes  
Transplanting date: 2008-02-05  
The latest irrigation date: 2008-04-14  
Sky in daytime: Overcast  
Sky in nighttime: Overcast  
Daily mean temp(°C): 13.5  
Daily mean RH(%): 92  
Daily range of temp(°C): 4  
Buttons: Save, Early warning

**Screenshot 2: Early Warning**  
**Warning**  
Cucumber downy mildew early warning!  
The predicted infection date is 2008-4-14.  
Warning obviation treatment:  
The ventilation in time is required. The Chlorothalonil smoke could be used.  
Buttons: OK, Quit

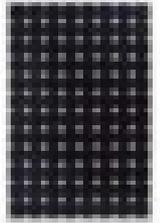
**Screenshot 3: Pesticide Usage**  
Field ID: 003605  
Damage Level: Low  
Pesticide Type: Fungicide  
Pesticide Name: Chlorothalonil  
Usage Date: 08-4-16  
Buttons: OK, Quit

**Confirmation Dialog:**  
The pesticide application is proper  
Buttons: OK

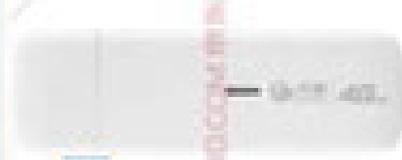
# Field image monitoring



高清720P国产红外网络高速球



电信4G无线网卡+3G无线路由器  
=1M以上上行速率



病斑面积识别

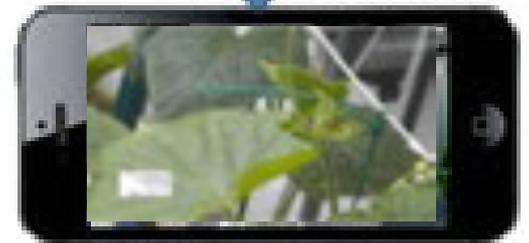
电脑端查看



新梢测量

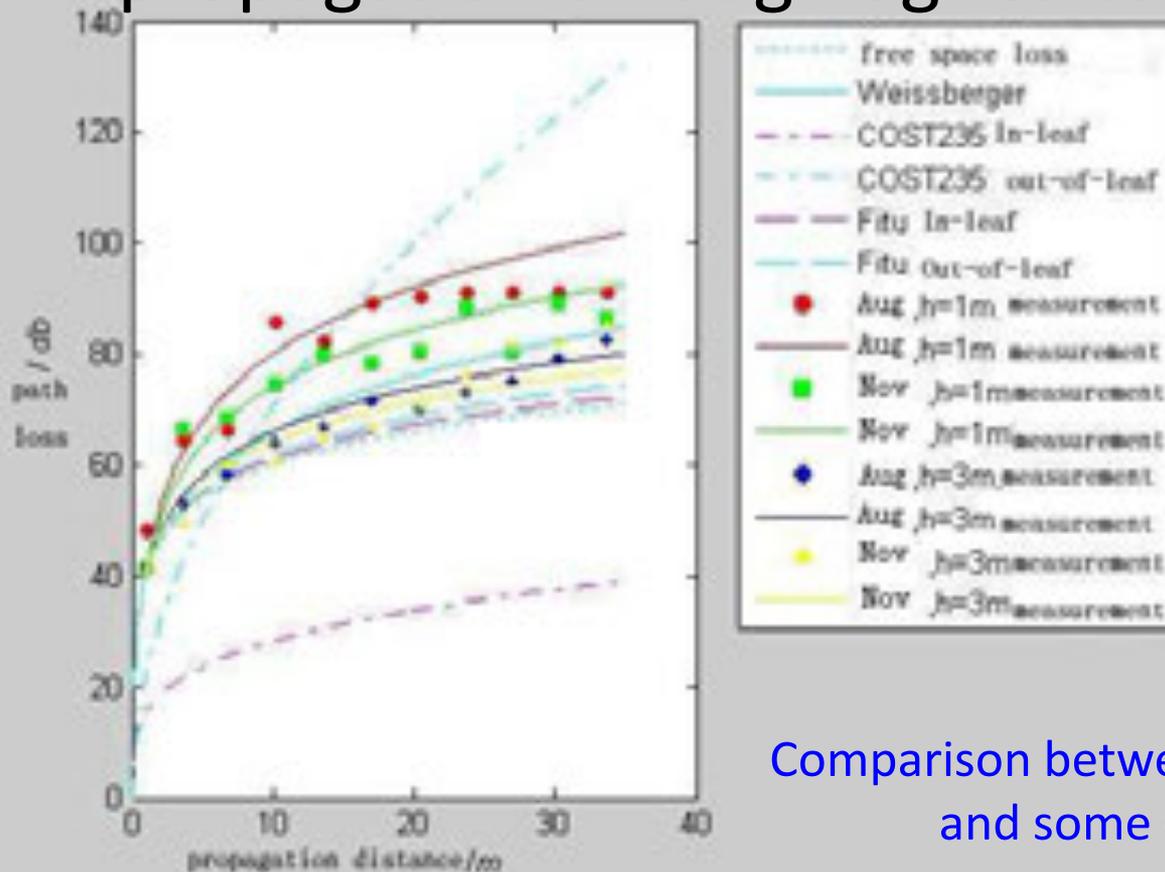


手机端查看



# (5) Wireless Sensor Network application

- Research on characteristics of radio propagation through agricultural environment



## Conclusions

The existed models fail in estimating the path loss in orchard.

The path loss change great in different heights at the same time

Great change exists in path loss at different times in the same height.

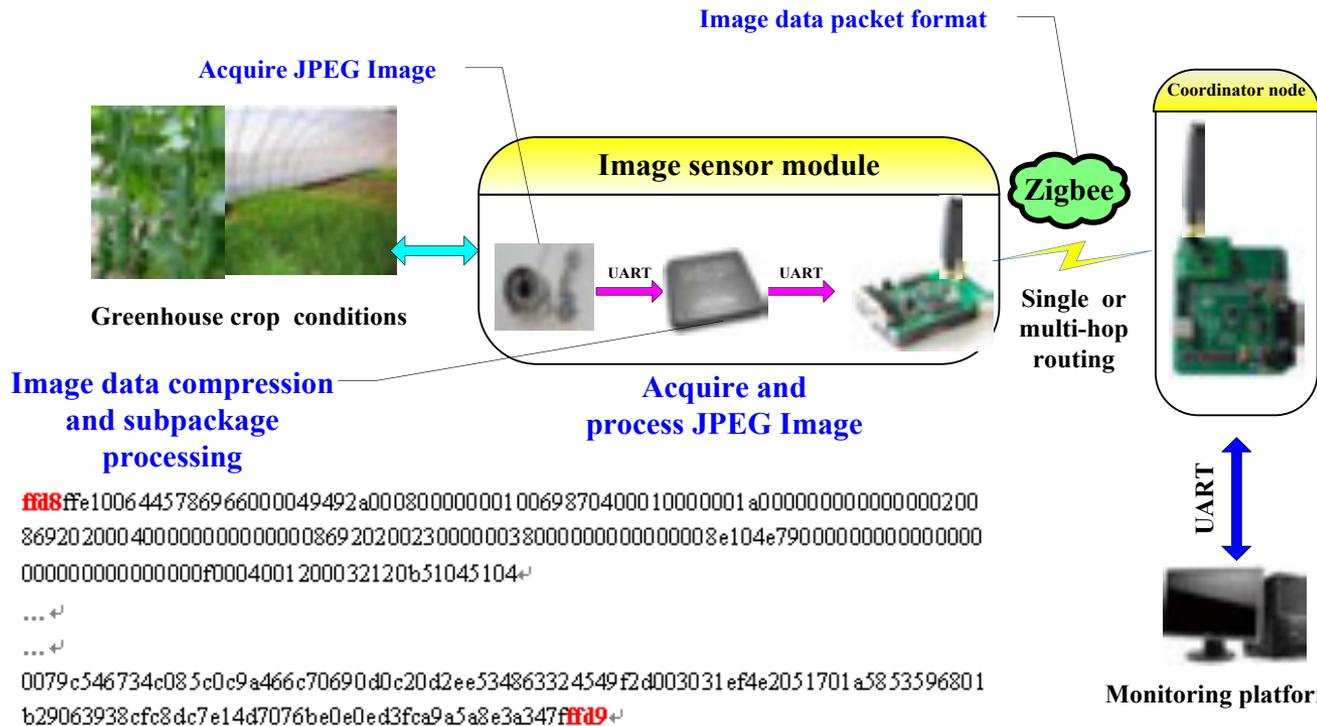
The new model can well estimate the path loss in different height and times.

Comparison between the measured data and some existed models

# (5) Wireless Sensor Network application

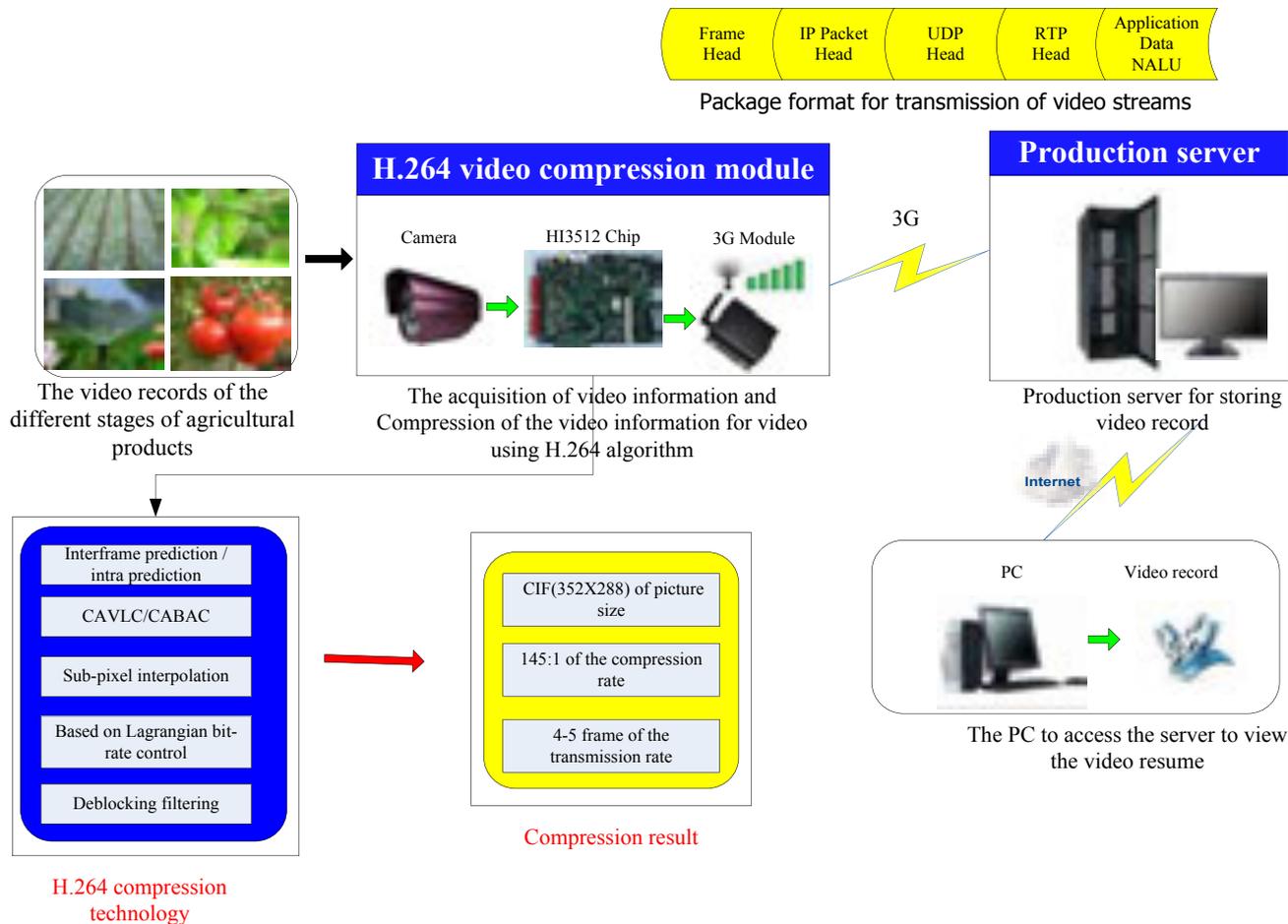
- ZigBee-based wireless sensor network image transmission technology

2Bytes	2Bytes	8Bytes	1Bytes	1Bytes	0-80Bytes
0xFF 0xD8	ZigBeeNetwork layer address	ZigBee MAC layer address	Serial number	Data payload Length	Data payload



# (5) Wireless Sensor Network application

- H.264 video compression technology



## ***3.3 Model***

# ***establishment***

# Field experiment



# Clarifying the meaning of warning

- These warnings would include disease occurrence (yes or no) and its probability.

**Table 1**

Categories and a summary of calculation results of the early warning model for primary infection of cucumber downy mildew in solar greenhouses (EWMPICDW) in each day.

<i>N</i>	Estimated – Yes	Estimated – No
Observed – Yes	Hits ( <i>X</i> )	Misses ( <i>Y</i> )
Observed – No	False alarms ( <i>S</i> )	Correct negatives ( <i>Z</i> )

# Forecasting the warning situation

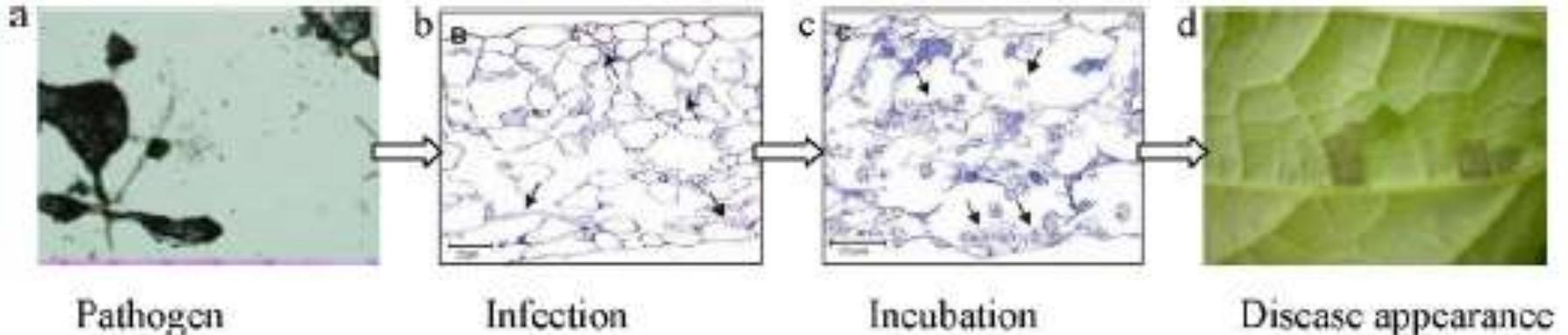


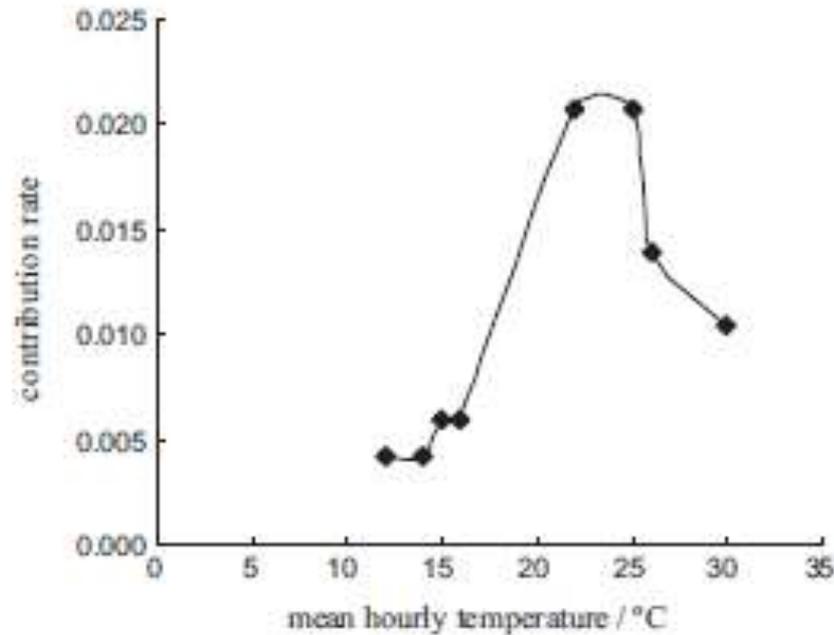
Fig. 3. The primary infection mechanism of cucumber downy mildew.

(Lindenthal et al., 2005)

- Infection condition early warning sub model
  - $LWD \times TLWD \geq 40 \text{ h } ^\circ\text{C}$  ( $LWD \leq 2\text{h}$ ,  
 $5 \text{ } ^\circ\text{C} \leq TLWD \leq 30 \text{ } ^\circ\text{C}$ ) (Cohen, 1977)

# Forecasting the warning situation

- Incubation period early warning sub model



(Fu and Yao, 1983)

Fig. 4. Fitted curve of the mean hourly temperature and contribution rate for incubation of cucumber downy mildew in solar greenhouses.

$$y = \frac{0.0165}{1 + 10389.2 \times \exp(-0.5743 \times t)} \quad (p = 0.0033)$$

# Validation by 4-year data

**Table 2**

Disease investigation results in Xiaotangshan and BAAPS.

Year	Point	Predicted infection date	Predicted occurrence date	Observed occurrence date	Year	Point	Predicted infection date	Predicted occurrence date	Observed occurrence date
Xiaotangshan					BAAPS				
2006	1 <sup>a</sup>	21-October	26-October	26-October	2008	31 <sup>b</sup>	N	N	N
2006	2 <sup>a</sup>	21-October	26-October	26-October	2008	32 <sup>b</sup>	N	N	N
2006	3 <sup>a</sup>	21-October	26-October	26-October	2008	33 <sup>b</sup>	N	N	N
2006	4 <sup>a</sup>	21-October	26-October	26-October	2008	34 <sup>a</sup>	30-October	4-November	21-November
2006	5 <sup>a</sup>	21-October	26-October	26-October	2008	35 <sup>c</sup>	2-December	16-December	20-November
2006	6 <sup>a</sup>	21-October	26-October	26-October	2008	36 <sup>a</sup>	13-November	17-November	20-November
2006	7 <sup>a</sup>	21-October	26-October	26-October	2008	37 <sup>a</sup>	12-November	17-November	16-November
2006	8 <sup>a</sup>	21-October	26-October	26-October	2008	38 <sup>c</sup>	2-December	9-December	16-November
2006	9 <sup>a</sup>	21-October	26-October	26-October	2008	39 <sup>c</sup>	25-November	1-December	14-November
2006	10 <sup>a</sup>	21-October	26-October	26-October	2008	40 <sup>a</sup>	11-November	16-November	16-November
2006	11 <sup>a</sup>	21-October	26-October	26-October	2008	41 <sup>d</sup>	12-November	17-November	15-November
2006	12 <sup>a</sup>	21-October	26-October	26-October	2008	42 <sup>c</sup>	N	N	14-November
2006	13 <sup>a</sup>	21-October	26-October	26-October	2008	43 <sup>b</sup>	N	N	N
2006	14 <sup>a</sup>	21-October	26-October	26-October	2008	44 <sup>c</sup>	11-November	16-November	14-November
2006	15 <sup>a</sup>	21-October	26-October	26-October	2008	45 <sup>d</sup>	11-November	16-November	15-November
2007	16 <sup>a</sup>	13-February	21-February	24-February	2009	46 <sup>a</sup>	16-April	20-April	19-April
2007	17 <sup>a</sup>	21-February	7-March	24-February	2009	47 <sup>b</sup>	N	N	N
2007	18 <sup>a</sup>	16-February	24-February	24-February	2009	48 <sup>b</sup>	N	N	N
2007	19 <sup>a</sup>	15-February	24-February	26-February	2009	49 <sup>d</sup>	16-April	20-April	19-April
2007	20 <sup>a</sup>	16-February	26-February	24-February	2009	50 <sup>b</sup>	N	N	N
2007	21 <sup>a</sup>	16-February	24-February	24-February	2009	51 <sup>c</sup>	N	N	20-April
2007	22 <sup>a</sup>	14-February	21-February	24-February	2009	52 <sup>b</sup>	N	N	N
2007	23 <sup>a</sup>	16-February	24-February	26-February	2009	53 <sup>b</sup>	N	N	N
2007	24 <sup>a</sup>	13-February	21-February	24-February	2009	54 <sup>c</sup>	N	N	20-April
2007	25 <sup>a</sup>	16-February	23-February	24-February	2009	55 <sup>c</sup>	N	N	20-April
2007	26 <sup>a</sup>	N <sup>e</sup>	N	N	2009	56 <sup>b</sup>	N	N	N
2007	27 <sup>b</sup>	N	N	N	2009	57 <sup>b</sup>	N	N	N
2007	28 <sup>b</sup>	N	N	N	2009	58 <sup>b</sup>	N	N	N
2007	29 <sup>b</sup>	N	N	N	2009	59 <sup>b</sup>	N	N	N
2007	30 <sup>b</sup>	N	N	N	2009	60 <sup>b</sup>	N	N	N

<sup>a</sup> The predicted infection date or predicted occurrence date was earlier than the observed occurrence date.

<sup>b</sup> The cucumber downy mildew did not appear, and the model did not present early warning (true negative points, TNP).

<sup>c</sup> The model did not present infection and occurrence early warning before the observed occurrence date.

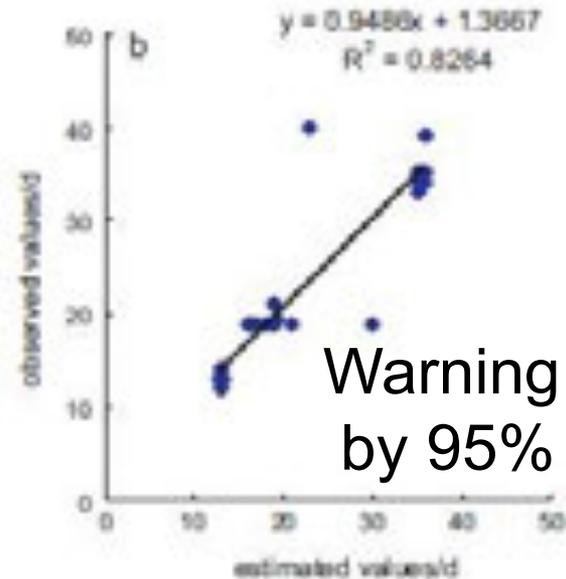
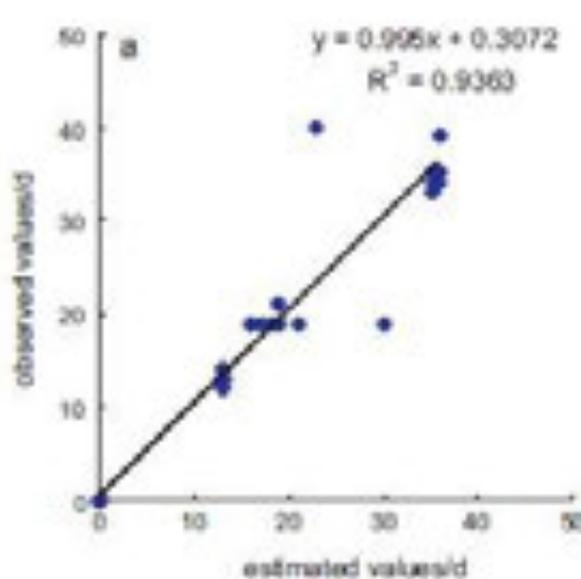
<sup>d</sup> The predicted infection date was earlier than the observed occurrence date, but predicted occurrence date was later than the observed occurrence date.

<sup>e</sup> N denoted no predicted infection, predicted disease occurrence or observed disease occurrence.

# Model evaluation

**Table 4**  
Kruskal analysis of early warning results of the early warning model for primary infection of cucumber downy mildew in solar greenhouses (EWMPCDW).

	Estimated - Yes	Estimated - No	Total number	Prior probability	Posterior probability
Observed - Yes	X = 84 P(B A) = 0.68	Y = 39 P(B A) = 0.32	123	P(A) = 0.68	P(A B) = 0.66
Observed - No	Z = 34 P(B A) = 0.06	W = 378 P(B A) = 0.94	612	P(A) = 0.32	P(A B) = 0.58
Total number	118	414	715		



Warning the disease by 95% probability

**Fig. 5.** Comparison of the occurrence date between observed values and estimated values under the early warning model for primary infection of cucumber downy mildew in solar greenhouses (EWMPCDW).

(Zhao et al., Computers and Electronics in Agriculture 2011)

## ***3.4 Decision and conducting***

# Early warning system application



## 黄瓜霜霉病预警模型

### (1) 菌源条件

如果温室前茬种植过黄瓜或发生过黄瓜霜霉病，或者附近温室或露地发生黄瓜霜霉病，就具备菌源条件。

### (2) 初侵染预警

计算每天的叶片湿润时间，叶片湿润时间的获得，采用每天超过93%的相对湿度的小时数作为估计。计算叶片湿润时间内的平均温度。

$$LWD * TLWD \geq 40 \quad (LWD \geq 2, 5 \leq TLWD \leq 30)$$

式中：LWD——叶片湿润时间，h；TLWD——叶片湿润时间内的平均温度，℃。满足上述条件，霜霉病菌就可能侵染。

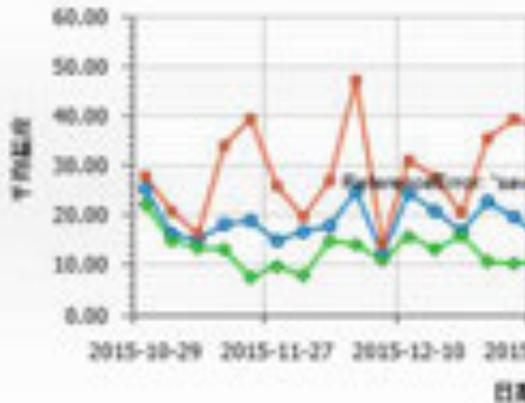
### (3) 潜育期/发病日期预警

此后开始启动每小时平均温度 $t$ 与潜育期贡献率 $y$ 的模型公式。当 $y$ 累计达到1时，潜育期结束。式中： $y$ ——潜育期贡献率，无量纲； $t$ ——每小时的平均温度，℃。

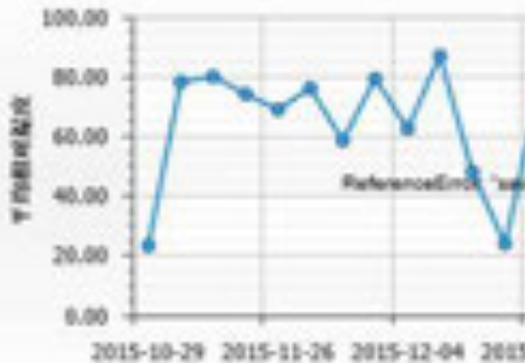
$$y = \frac{0.0165}{1 + 10389.2 \cdot \exp(-0.5743 \cdot t)}$$

### (4) 发病概率预警

级别	绿	蓝	黄	橙	红
初侵染发生分级	无警	轻警	中警	重警	巨警
霜霉病初侵染发生概率 $a$ (%)	$a=0$ 低	$0 < a \leq 40$ 较低	$40 < a \leq 60$ 中等	$60 < a \leq 80$ 较高	$80 < a \leq 100$ 很高
对应温湿度范围	日均温低于15或高于25℃	日均温15-20℃，相对湿度60-	日均温15-20℃，相对湿度85%	日均温20-25℃，相对湿度60-	日均温20-25℃，相对湿度85%



下图是定植以来每日



# Visual simulating appearance of plant leaves infected by disease and insect pests



a. 黄瓜白粉病  
a. Powdery mildew of cucumber



b. 茄子白粉病  
b. Powdery mildew of eggplant



c. 小麦叶锈病  
c. Wheat leaf rust

图7 实际病害图像

Fig.7 Actual plant disease images.

本文算法可通过病情调节参数  $\alpha$ ，进而控制病情指数，进行量化的病情模拟，图8为不同病情指数下白粉病表现模拟 ( $D_{ys}=0.44$ ,  $P_{ys}=0.47$ )，与

图7a进行对比可知，本文方法在病斑分布、霉层表现等方面均符合实际病斑的特征。



a. 实际病情0级  
a. Disease index is 0



b. 模拟病情2级  
b. Disease index is 2



c. 模拟病情3级  
c. Disease index is 3



d. 模拟病情4级  
d. Disease index is 4

注:  $D_{ys}=0.44$ ,  $P_{ys}=0.47$

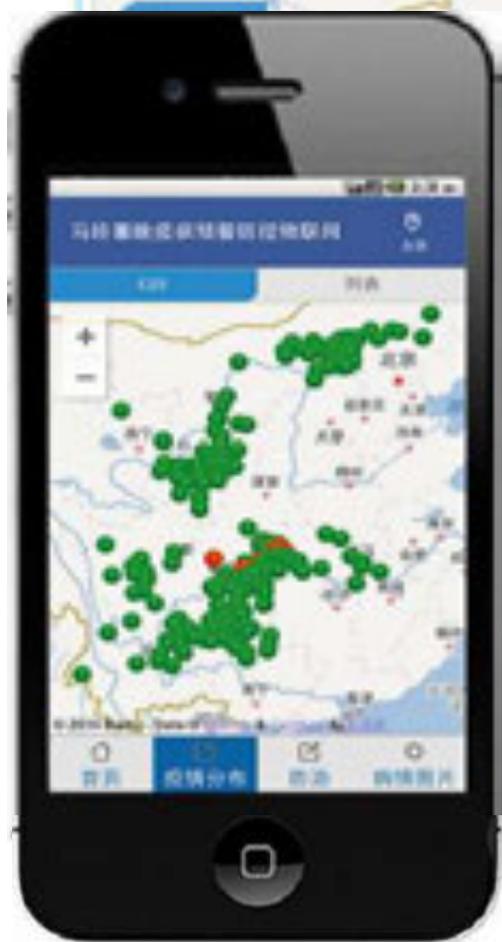
图8 不同病情指数下的黄瓜白粉病表现

Fig.8 Appearance of powdery mildew of cucumber of different disease indexes

# New systems



# Potato late blight warning system



监测点数据	
重庆市	
当前天气	无病状
预计时间	第1代3次感染1.00分
温度: 13.0°C	湿度: 94%
降水: 0mm	风速: 0m/s
最近更新时间: 2015-05-06 22:00	
经度: 108.4	纬度: 31.71
地址: 重庆市城口县邓坝	
预计时间	第1代3次感染1.00分
预计时间	第4代4次感染1.00分
预计时间	第2代4次感染1.71分
预计时间	第4代4次感染1.71分
预计时间	第1代3次感染1.00分
预计时间	第1代4次感染1.00分
预计时间	第1代3次感染1.00分

# Spraying machine



# Robot for spraying



**Robot platform for multi-span greenhouses**



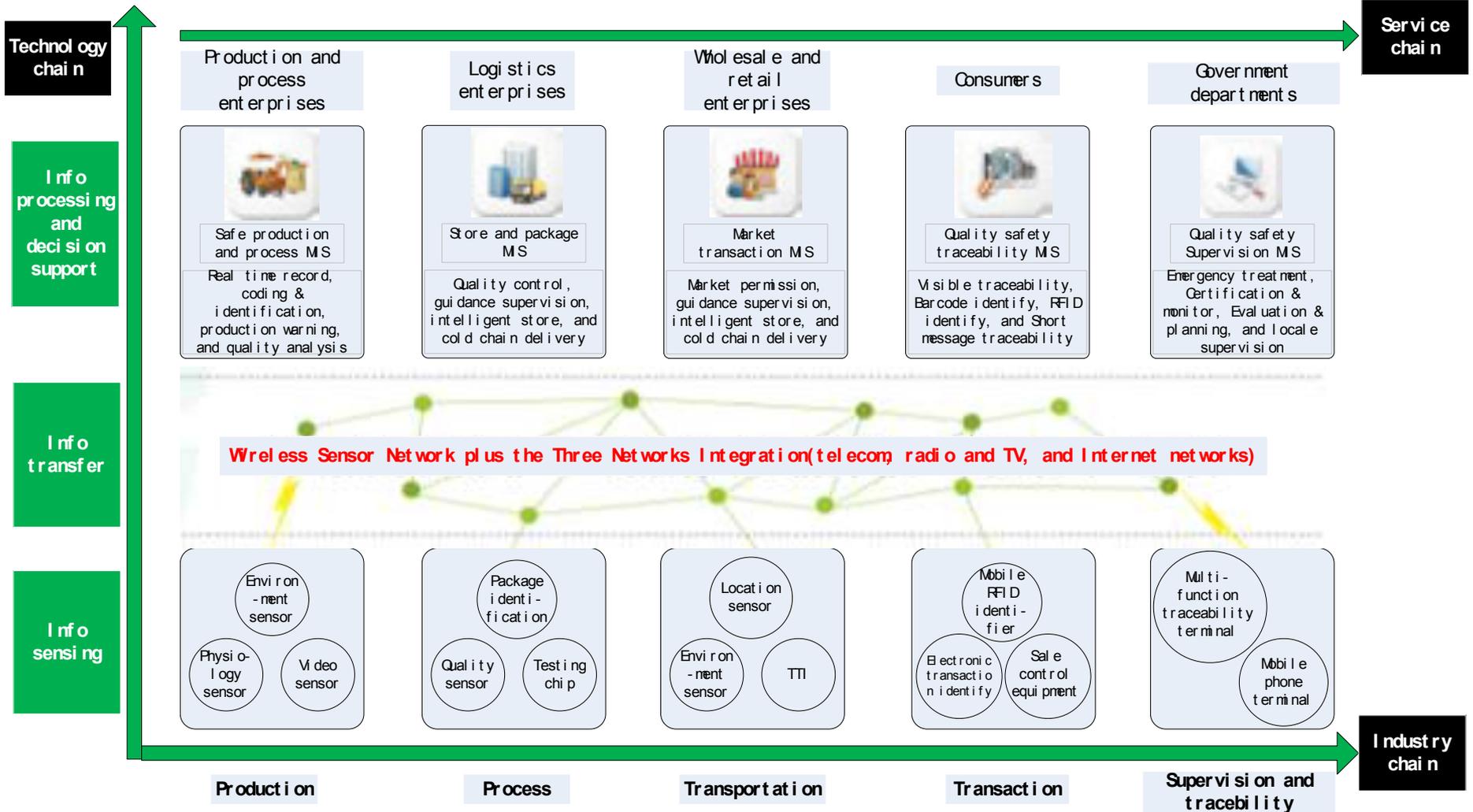
**Remote Spray robot for solar greenhouses**

# Variable rate spraying system based on machine vision

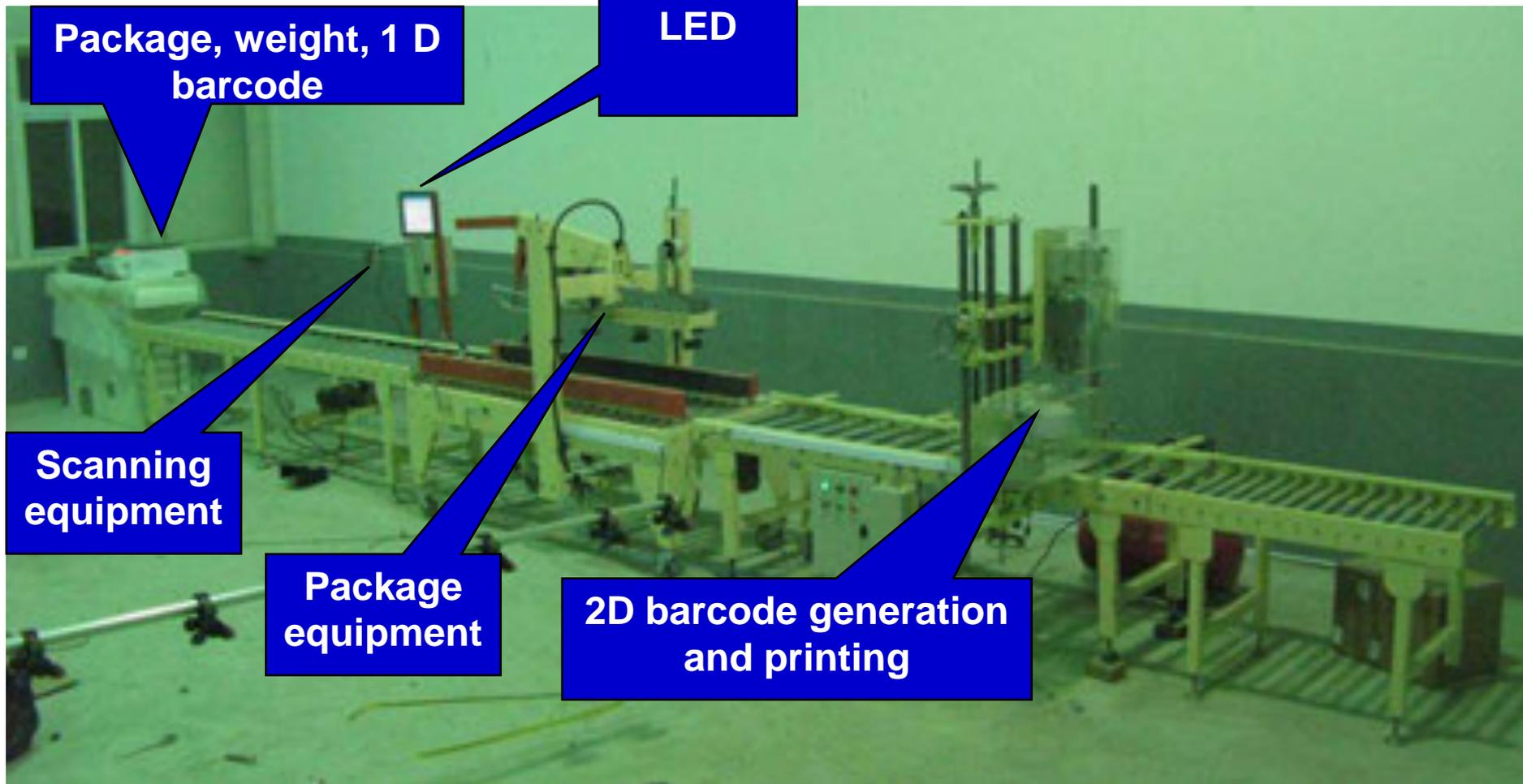


*This kind of sensor-based variable rate sprayer can find weeds on-line in the field automatically, so where is weeds where is spraying.*

# 4. Logistics



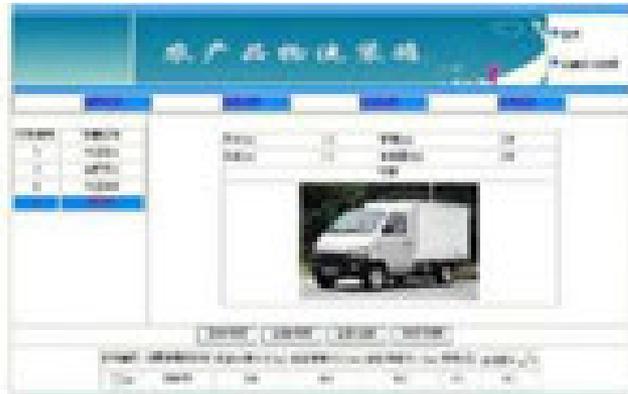
# Auto packaging line for agricultural products



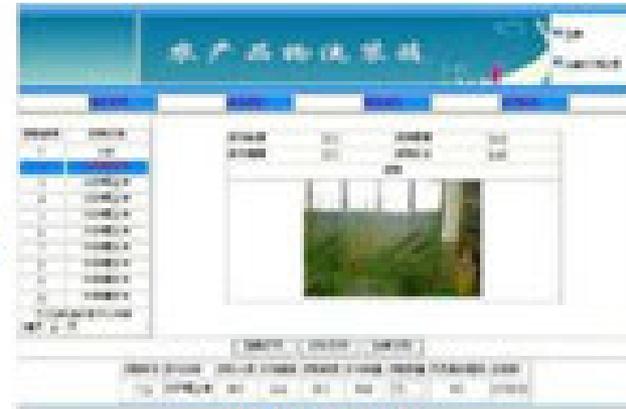
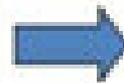
# Logistics management system



# Logistics loading and 3D display



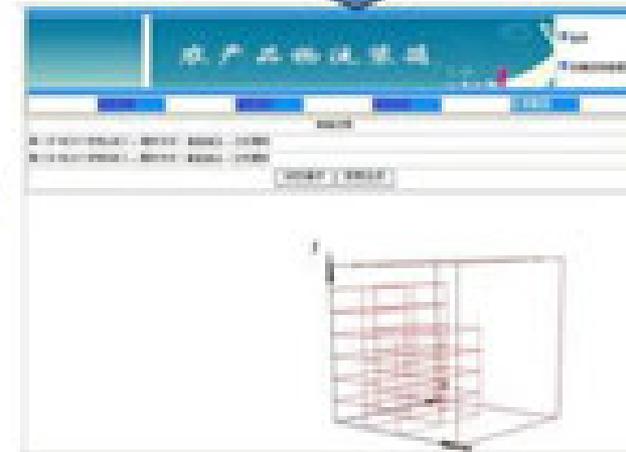
Vehicle



Product

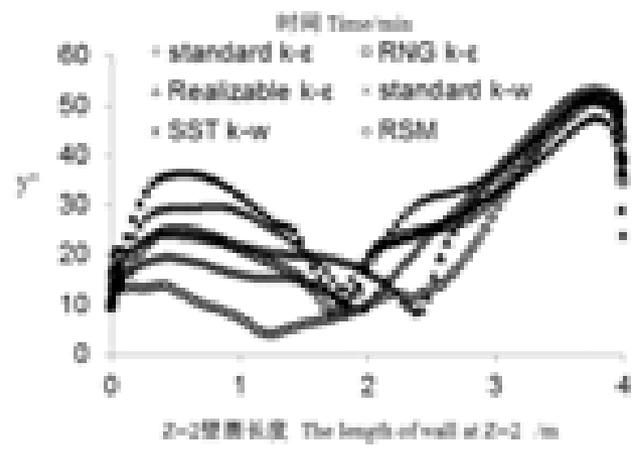
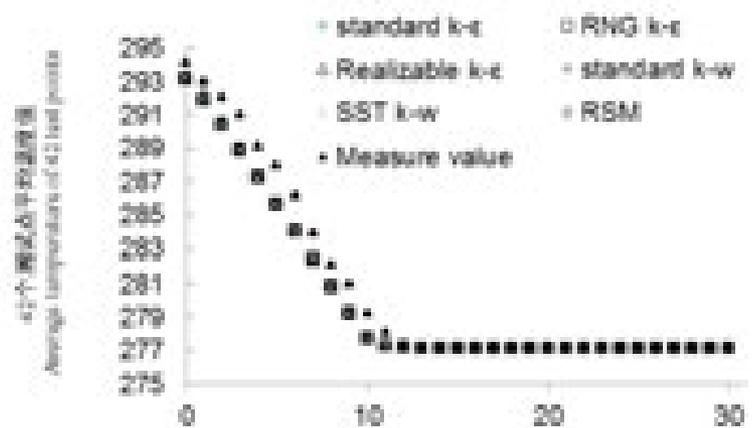
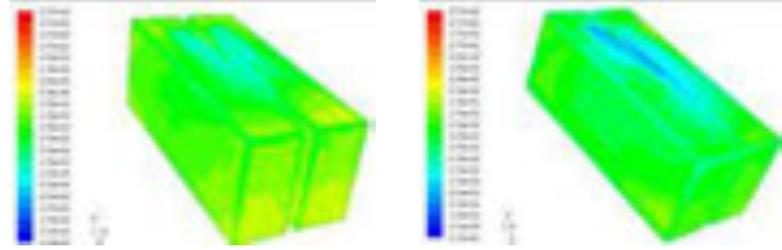
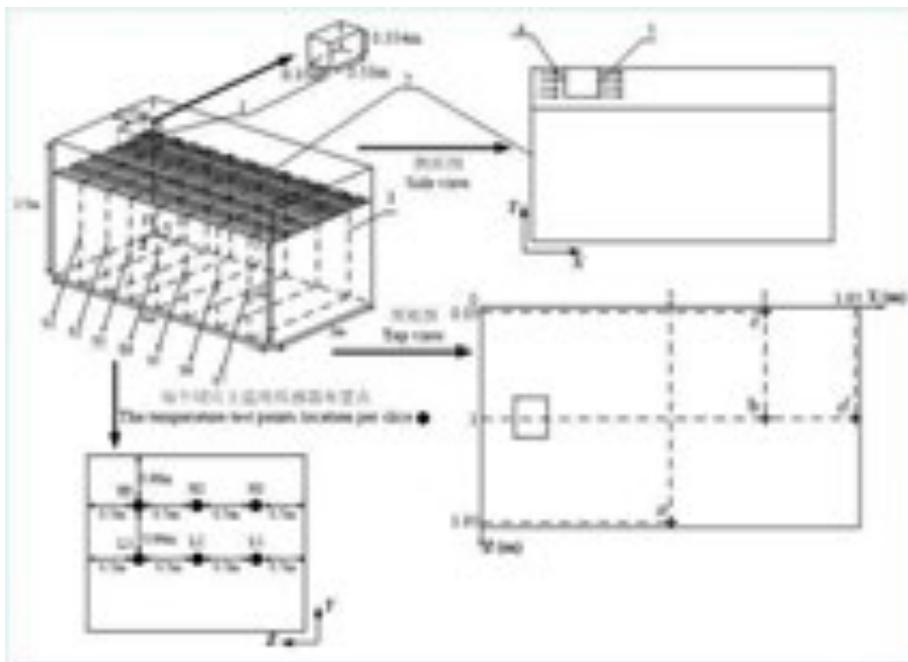


3D loading



Prior grade

# Temperature dynamic modeling in cold chain



# Transaction management

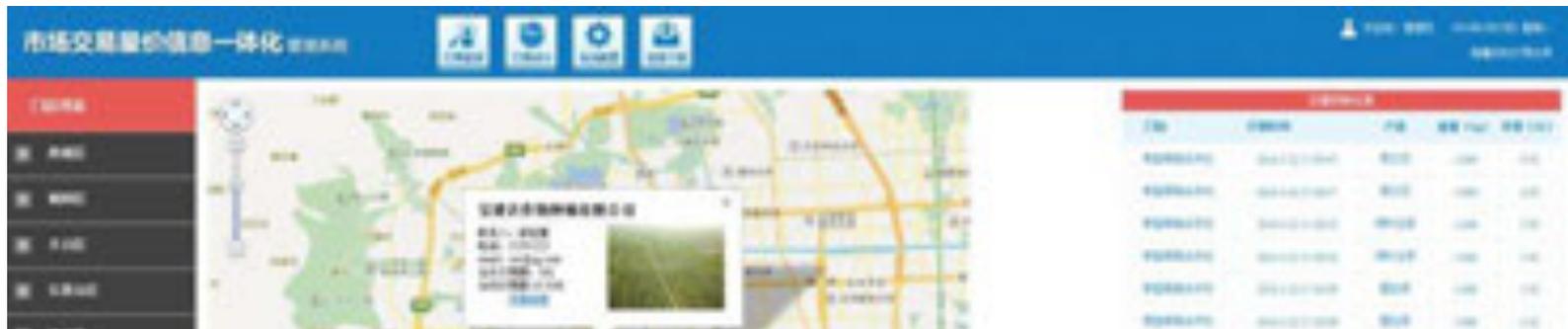
- Electronic scale for traceability using barcode

Type	Portable	Pillar base	weigh-bridge
Max scope	30Kg	300Kg	1t or individual size
Division value	10g	20g	0.1kg
Main functions	Weighting, location, 2D barcode printing and data wireless transfer		
Characteristics	RFID identification	Multi-form of barcode printing	IPC control and touch screen
Applied scene	High-level agri-product, cooperative with direct package in field	Cooperatives or whole sale market with mid-amount	Cooperatives or whole sale market with big amount



# Transaction management

- Transaction management system



# Quality traceability-website



# Quality traceability-cell phone

- Support Android, IOS with 1D and 2D barcode



# Quality traceability-touch screen



# Government supervision

- Environment evaluation systems for agricultural production field





# 5. Application

- Applied in more than 10 provinces with 254 bases





## ■ Tianjin case

Cooperated with Tianjin  
Pollution-Free Agri-Products  
(Crop Planting) Management  
Center

2012-2015: **30000 ha** non-  
pollution vegetable bases (total  
vegetable area is 90000 ha in  
Tianjin, with 70000 ha in  
greenhouses, 7.5 billion RMB);  
**260 million tons**, 57% of total  
vegetable supply for Tianjin;  
Establish the supervision  
system from Municipal, county,  
town to enterprise;  
More than **5 million** production  
record in the platform, to  
support the reduction of 19  
million RMB



Training in Tianjin



Applied in Tianjin vegetable traceability for  
supermarket

# Application-typical cases

- Digital orchard management and DSS in Shandong province



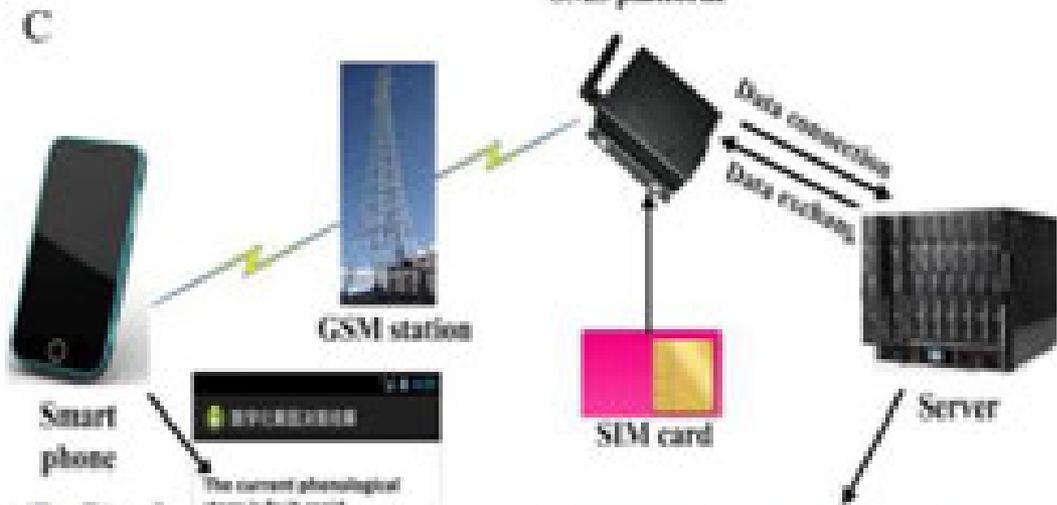
B

$$RPDE = RTE \times RSE$$

$$PDT = \text{sum}(RPDE)$$

$$RTE(T) = \begin{cases} 0 & (T < T_0) \\ (T - T_0) / (T_m - T_0) & (T_0 \leq T \leq T_m) \\ 1 & (T_m \leq T \leq T_n) \\ (T_n - T) / (T_n - T_m) & (T_n \leq T \leq T_n) \\ 0 & (T > T_n) \end{cases}$$

$$RSE(DC) = \begin{cases} 0 & (DC \leq DC_0) \\ (DC - DC_0) / (DC_n - DC_0) & (DC_0 < DC \leq DC_n) \\ 1 & (DC > DC_n) \end{cases}$$



Smart phone

Decision results

The current phenological stage is fruit rapid development period. Today July 17, 2008 is 55 PDT after the full bloom, then the fruit diameter and length estimation is 5.0 and 4.5 cm, respectively. The highest temperature is 33°C, and soil moisture is 14.2%, which is lower than the optimal standard. Thus it is suggested to conduct irrigation according to the weather.



# Application-typical cases

- The sturgeon caviar processing traceability for the first class food of *lufthansa*



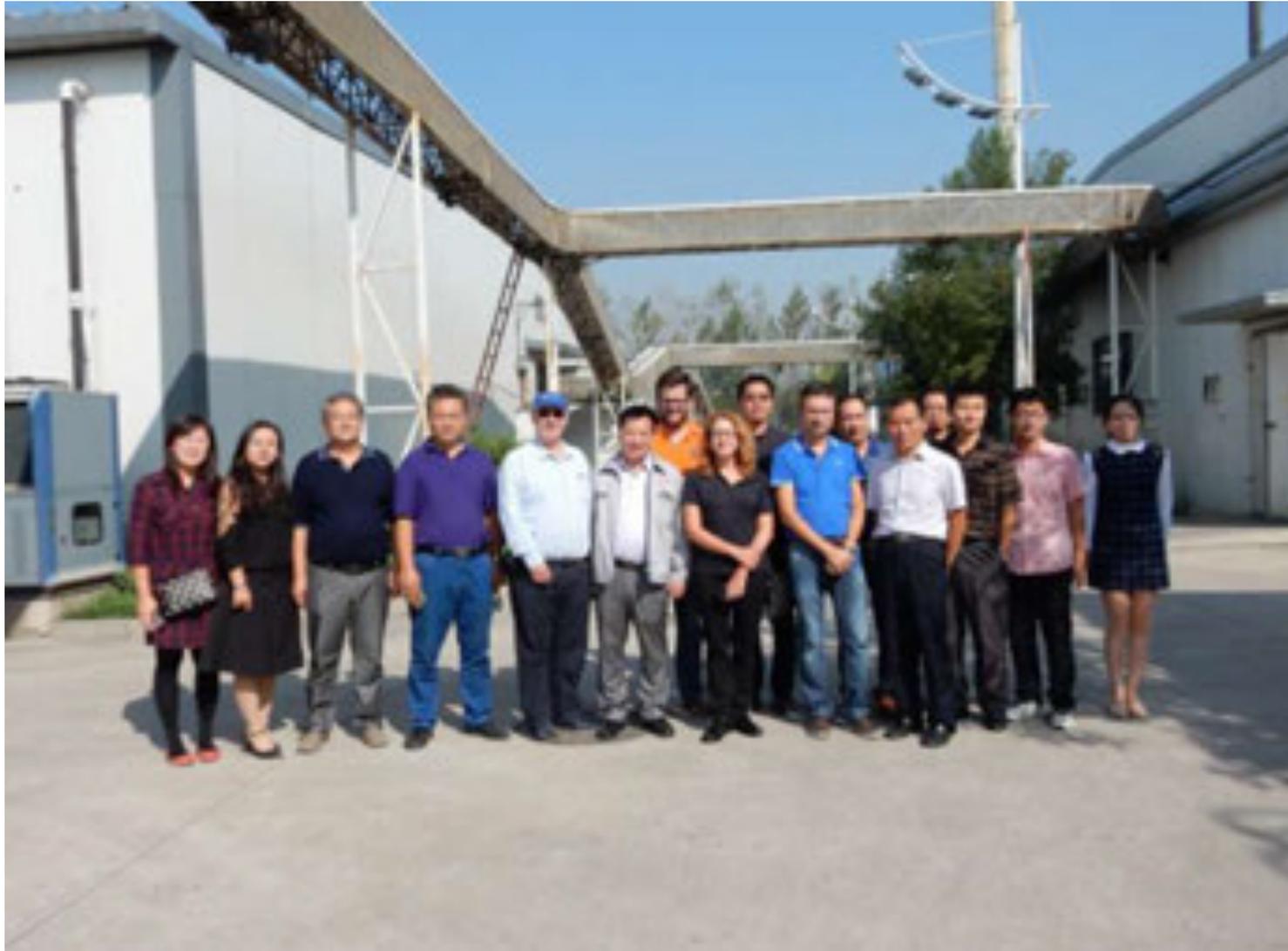


# Application-typical cases

- Agri-product traceability for the whole supply chain of field to community model



# 6. Cooperation with Spain



# INTRODUCTION of TEAP (PIRSES-GA-2013-612659)

- A Traceability and Early warning system for supply chain of Agricultural Product: complementarities between EU and China” (TEAP)

-Marie Curie Actions → Mobility

- IRSES → *International Research Staff Exchange Scheme*

- Objectives of the program:

- Exchange/sharing of “actual” knowledge
- Foster collaboration between institutions
- Analyzing possible collaborations
- Preparing further research projects.

It is a Mobility action!! → Sharing/Improving actual knowledge.

# 1) INTRODUCTION

## PARTICIPANTS



- UAL - University of Almeria
- AUA - Agricultural University of Athens
- UB – University of Bonn
- UNIPI – University of Pisa
- UPM - Polytechnic University of Madrid

- NERCITA - Beijing Research Center for Information Technology In Agri.
- CAU - China Agricultural University
- SDAU - Shandong Agricultural University
- TJCC - Tianjin Climate Center
- TMMCNAP - Tianjin Pollution-Free Agri-Products Management Center
- GZNCP -Guangzhou Agricultural Products Quality & Safety Supervisory Institute

## 2) OBJECTIVES

### Specific – Thematic Objectives

- Share knowledge about four main lines:
  1. Good Agricultural Practices and Quality Standards in application;
  2. Alert programs in the production and disease warning models;
  3. HACCP software in the logistics;
  4. Traceability systems for the supply chain of agricultural products “seed-to-plate”.

## 2) OBJECTIVES

### General – Final Objectives

- Improve future collaboration between partners:

A. Preparing new research common projects, such as Horizon 2020 Work Programme

B. Developing thematic networks with the participation of both sides;

C. Supporting long time expertise exchange.

# 3) STRUCTURE

## - Work Packages:

<b>Work package n°</b>	<b>Work package title</b>	<b>Coordinators</b>	<b>Start month</b>	<b>End month</b>
1	Agricultural Products Quality and Safety Standards in application.	NERCITA / AUA+UAL	11-2013	09-2014
2	The optimum techniques of environment, fertilizer, water management for horticulture	AUA+UNIFI / CAU + SDAU	11-2013	07-2014
3	Early detection of pathogens and pests: molecular, serological and conventional techniques.	UB / NERCITA + CAU	09-2014	02-2015
4	Integrated Production and alert programs.	UAL / TJCC+ GZNCP	09-2015	05-2016
5	HACCP system in the fresh agri-product logistics for quality safety control.	UPM+AUA/ NERCITA	02-2015	08-2015
6	Traceability Systems in EU and China.	CAU+NERCITA/ AUA	06-2016	09-2016
7	Common challenges in AP quality. Proposal of joint research activities	NERCITA /UAL	09-2016	08-2017

# TEAP kick-off meeting, 2013



# Study on greenhouse environment modeling and disease warning

- Cooperation and write a paper “*Development of Air Temperature Model for Chinese and Spanish Traditional Greenhouses*” to IJABE.
- Prof. Xue and Li were invited for Jorge’s thesis defending meeting. Ms. Wang Hui has been enrolled as the PhD candidate of computer major in ARM group of UAL.



# Study on cold chain logistics

- Cooperated with Prof. Luis Ruiz García, Departamento de Ingeniería Agroforestal, UPM, and write two papers:
- 1) Artificial Neural Networks and thermal image for temperature prediction in apples. Food and Bioprocess Technology
- 2) CFD simulation of airflow and heat transfer during forced-air precooling of individual apples. International Journal of Refrigeration



# Study on agri-product supply chain

- Cooperated with Fernando Bienvenido of UAL, Cynthia Giagnocavo from Coexphal/UAL, Pedro Hoyos Echevarría of IIPM



# Some visits





# 北京市农林科学院

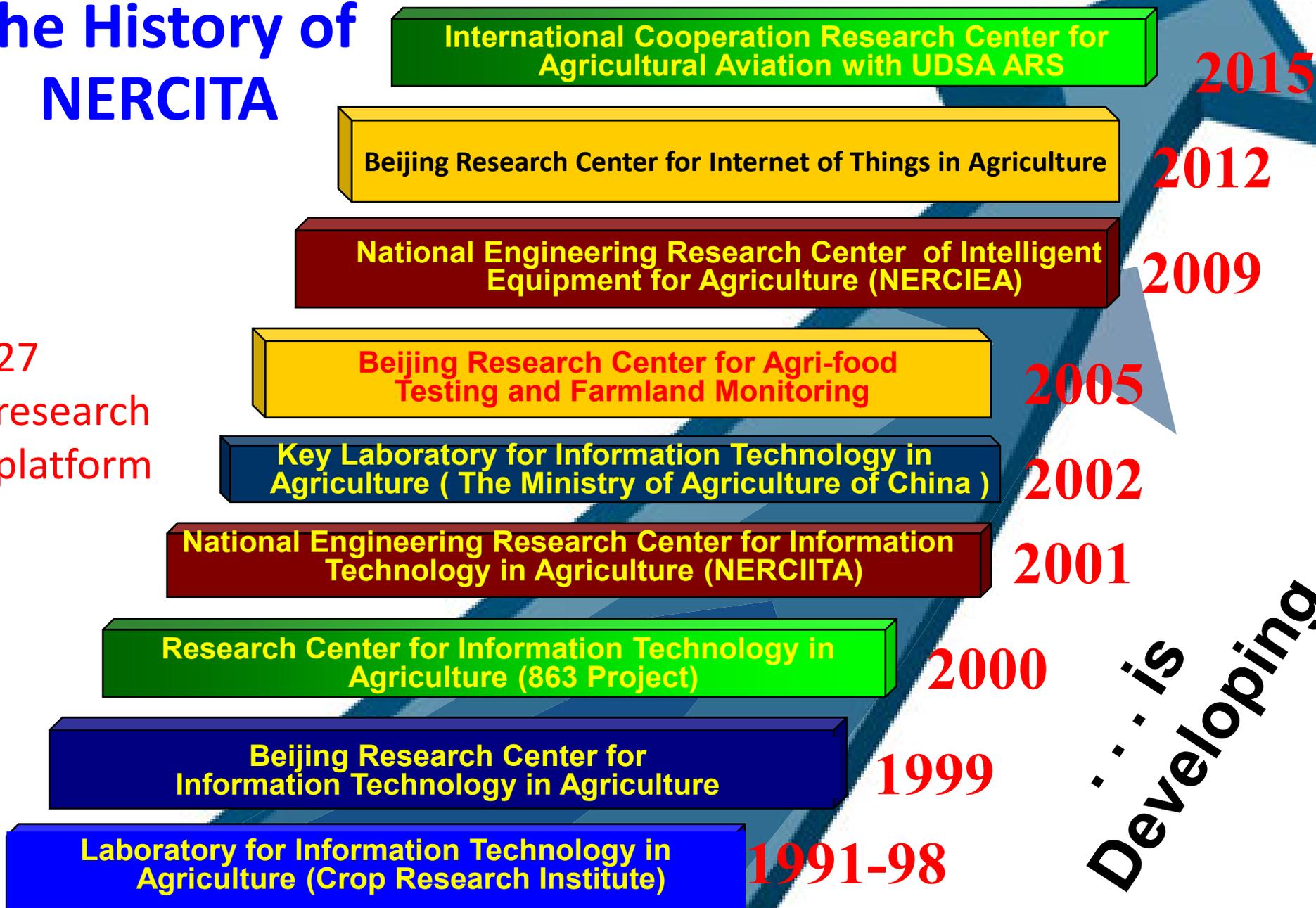
Beijing Academy of Agricultural and Forestry Sciences

## ■ National Engineering Research Center for Information Technology in Agriculture



# The History of NERCITA

27  
research  
platform



... is  
Developing

# ● Departments

## ■ 15 Research Dept. and 6 Administration Dept.:

- Software Engineering
- Information Engineering
- Cartoon and Animation Design
- Intelligent System
- Environment Resources
- Remote Sensing (RS)
- Logistic Information
- Intelligent Equipment
- Agricultural Automation
- Precision Agriculture
- Biological Equipment
- Strategy Research
- Digital Farming
- Intelligent Testing
- Agricultural Aviation
- ◆ Administration Division
- ◆ Program and finance Division
- ◆ Sci-Tech Management Division
- ◆ International Cooperation Division
- ◆ Achievement Transfer
- ◆ Experimental Station

● **One enterprise:** Beijing Paid Weiye Science and Technology Co. ltd

● **One base:** Xiaotangshan National Precision Agriculture Research and Demonstration Base

● **One Academic Society:** Beijing Society of Agricultural Informatization

# ● Development Strategies

Technological Innovation According to Demand

Sustainable Development

- Technological Innovation
- Platform Construction
- Products development

Hi-Tech

Ease of Use

Participate

Technological Innovation

Fit Market Competition

Resources Integration, Advantage Development

National Demand  
Application Demand

Technological  
Innovation



Demonstration  
Extension



Industrial  
Development



Competitive

# Human Resources



- **Research Team:** 408 in total, 119 regular staff, 161 employed by enterprise, 128 Master and Doctor students with Post-doctor
- **Titles:** 16 investigators , 26 associate investigators, 5 senior engineers; 80% with Master and Doctor degree, 100 Doctors
- **Team:** 硕/博导13人; 863专家1人; 千人计划1人; 国务院津贴3人; 国家百千万1人, 农业部杰出人才及创新团队 1人, 北京百名领军人才 1人, 北京百千万5人; 北京突贡2人, 北京新星25人, 北京优青4人, 北京优秀人才22人, 农科院青年基金 14 人。
- **Major:** Computer/Electronics/Automation/Mechanical equipment:40%, Agriculture: 30%, researchers combined with computer and agricultural sciences: 30%

# Status

- **Planning and design of ICT in agriculture for Ministry of Agriculture, Ministry of Science and Technology, Ministry of Industry and Information**
- **Team leader organization for agricultural application of national standard working group for internet of things**
- **National consulting expert for rural informatilization**
- **National high-tech program expert**

## ● Research achievement and effects

- More than 80 Invention patents, 137 practical models patents; more than 600 software registrations80;
- Published more than 1203 papers indexed by SCI/EI
- 22 S&T awards with more than provincial level, with 3 national awards
- Extension to 30 provinces with economic benefit of 1 billion yuan



# ● 3 national and 1 international awards



## 国家科学技术进步奖 证书

为表彰国家科学技术进步奖获得者，  
特颁发此证书。

项目名称：农业专家系统研究及应用

奖励等级：二等

获 奖 者：北京农业信息技术研究中心



证书号：2006-J-250-2-15-001



## 国家科学技术进步奖 证书

为表彰国家科学技术进步奖获得者，  
特颁发此证书。

项目名称：精准农业关键技术研究与示范

奖励等级：二等

获 奖 者：北京农业信息技术研究中心



证书号：2007-J-251-2-03-001



## 国家科学技术进步奖 证书

为表彰国家科学技术进步奖获得者，  
特颁发此证书。

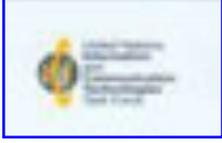
项目名称：数字农业溯源关键技术产品与系统

奖励等级：二等

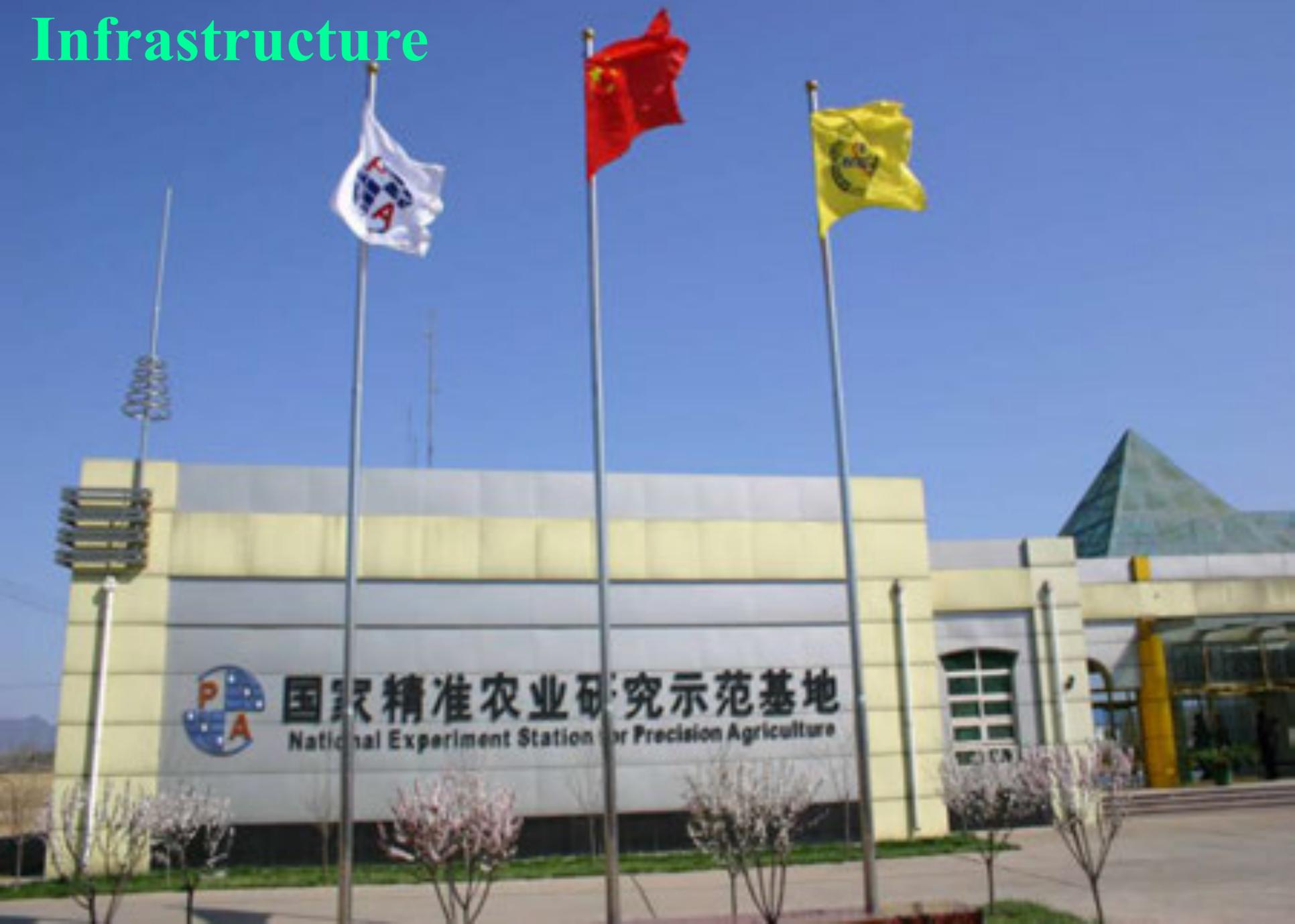
获 奖 者：北京农业信息技术研究中心



证书号：2010-J-251-2-02-001



# Infrastructure



国家精准农业研究示范基地  
National Experiment Station for Precision Agriculture

# Xiaotangshan base: window



# ● National Experimental Station for Precision Agriculture



Laboratory with 1050M<sup>2</sup>



# Equipments



170 hp Tractor



Maize Harvester with Sensors



Disk Harrow



Combine Harvester

# 16 Greenhouses



**Farm Machine  
Warehouse with  
1130M<sup>2</sup>**



# Further work

- **1) Cooperation in the model and system in different area of ICT in agriculture.**
- **2) Supply chain management of agri-products**
- **3) Apply the research in the practices.**
- **4) Future research project.**



Thank you!