Improving fertilization practices of small farmers with help of soil geo-database

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GSP WORKSHOP  19 - 23 March 2012, Rome
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3. Principle of Harvest Genius
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1. Problems related with unreasonable fertilization

① High cost of production and low income of farmers

Small Chinese farmers in comparison with farmers in developed countries:
- 424 ¥/ha more fertilizer cost
- poorer product quality (unbalanced fertilization)
- Total economic loss: 66 bill. annually

<table>
<thead>
<tr>
<th>Country</th>
<th>China</th>
<th>Fr</th>
<th>D</th>
<th>USA</th>
</tr>
</thead>
<tbody>
<tr>
<td>N-Fertilizer (kg/ha)</td>
<td>171</td>
<td>126</td>
<td>120</td>
<td>58</td>
</tr>
<tr>
<td>P-Fertilizer (kg/ha)</td>
<td>71</td>
<td>43</td>
<td>30</td>
<td>22</td>
</tr>
<tr>
<td>Yield (kg/ha)</td>
<td>4756</td>
<td>7244</td>
<td>6470</td>
<td>5400</td>
</tr>
</tbody>
</table>
1. Problems related with unreasonable fertilization

② NP-overuse in vegetables, fruits and flowers crops results in crop and soil quality decreases.
1. Problems related with unreasonable fertilization

③ Over fertilization induce water pollution
- Ground water nitrate pollution

Critical region of ground water nitrate pollution

In high fertilizer application area:
- 45% exceeded 50 mg NO₃/l .
- 20% exceeded 89 mg NO₃/l (Zhang et al, 1996)
## Water quality changes in important watersheds

<table>
<thead>
<tr>
<th>Watershed</th>
<th>60s</th>
<th>70s</th>
<th>80s</th>
<th>90s</th>
<th>now</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dianchi</td>
<td>II</td>
<td>III</td>
<td>IV</td>
<td>V</td>
<td>V+</td>
</tr>
<tr>
<td>Taihu</td>
<td>I-II</td>
<td>II</td>
<td>III</td>
<td>IV-V</td>
<td>V+</td>
</tr>
<tr>
<td>Chaohu</td>
<td>good</td>
<td>III</td>
<td>IV</td>
<td>V</td>
<td>V+</td>
</tr>
<tr>
<td>Hongze</td>
<td></td>
<td>middle</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dongting</td>
<td></td>
<td>middle</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Boyang</td>
<td></td>
<td>middle</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### 1. Problems related with unreasonable fertilization

- **Over fertilization induce water pollution**
  - Eutrophication

TN

TP
eutrophicated
1. Problems related with unreasonable fertilization

- The growing factors for non-point source pollution will lead to even worse situation in the early 21 century

### N- and P-inputs in arable land in main watersheds in China

<table>
<thead>
<tr>
<th>Source</th>
<th>N kg/ha</th>
<th>P2O5 kg/ha</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>60's</td>
<td>80's</td>
</tr>
<tr>
<td>Fertilizers</td>
<td>5</td>
<td>135</td>
</tr>
<tr>
<td>Animal prod.</td>
<td>19</td>
<td>101</td>
</tr>
<tr>
<td>Rural life</td>
<td>29</td>
<td>49</td>
</tr>
<tr>
<td>Total</td>
<td>53</td>
<td>285</td>
</tr>
</tbody>
</table>
overuse in vegetables and flowers are common

Celery
N: 1014 kg/ha
P$_2$O$_5$: 717 kg/ha

lettuce
N: 777 kg/ha
P$_2$O$_5$: 422 kg/ha

Rose
N: 1703 kg/ha
P$_2$O$_5$: 1181 kg/ha

Carnation
N: 1580 kg/ha
P$_2$O$_5$: 1325 kg/ha
2. Status of fertilization technique
2. Status of fertilization technique

Optimal Fertilizer Recommendation (OFR) is the main approach: since 70s


OFR

Expert


Fertilizer receipt

Farmer
Soil Nutrient Classes 0 1 2 3 4 5

--- | --- | --- | ---
Wheat | >8 | P$_2$O$_5$ | 110
K$_2$O | 95 | 70 | 45
6-8 | P$_2$O$_5$ | 95 | 70 | 45
K$_2$O | 85 | 60 | 35
Raps | >3.5 | P$_2$O$_5$ | 100
K$_2$O | 90 | 65 | 40
2-3.5 | P$_2$O$_5$ | 80 | 55 | 30
K$_2$O | 75 | 50 | 25

Developed countries: regional fertilization nutrient recommendations have been developed.
Developed countries:
Farmers with large management scale can easily understand and follow the **Optimal Fertilization Nutrient Recommendation.**
2. Status of fertilization technique

① Developed counties:
  average N-efficiency: 50—60% by using **OFNR**.

② China:
- Demonstration studies guided by researchers showed that N-efficiency can also arrive 50—60% since 1980s
- State wide average N-efficiency < 35% only

Why OFR still not adopted by majority of farmers after 30 years extension?
Large efforts has been made by the state to understand soil nutrient status and improve farmers’ fertilization. Effects were/are not significant.

China soil nutrient investigation

◆ 1979-1986: 2 mill. samplings (500 mill. ¥)

Results: still not finish data processing

◆ 2005-now: 4 mill. samplings (7 bill. ¥)

Effects?
In order understand “why”, 20,000 farmer’s fertilization behaviors have been studied in 30 provinces, 731 field experiments with duration of 3-10 years have been carried out since 1999.
2. Status of fertilization technique

Constraints of Optimal Fertilizer Recommendation (OFR) for small farmers

① Small farmers can not understand and follow the fertilization nutrient recommendation.

not able to transfer OF NR to fertilizer receipt for base fertilization and top dressings

<table>
<thead>
<tr>
<th>Crop</th>
<th>N</th>
<th>P$_2$O$_5$</th>
<th>K$_2$O</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wheat</td>
<td>10-15</td>
<td>6-10</td>
<td>6-8</td>
</tr>
<tr>
<td>Corn</td>
<td>10-18</td>
<td>5-8</td>
<td>8-12</td>
</tr>
<tr>
<td>Rice</td>
<td>10-18</td>
<td>5-8</td>
<td>6-8</td>
</tr>
</tbody>
</table>
2.2 Constraints of OFR for small farmers

② Farmer’s actual condition can not always be included in optimal fertilizer receipt, so that farmers can hardly follow it.

Receipt 1
Base: Manure 1 ton
   Urea 5
   KCL 12
   SSP 60
Top 1 Urea 5
Top 1 Urea 15

Receipt 2
Base Manure 1 ton
   Mixture (15-15-15) 35
Top 1 Urea 15

Farmer A
Base: Manure 5 tons

Farmer B
Base: Mixture (10-15-5) 50
Top 1 Mixture (10-15-5) 25
Top 2 Urea 20
Constraints of OFR for small farmers

③ Changing fertilizer types, fertilization times and periods is likely to cause yield depression.

Farmer's receipt
Seedling fertilization
Urea 20

Expert's receipt
Seedling fertilization
Urea 10
SSP 20

Too much acid in local SSP induce seedling wilt.
2. Status of fertilization technique

Summarized points
Farmers with large management scale can easily follow OFNR.

Small farmers in developing regions
① cannot understand and follow OFNR.
② OFR not always suits farmers technique conditions.
③ Changing fertilizer types, times and periods may cause yield depression.
④ FR strong depending on on-situ condition.
3. Principle of Harvest Genius
• Characteristics of small farmer’s fertilization

Decision priorities
- Manure or fertilizer sorts available
- Fertilization times
- Fertilization period

Knowledge shortages
- Crop nutrient requirement
- Soil nutrient supply
- Fertilizer nutrient requirement and ratio
Farmers is likely to accept correction to their own practice
Retaining: fertilizer sorts, times & period
Correcting: fertilizer nutrient amounts and ratio

Opt. Fert. Receipt

Base: Urea 5
KCL 12
SSP 60
Top 1 Urea 5
Top 1 Urea 15

Farmers’ practice

Base: manure 2 m³
SSP 150
Tops: 12 times
comp. 20

Correction to Farmer

Base: manure 2 m³
SSP 90
Top: 12 times
comp. 10

Fertilizer Nutrient amounts (kg/mu)
Principle of Harvest Genius

OFR

Expert

OFNR

Opt. Fert. Receipt

Farmers

Interactive Recommendation

Expert

OFNR

Intelligent System

Farmers

Fer. type times period

Interact. fert. receipt

Farmers

Principle of Harvest Genius
4. Technique Development
4. Technique Development

Interactive Recommendation

- **Expert**
- **Farmer**
- **Communicator**

**OFNR**

- Fer. type
- times period

**Intelligent System**

- Interact. fert. receipt

**Site specific OFNR**
- soil geo-database
- crop nutrient requirement from experiment

**Farmers**
Site specific OFNR

- soil geo-database

Legacy and new soil data
- Long-term property: texture, parent materials, etc.
- Short-term property: nutrients, pH, OM, etc.
◆ Summarize crop nutrient requirements from field experiments in different regional conditions.


crop nutrient requirement

Soil nutrient supply
Fertilization decision flow
13 model cluster, 67 sub-models
② **communicator**: as simple as possible to understand and finish essential input

<table>
<thead>
<tr>
<th>已施</th>
<th>肥料种类</th>
<th>施肥类型</th>
<th>施肥期移栽后旬（周）</th>
<th>施肥量</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>猪粪</td>
<td>基肥</td>
<td>0</td>
<td>3</td>
</tr>
<tr>
<td>0</td>
<td>碳铵</td>
<td>基肥</td>
<td>0</td>
<td>100</td>
</tr>
<tr>
<td>0</td>
<td>过磷酸钙</td>
<td>基肥</td>
<td>0</td>
<td>40</td>
</tr>
<tr>
<td></td>
<td>二铵</td>
<td>1次追肥</td>
<td>1</td>
<td>100</td>
</tr>
<tr>
<td></td>
<td>复合肥</td>
<td>1次追肥</td>
<td>1</td>
<td>60</td>
</tr>
<tr>
<td></td>
<td>尿素</td>
<td>2次追肥</td>
<td>5</td>
<td>5</td>
</tr>
</tbody>
</table>
③ Intelligent system: working autocephaly

13 model cluster, 67 sub-models with dozens of thousands logics
5. Application
Farmer A
Base: manure 1 m³
Top 12 times
Comp. 20 kg

Farmer B
Base: pig manure 7 m³
Top non

Beans: OFNR
N 6
P₂O₅ 16
K₂O 10

Hainan, Sanyan, 羊栏镇槟榔村
Farmers are eager to see if their practices are ok or not
Hebei prov. Yutian County
Beijing, Daxing
By Farmer’s friendly menu, HG can give IR for 250 crops. Both digital geo-soil data and newest soil testing results can be applied for decision.
## Comparison

<table>
<thead>
<tr>
<th>Crops</th>
<th>Methods</th>
<th>Accept. %</th>
<th>Yield depres.%</th>
<th>n</th>
<th>NP-input kg/mu</th>
<th>Rel.Y %</th>
<th>n</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Main crops</strong></td>
<td>Farmer</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>IR</td>
<td>98.7</td>
<td>2.8</td>
<td>1565</td>
<td>19.7</td>
<td>109.8</td>
<td>471</td>
</tr>
<tr>
<td></td>
<td>OFR</td>
<td>65.1</td>
<td>19.7</td>
<td>1372</td>
<td>17.7</td>
<td>107.3</td>
<td>424</td>
</tr>
<tr>
<td><strong>Vegetables</strong></td>
<td>Farmer</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>IR</td>
<td>98.2</td>
<td>3.5</td>
<td>2532</td>
<td>28.1</td>
<td>119.2</td>
<td>362</td>
</tr>
<tr>
<td></td>
<td>OFR</td>
<td>21.9</td>
<td>60.8</td>
<td>2186</td>
<td>23.7</td>
<td>90.4</td>
<td>342</td>
</tr>
</tbody>
</table>
6. Remaining constraint and perspective
Main constraint
◆ Only personal computer version available
One equipment set: one day 1-3 villages
  a computer
  a project
  a portable screen
  a printer
  a car

Extension peoples are needed
Extension system financed by state was broken and could hardly be run as 1980s.

State (Administration & Research)
↓
Province (Administration & Research)
↓
County (Administration)
↓
Township (few, administration)
↓
Village (no)
↓
Farmer (no)
Difficulty to arriving farmers without HG-running infrastructure
Farmers give real appraisement on IR
Internet & mobile phone platform are needed
to make interactive recommendation arriving every small farmers directly.

State, provincial & large company services

Extension service (2400 counties 1 mill. villages)

Farmer (hundred mill.)
Perspective

In developing regions and countries

- Small farmers are main producers (more than 80% of the world)
- Lack of extension service is common situation
- IR and HG will be very useful for these regions
With help of HG and IR, small farmers will get benefits from research works of global digital soil mapping.
HG & IR has been developed through initial creation and activities. That means also very slow development and extension (since 1999).

We are glad to getting international cooperation in order to speed up the share of the technique to all small farmers of the world
Thanks!