International Symposium on Improvement of Nutrient Use Efficiency under Zero Growth of Chemical Fertilizers in China (2016.03.18 Beijing)

Stupid apparent recovery efficiency (ARE) retarded advance of soil and fertilizer research in China

Huo-Yan Wang

State Key Laboratory of Soil and Sustainable Agriculture, Institute of Soil Science, Chinese Academy of Sciences

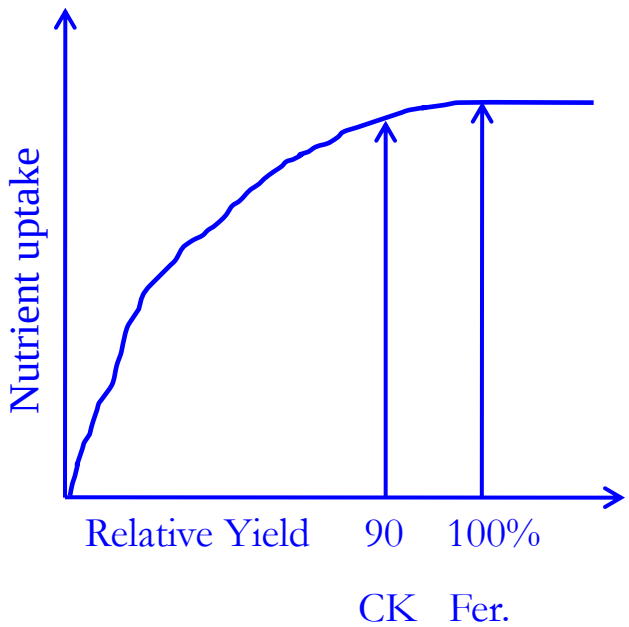
1. ARE is not a good FUE index
2. ARE can not reflect nutrient loss rate
3. ARE can not show goodness of soil nutrient holding capacity
4. Ways for higher ARE may not correct

ARE is not a good FUE index

It's very good even the FUE is low!

FUE (ARE) calculation：

$$NU_{fertilized} - NU_{control})/ NF * 100\%$$



For example, P uptake of CK and P applied treatments were 60 and 75 kg/ha， respectively, P fertilizer dose was 75kg/ha, the PUE was calculated as 20%。

For P applied treatment, if the P loss in running off or leaching was very low. P input and output kept balance, soil P fertility could maintained, the high yield could be sustained, it was already perfect.

What's the problem with ARE of 20%?

ARE is not a good FUE index

It's very good even the FUE is low!

Calculation of FUE for NPK treatment of Fengqu long-term field experiment:

For NPK treatment during 16 yr, amount of K fertilizer: 3984 kg/ha, Soil K reserve increased: 462 kg/ha, plant K uptake: 3471 kg/ha, plant K uptake of NP treatment: 2352 kg/ha. The ARE of K is:

（3471–2352）/3984×100% = 28.1 %

The RKUE is：

3471 / （3984 – 462）× 100% = 98.6 % Loss rate 1.4%

（Wang and Zhou. Acta Pedologica Sinica, 2014(2))

ARE is not a good FUE index

Low ARE in literature resulted in a critically underestimated benifits of fertilizer by public

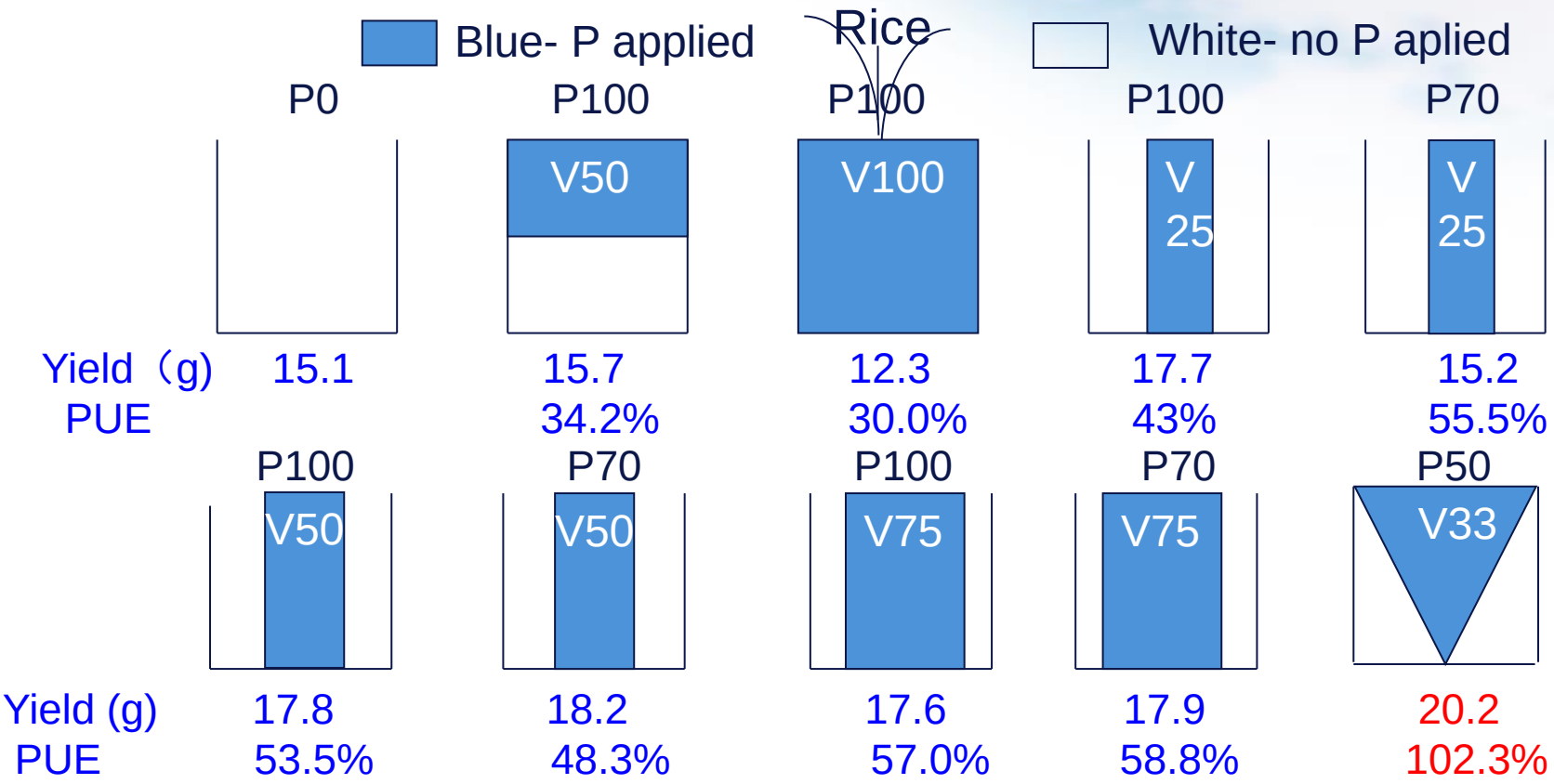
Reported ARE of main crops in China

	N	P	K	Data resouce
1997	30%-35%	10%-20%	35%-50%	Li et al., 1997
2008	28%	12%	31%	Zhang et al., 2008
2013	33%	24%	42%	CAM, 2013

What the change of ARE could imply?

ARE is not a good FUE index

High FUE is not sustainable !



Rice yield and PUE as affected by various P application pattern (pot culture).

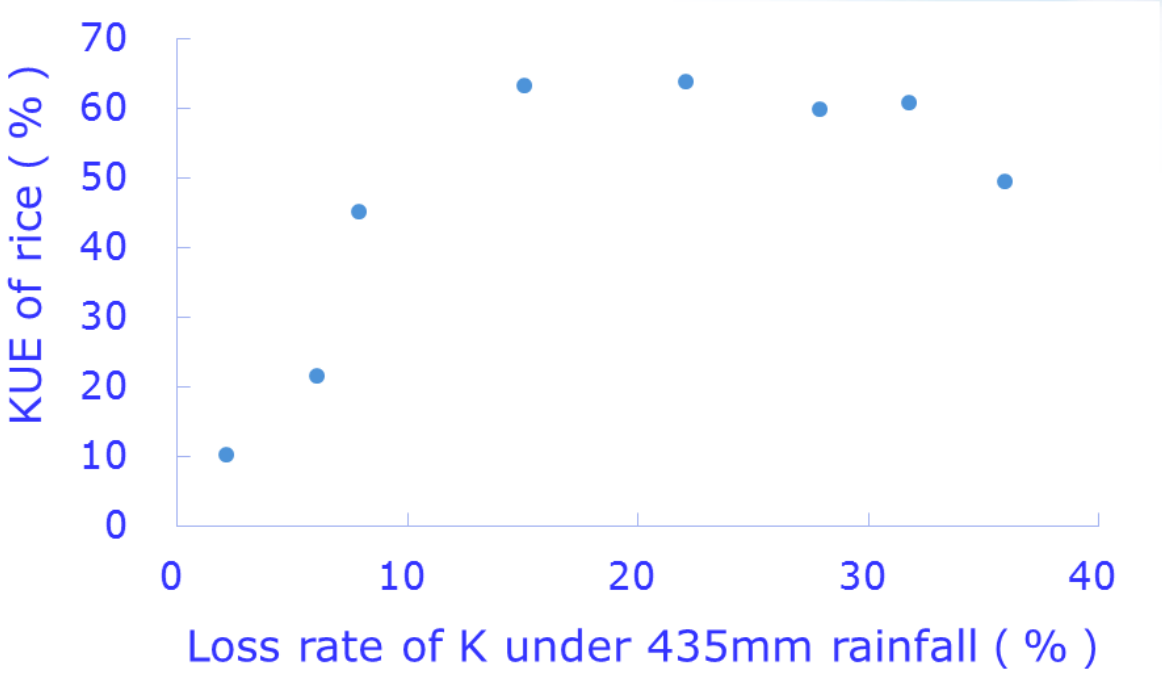
ARE is not a good FUE index

People never know what's the best ARE value for the best fertilization !

For different soil-plant systems, what's the best FUE, how to judge it's the best? So far there is no answer for this question.

ARE can not reflect nutrient loss rate

The higher the ARE of K, the lower the soil K holding capacity and the higher the K loss risk



The relation between KUE of rice (pot culture) and the K loss rate (column leaching) of different soils （unpublished data）

ARE can not reflect nutrient loss rate

Comparing one-time root-zone fertilization with FP split fertilization（^{15}N）

Treat.	Yield (kg/ha)	N residue %	N loss %	NUE of ^{15}N	ARE	RNUE
CK	375±30 b					
Split	681±63 a	19.5±3.4 b	58.5±5.7 a	22.0±2.4 b	37.9±5.7 b	27.5±4.1 b
Root-zone	609±72 a	43.7±5.3 a	4.0±4.2 b	52.3±2.2 a	58.3±3.8 a	93.3±6.8 a

（N fertilizer：Urea, Dose:225 kg N /ha, Split: 4-3-3 three times）

（unpublish）

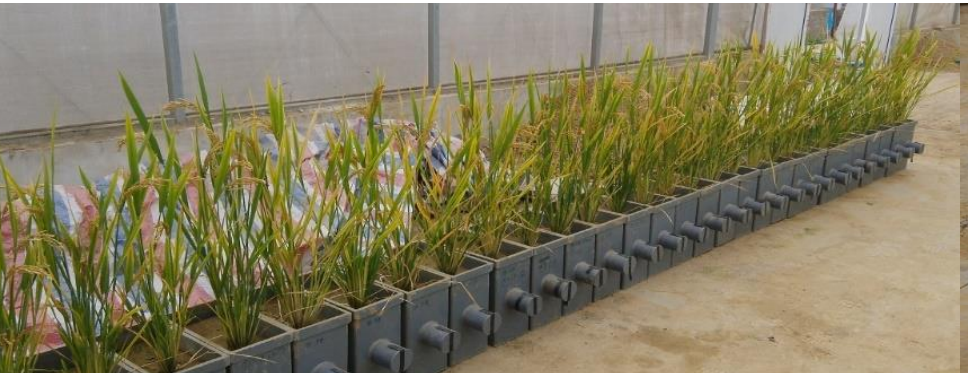
ARE can not reflect nutrient loss rate

Effect of fertilization methods on NUE of rice (^{15}N isotope)

Treat.	Yield (g/pot)	N residue %	N loss %	NUE of ^{15}N	ARE	RNUE
CK	12.7±0.6 c					
FP4-3-3	21.9±0.6 ab	28.4±0.4 b	37.6±0.7 a	34.0±0.5 b	40.9±1.6 b	47.5±0.8 c
RZF1	22.0±1.6 ab	42.8±4.6 a	18.1±1.4 b	39.1±4.4 ab	40.3±3.6 b	68.1±3.0 b
RZF2	24.9±0.8 ab	34.4±2.4 ab	17.5±0.5 b	48.2±2.8 a	49.0±3.4 a	73.3±1.7 b
RZF3	20.5±0.7 a	39.8±3.4 a	10.4±3.1 c	49.8±3.5 a	51.4±4.8 a	82.8±4.7 a

（N fertilizer：Urea，Dose：0.9g N/pot，RZF: one-time hole application）

（unpublish）



ARE can not show goodness of soil nutrient holding capacity

ARE has negative relation to soil fertility and soil nutrients holding capacity

FUE (ARE) calculation：

$$NU_{fertilized} - NU_{control}) / NF * 100\%$$

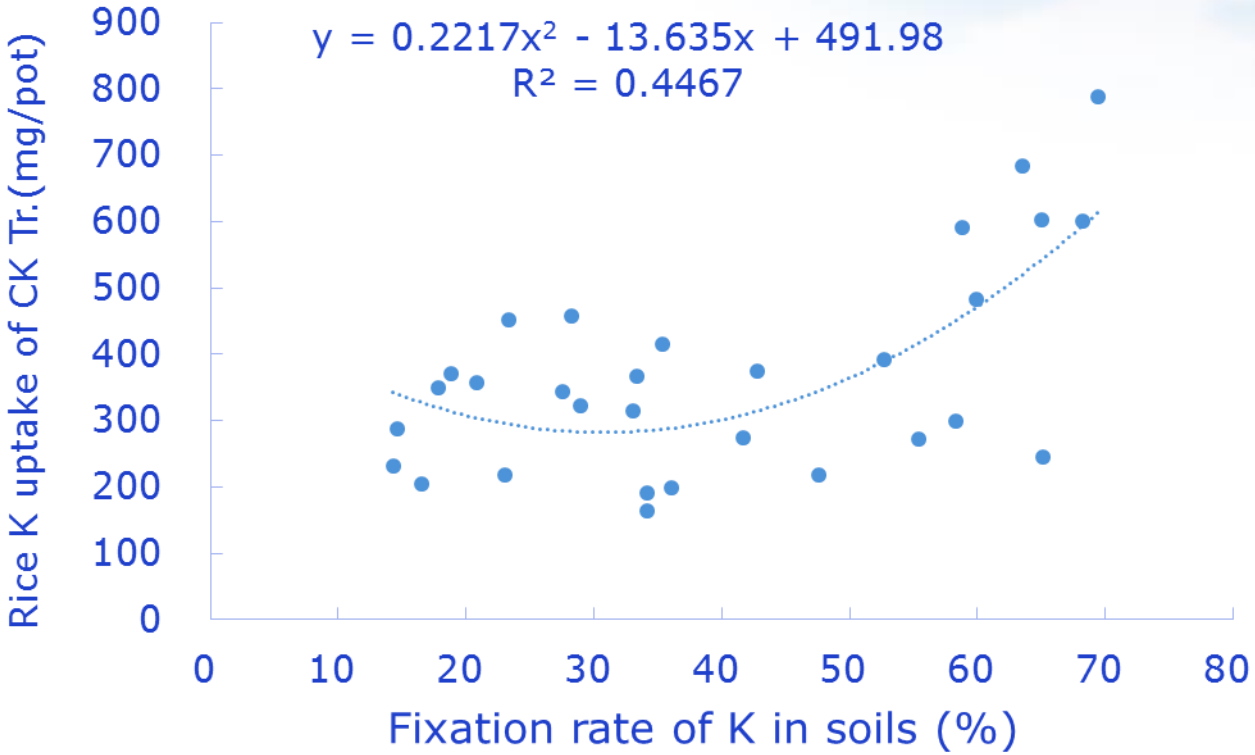
The higher the soil fertility and nutrient holding capacity (NHC), the higher nutrient supply buffering capacity, and the higher nutrient uptake without fertilization, which lead to lower FUE.

Different FUE were reported in literature. The FUE of the soil with low NHC (sandy, sloppy or low yield soils) was higher than FUE of the soil with higher NHC (high yield, high fertility)

For different nutrients, the rule is the same: The higher the soil NHC for the nutrient, the lower the FUE, such as FUE of NPK.

ARE can not show goodness of soil nutrient holding capacity

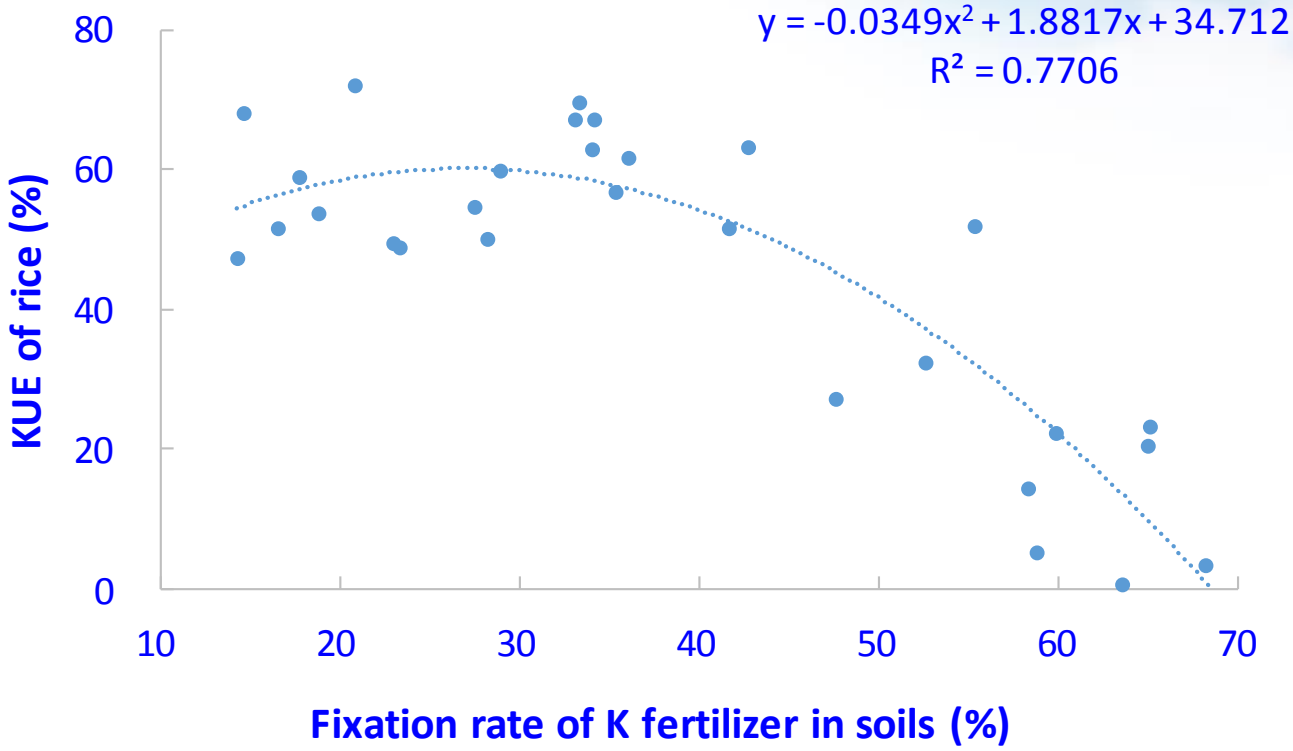
The higher the K holding capacity of soil, the higher the K supply without K fertilization



The relationship between rice K uptake of CK Tr. and K fixation rate in soils

ARE can not show goodness of soil nutrient holding capacity

The higher K fixed rate in soil, the lower the KUE!



The relationship between KUE of rice and K fixation rate for 10 soils

ARE can not show goodness of soil nutrient holding capacity

Fixation rate of K and K recovered by successive 8 seasons of ryegrass

Soil	K fixation rate %	K recovery rate%
Shandong, Laiyang	86.6 ± 3.4	92.1 ± 0.4
Hunan, Wangcheng	31.4 ± 2.8	18.4 ± 5.3
Henan, Fengqiu	41.3 ± 3.5	47.2 ± 6.5
Jiangsu, Changshu	64.5 ± 1.2	60.6 ± 0.7

Nutrients fixation is very good, but not bad!

Fixation results in NHC, which explains why soil is good than sand!

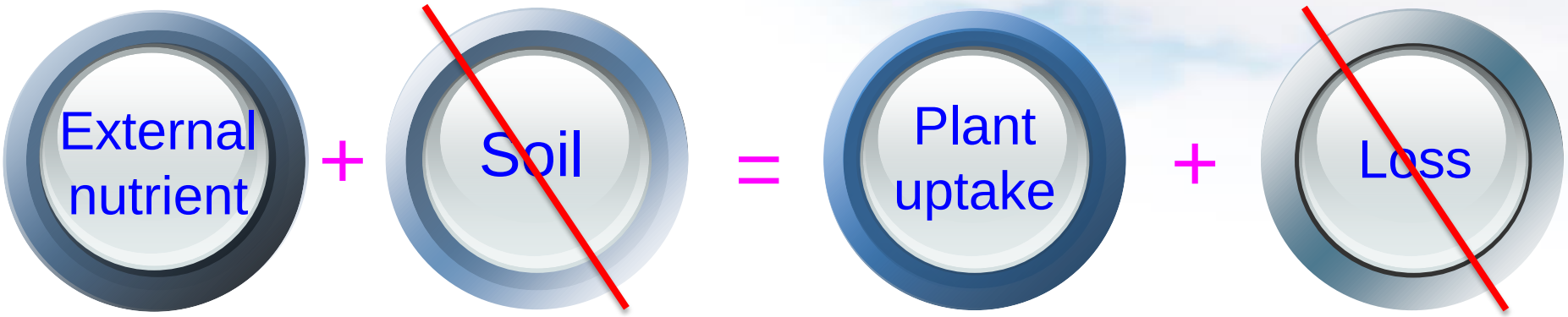
Low ARE but high NHC, why should we improve ARE?

Ways for higher ARE may not be correct

The most easy way to improve ARE is just reduce amount of fertilizer. It's of course right when some farmer do over-fertilization. But some recommended reduced fertilizer dose may not correct since most of the results were based on one or two seasons of data. If the nutrients exhaustion occurred in soil, it can not be sustainable. Thus, simply reduce the fertilizer dose may not be correct.

Ways for higher ARE may not be correct

How to decide the fertilization dose?



For a stable crop field, the target for fertilization management are: Higher and stable crop yield, higher economic efficiency

The RNUE as higher as 100%, that is the loss rate is zero,

Soil fertility do not over accumulated or exhausted, generally maintain balance, that is the fertility change is also zero,

Thus: Fertilization dose = Plant nutrient uptake （removal）

Ways for higher ARE may not be correct

The ideally dose = nutrients removed by plant harvest

The rational dose = nutrients harvest + loss

The minimum of fertilizer dose equals to nutrients harvest. How much fertilizer could be reduced depends on the loss. Thus the loss rate is a key factor to decide the rational fertilizer dose!

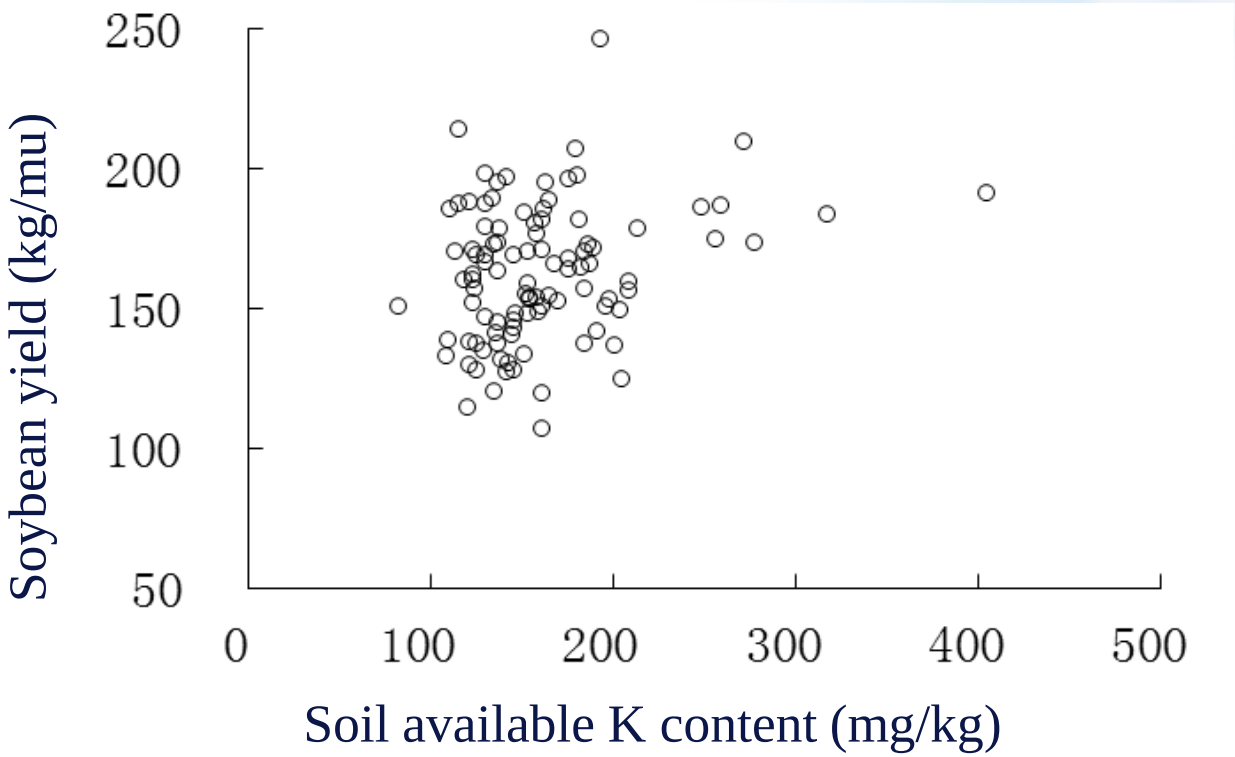
Ways for higher ARE may not be correct

If the fertilizer dose recommended is lower than the amount nutrient harvest, it is may not be correct even for some soil with rational higher fertility:

According to soil testing and fertilizer recommendation system, a lower fertilizer dose will be recommended on the fertile soil. Eventually, the fertile soil with very good nutrients buffering capacity which was not sensitive to fertilization will be changed into the soil with low fertility and sensitive to fertilization, which is opposite to the target of soil fertility improvement, thus it also may not be correct.

Ways for higher ARE may not be correct

Higher soil K fertility is good for stable and higher crop yield

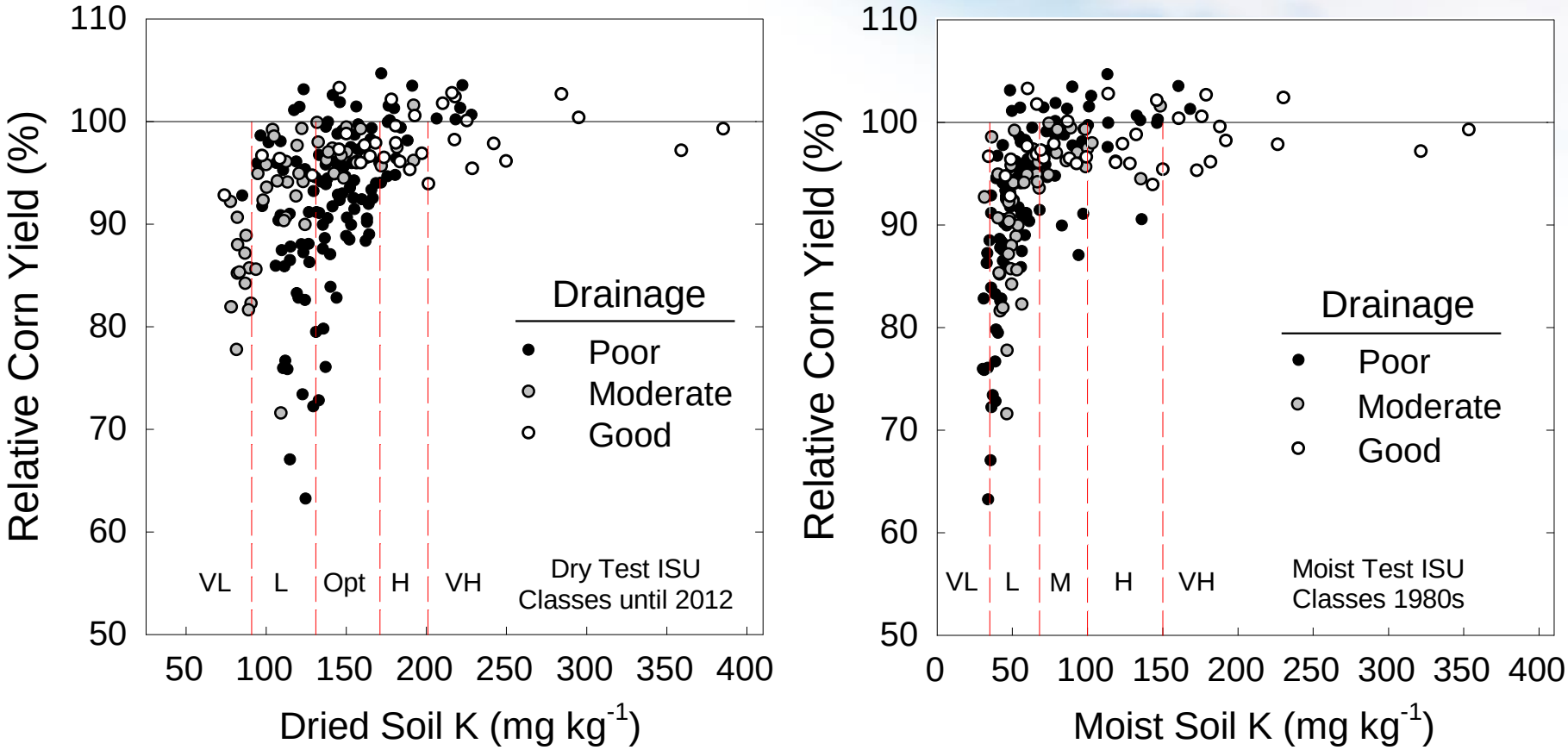


The relationship between soil available K and soybean yield

Ways for higher ARE may not be correct

The lower soil K fertility will decline yield under bad climate

Adapted from Barbagelata & Mallarino 2012 (data 2001 to 2006)



15-cm depth; NH_4OAc test shown; same results with Mehlich-3

Ways for higher ARE may not be correct

Reaching a higher ARE is not a good target for efficient utilization of fertilizer.

Higher ARE does not mean the lower loss rate. Higher ARE will conceal the real fertilization problem unsolved.

Improvement of soil fertility and soil nutrient holding capacity could increase crop yield and make the fertilization easy, but will lead to a lower ARE.

With a rational fertilizer dose, the lower the ARE, the better the soil fertility and quality！

Soil has both very good P holding capacity and very low loss rate of P. It is impossible and meaningless to achieve a ARE of 30% for P fertilizer even this target was set in the national project which will be carried out soon.

Suggestions

Soil fertilizer research should use the loss rate or the real nutrient use efficiency as the key index for soil fertility improvement, evaluation of fertilizer efficiency and for recommendation of fertilizer dose even it’s difficult to get the data of the loss rate. To know the loss rate, and to reduce the loss rate is the right and the key task for future soil and fertilizer research!

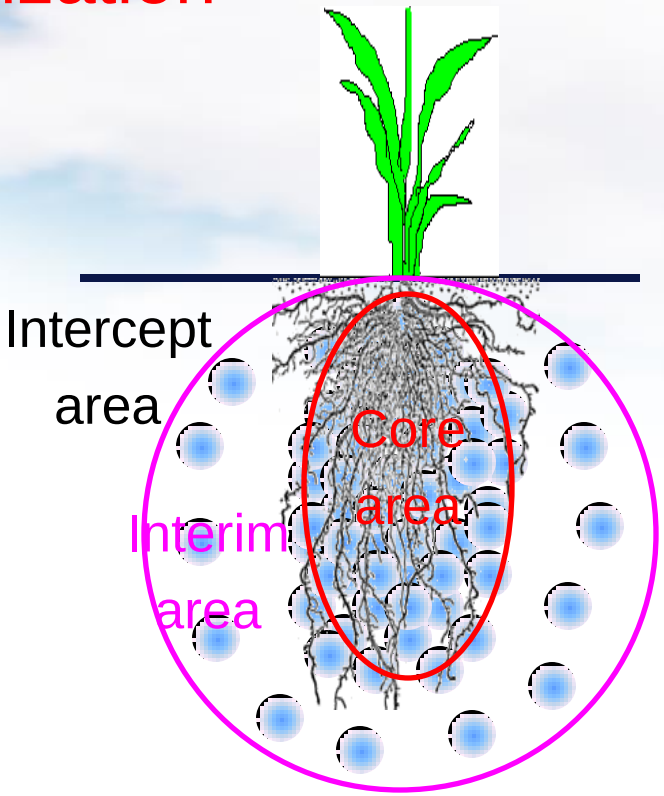
Approaches to reduce fertilizer：1、Improve the nutrient holding capacity of soils（including use fertilizer dissolving slowly). 2、Develop and exploit root-zone fertilization technique.

A revolution of agriculture technique — Root-zone fertilization

What is RZF?

Apply proper amount of fertilizer with certain technique to crop active-root zone. To make the dynamic diffusion zone of fertilizer match well to the extension zone of active roots of the crops. This fertilization technique is RZF.

RZF aims to match well the concentration, amount, space and even time of nutrients fertilized to what crops need.



For most cereal drops, one time RZF could reach the targets: saving labour, high yield and lower nutrient loss rate even without control-release fertilizer !!!

Thank you for your attention!

Acknowledgment to the foundations:

The National Basic Research Program of China (2013CB127401)

The National Department Public Benefit Research Foundation (201203013)

The National Natural Science Foundation of China (41271309)