# Characteristics of Soil Nutrients in Farmland in the Paddy-upland Rotation Region of Chengdu Plain -a Case Study of Pidu District, Chengdu City

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**2018.08.27**

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# I. Introduction of Paddy-upland Rotation

## 1 Paddy-upland Rotation and Multiple Cropping

**Multiple Cropping （such as continuous cropping and crop rotation ）**

- Han Dynasty（202-220 BC）： Multiple cropping had been well documented
- Song Dynasty（960-1276）： Multiple cropping rotation plays an important role in agricultural production（ wheat-rice double cropping, double cropping rice ）

**Paddy-upland Rotation （such as multiple cropping of rice and wheat ）**

- Tang Dynasty（618-907）： Paddy-upland rotation had been well documented in history of Yunnan
- Song Dynasty（960-1276）： It appeared but was not common in Yangtze-Huaihe river basin
- Song and Yuan Dynasties（960-1368）： A variety of forms was formed

# 2 Ecology Significance of Paddy-upland Rotation

A biological measure combined with land use and land maintenance；

- Has a balanced use of soil nutrients；
- Increase the yield per unit area;
- Improve soil physical and chemical properties；
- Adjust soil fertility；
- Control insect pests.

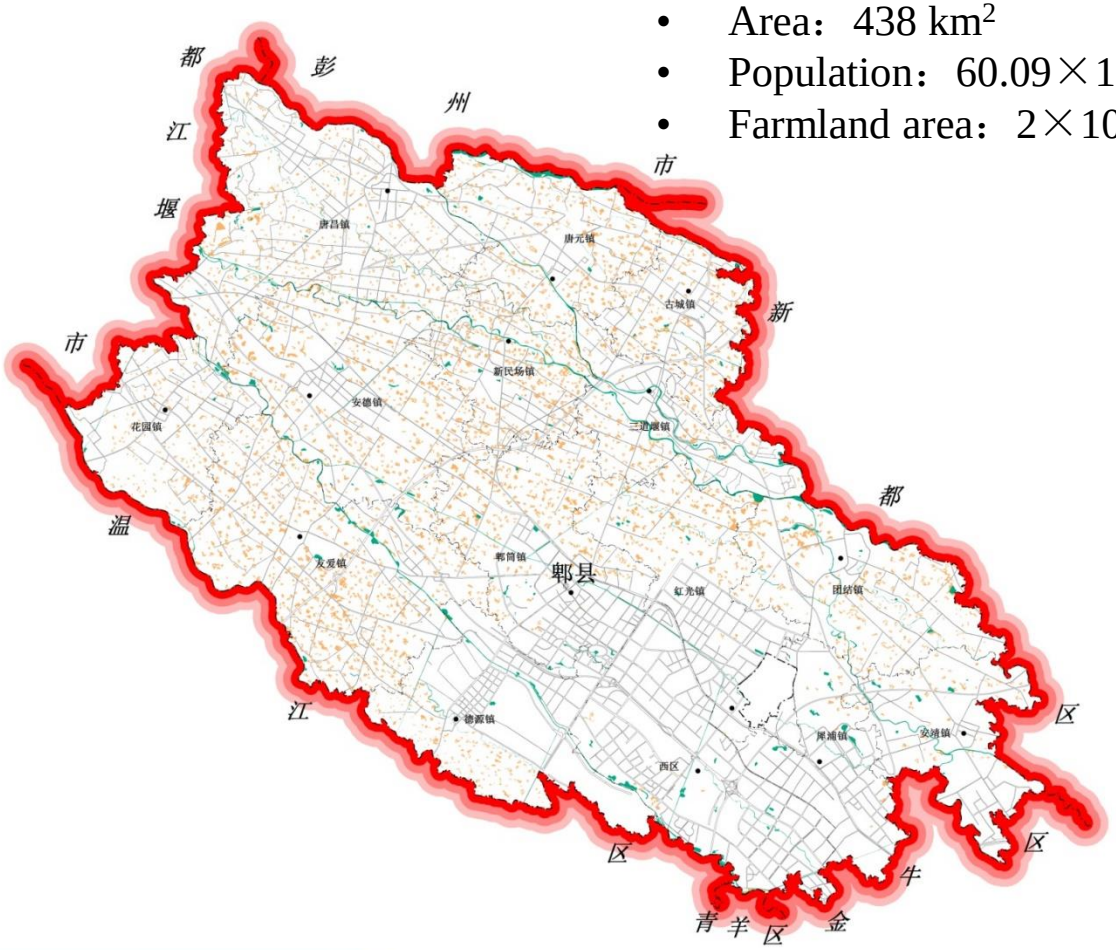
**Paddy Field**

**Upland Field**

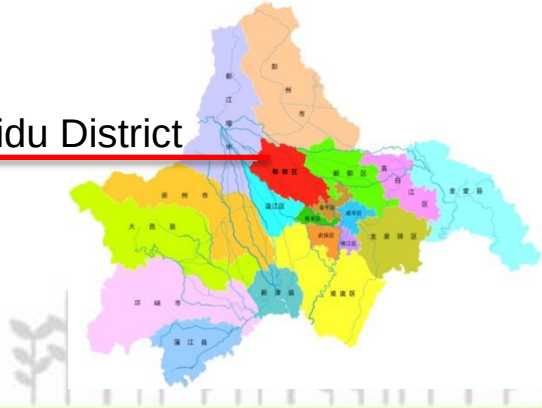
# II. Paddy-upland Rotation of Pidu District

## 1 Introduction of Pidu District

- Area：438 $km^2$
- Population：$60.09\times10^4$
- Farmland area：$2\times10^4$ $hm^2$

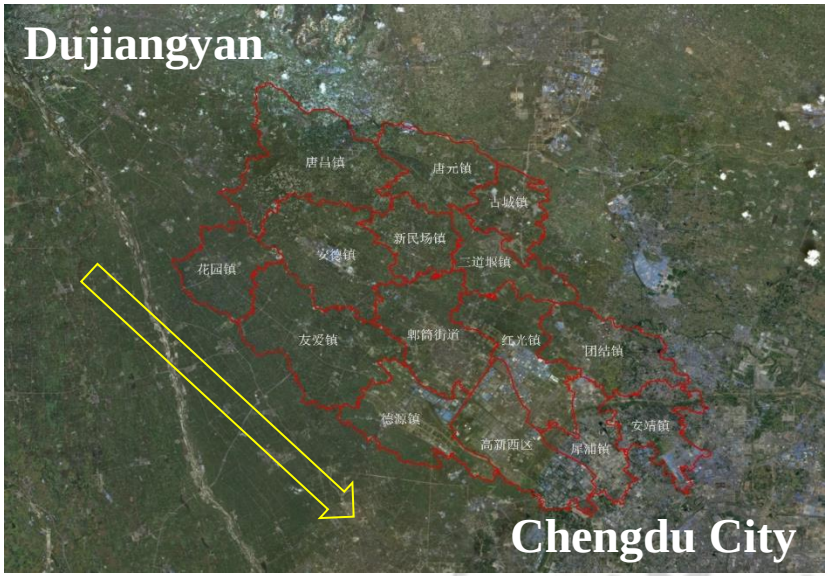




# 2 Characteristics of Ecological Environment

- Located in the alluvial plain of the Minjiang River;
- Has abundant rainfall and four distinct seasons;
- Belongs to Dujiangyan irrigation area with a  rich Irrigation and drainage system;
- It slopes from northwest to southeast, the relative height is no more than 2m;
- Soil is paddy soil and suitable for all kinds of crops.



# 3 Planting Patterns

## 1）Paddy-upland Rotation

Rice-rape

Rice-garlic

Rice-round carrot

Rice-potato

Rice-mustard

Rice-broccoli

# 2）Dry Farming




Plant leeks ----　　Cover the roots ----　　Harvest leeks and leek shoots

**Continuous cropping of leeks**

Continuous cropping of lettuce



Crop rotation of water spinach, flower Chinese cabbage and mustard

# Geographical Indication Products

Tangyuan Leek Shoot

Yunqiao Round Carrot

Deyuan Garlic

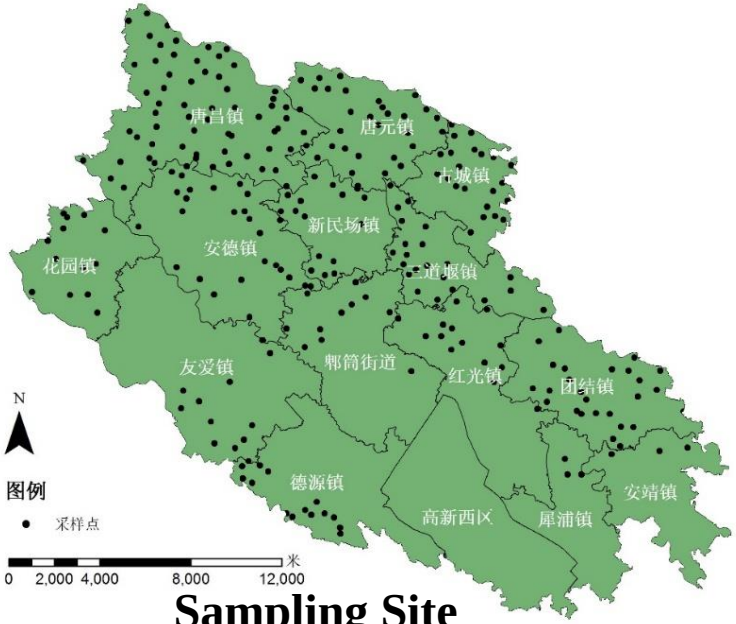
# 4 Purpose of This Research

- Analyze the soil nutrient contents and spatial distribution under the background of high-intensity land use in Pidu district;
- Discuss the effects of various factors on spatial variation of soil nutrient contents;
- Provide reference for regional agriculture sustainable management and ecological environment protection.

# III. Characteristics of Soil Nutrients in Pidu District

## 1 Data sources

- Soil testing data before fertilizing in 2015, including pH, soil organic matter (SOM), total nitrogen (TN), available nitrogen (AN), available phosphorus (AP) and available potassium (AK);
- Farm survey data, including soil conditions, plant crops, yield and fertilization;
- After removing the outliers, 287 effective data were obtained.




**Sampling Site**

**Farm survey**

# 2 Descriptive Statistics Characteristics of Soil Nutrients


- The median of 5 soil indices was lower than the mean, and the skewness was greater than 0, with the distribution belonged to right skewness.
- The CV of TN is less than 0.25, showing its little change in the region; the CV of SOM, AN, AP and AK is between 0.25 and 0.5, indicating certain differences in the region, but not significant.
- The analysis of the data normality shows that the AN conforms to normal distribution. SOM, TN, AP and AK also conform to normal distribution after log-transformation, which meet the needs of statistics analysis and spatial interpolation.

| Nutrients | Numbers | Minimum | Median | Maximum | Mean | SD | CV | Skewness | Distribution type |
|---|---|---|---|---|---|---|---|---|---|
| SOM | 287 | 12.12 | 21.40 | 39.30 | 22.35 | 5.99 | 0.27 | 0.61 | Log normal |
| TN | 287 | 0.75 | 1.06 | 2.04 | 1.15 | 0.24 | 0.21 | 0.92 | Log normal |
| AN | 287 | 40.50 | 95.00 | 149.00 | 95.38 | 24.12 | 0.25 | 0.06 | Normal |
| AP | 287 | 10.26 | 19.40 | 42.00 | 21.01 | 5.22 | 0.25 | 1.54 | Log normal |
| AK | 287 | 48.00 | 92.00 | 205.00 | 104.58 | 41.71 | 0.40 | 0.63 | Log normal |

Note: The unit of SOM and TN content is g/kg, and the unit of other elements contents is mg/kg.

# 3 Proportion of different grade soil nutrient

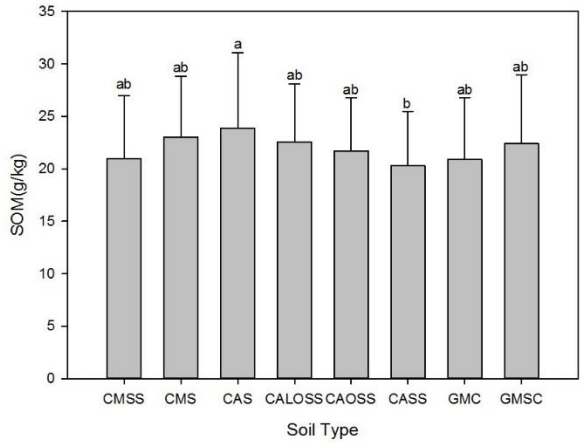
According to the national second soil census nutrient grade classification standard,

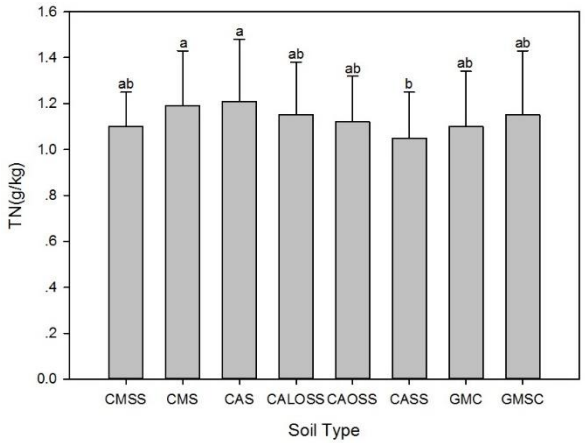
- AP is higher and the ratio of moderate level above achieves 100%;
- TN and AN are common and the ratio of moderate level above is about 65%.
- AK content is low, only about 44% of it reaches moderate above level.
- In general, the soil nutrients in the farmland of Pidu District are not superior, and the proportion of soil nutrient deficiency is still quite large.

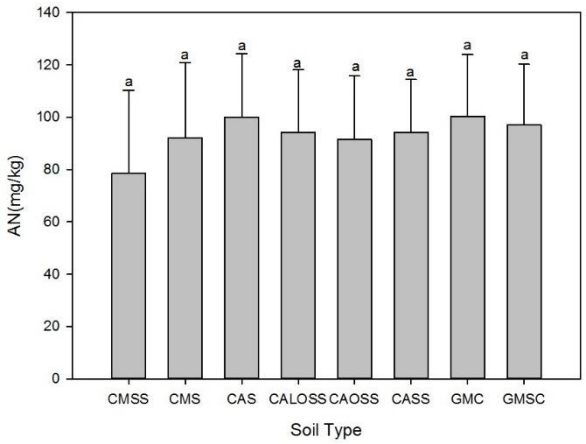
| Nutrients | Rich | | Less rich | | Moderate | | Less deficient | | Deficient | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Content | Ratio(%) | Content | Ratio(%) | Content | Ratio(%) | Content | Ratio(%) | Content | Ratio(%) |
| TN | ＞2 | 0.67 | ＞1.5~2 | 9.33 | ＞1~1.5 | 55 | ＞0.75~1 | 34.67 | ≤0.75 | 0.33 |
| AN | ＞150 | 0 | ＞120~150 | 18 | ＞90~120 | 47 | ＞60~90 | 26.33 | ≤60 | 8.67 |
| AP | ＞40 | 0 | ＞20~40 | 45.33 | ＞10~20 | 54.67 | ＞5~10 | 0 | ≤5 | 0 |
| AK | ＞200 | 1.33 | ＞150~200 | 17 | ＞100~150 | 26 | ＞50~100 | 54.34 | ≤50 | 1.33 |

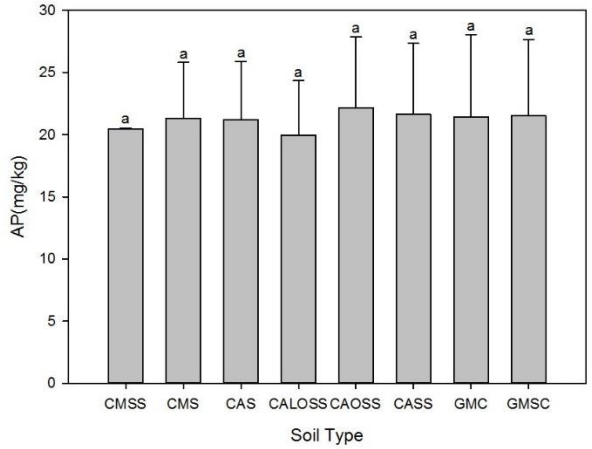
Note: The unit of SOM and TN content is g/kg, and the unit of other elements contents is mg/kg.

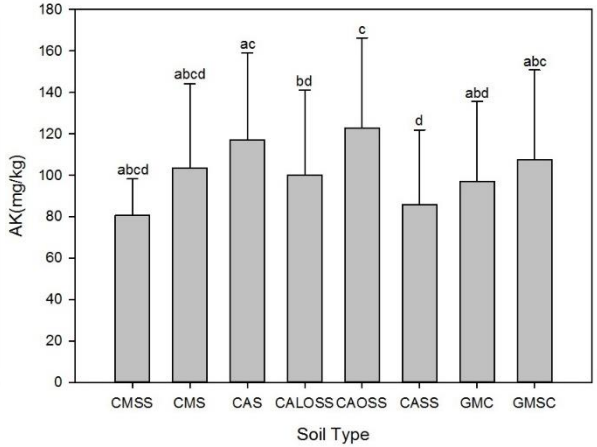
# 4 Difference of Different Soil Types



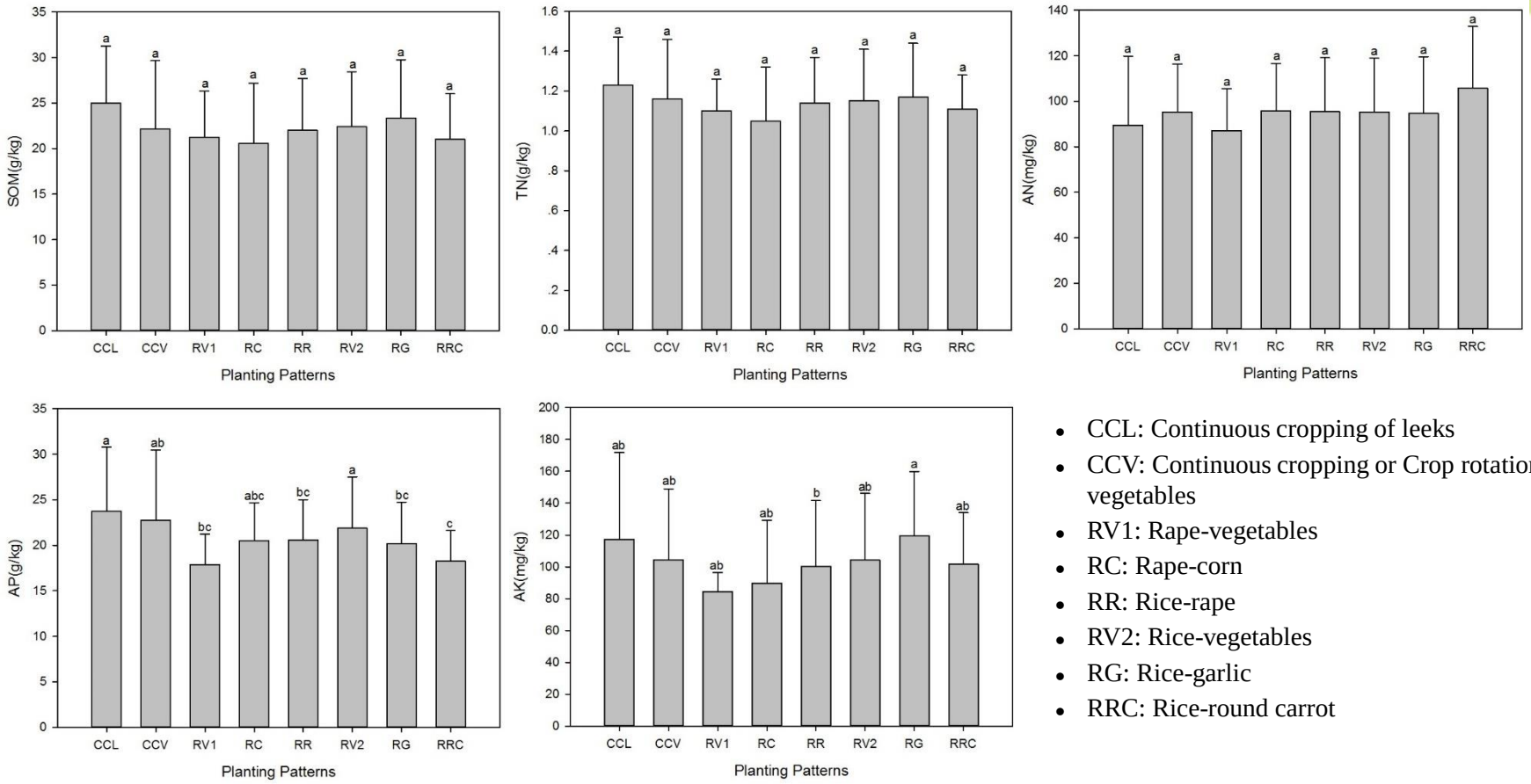




- CMSS: Calcareous moisture sandy soil
- CMS: Calcareous moisture soil
- CAS: Calcareous alluvial large clay
- CALOSS: Calcareous alluvial large oil sandy soil
- CAOSS: Calcareous alluvial oil sandy soil
- CASS: Calcareous alluvial sandy soil
- GMC: Grey-brown moisture clay
- GMSC: Gray-brown moisture sandy clay

**There is a certain difference between SOM and TN; there is no significant difference between AN and AP; AK has the biggest difference.**

# 5 Difference of Different Planting Patterns




- CCL: Continuous cropping of leeks
- CCV: Continuous cropping or Crop rotation of vegetables
- RV1: Rape-vegetables
- RC: Rape-corn
- RR: Rice-rape
- RV2: Rice-vegetables
- RG: Rice-garlic
- RRC: Rice-round carrot

No significant difference between SOM, TN and AN; a certain difference between AP and AK;

- The pattern of CCL has high requirements on soil nutrient content, especially on AP; RRC has high requirements on AP; and RG has high requirements on AK.
- The requirements for soil nutrient content in RV1 and RC are lower than those of other models.

# 6 Correlation Analysis of Different Soil Nutrients

- There was a significant positive correlation between SOM and AN and AP, indicating that the accumulation and decomposition of SOM had an important effect on the distribution of AN and AP in soil.
- AN was positively correlated with AP and AK, and was related to the extensive application of compound fertilizer in this area.

| Indicator | SOM | TN | AN | AP | AK |
|---|---|---|---|---|---|
| **SOM** | 1 | -0.034 | 0.192** | 0.936** | -0.08 |
| **TN** | | 1 | -0.064 | -0.056 | 0.011 |
| **AN** | | | 1 | 0.156* | 0.220* |
| **AP** | | | | 1 | -0.057 |
| **AK** | | | | | 1 |

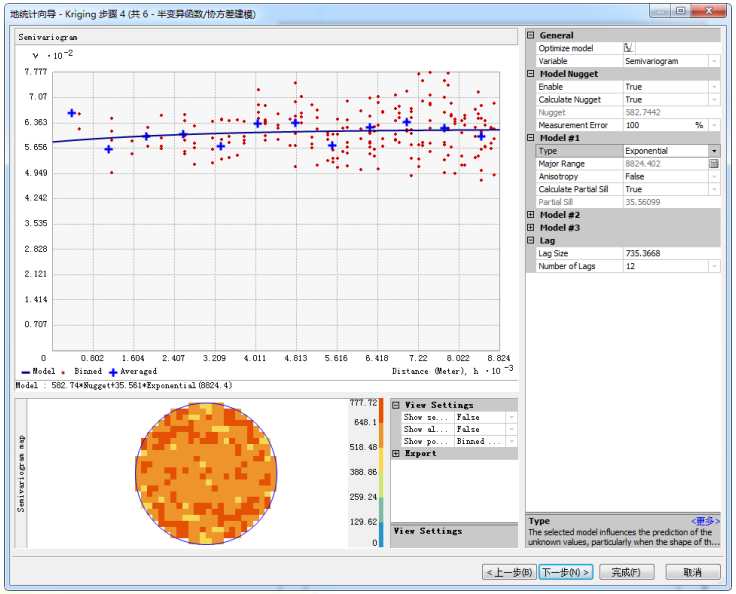
# IV. Spatial Distribution of Soil nutrients

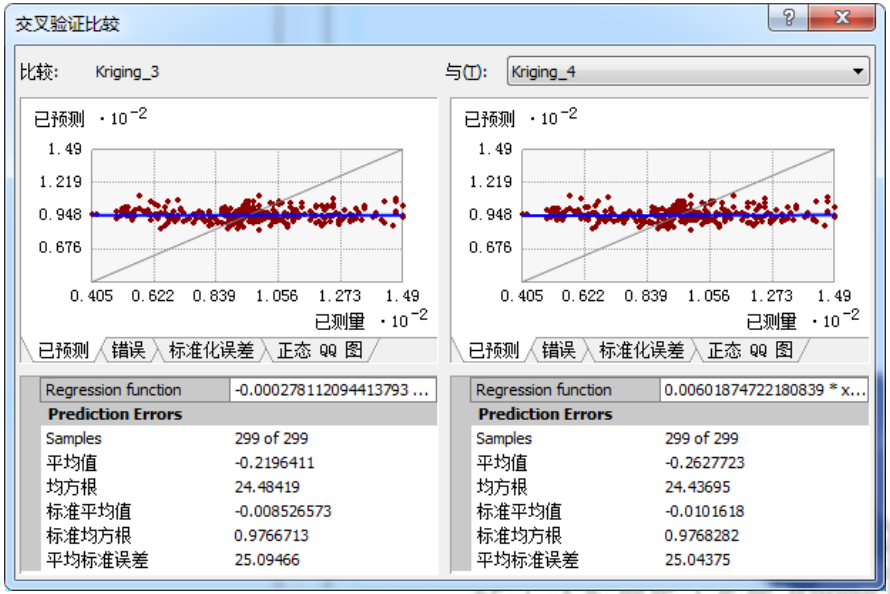
## 1 Research method

The ArcGIS geostatistical module is used to select the optimal semi-variogram function model, and the interpolation is performed by the ordinary Kriging method.

The model selection follows the following principle:

- ME is closest to 0;
- RMS is the smallest and closest to ASE;
- RMSS is closest to 1.



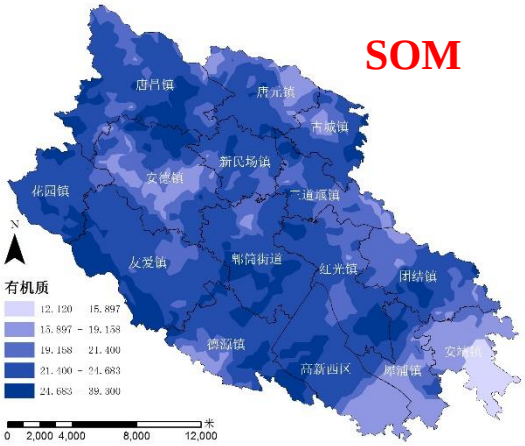
# 2 Best semi-variance models and the related parameters

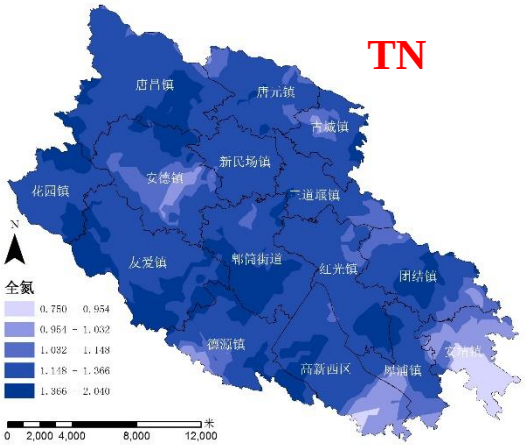
| Nutrients | Model | Nugget | Partial sill | Nugget/sill | Range/m | ME | RMS | ASE | RMSS |
|---|---|---|---|---|---|---|---|---|---|
| SOM | Spherical | 15.0254 | 38.8178 | 0.39 | 608.96 | 0.0034 | 6.3159 | 6.5745 | 0.9600 |
| TN | Gaussian | 0.0595 | 0.0684 | 0.87 | 608.96 | 0.0016 | 0.2629 | 0.2777 | 0.9470 |
| AN | Exponential | 582.7442 | 618.3052 | 0.94 | 8824.40 | -0.0085 | 24.4842 | 25.0947 | 0.9767 |
| AP | Exponential | 28.5314 | 29.3353 | 0.97 | 6336.49 | -0.0001 | 5.3766 | 5.5299 | 0.9733 |
| AK | Exponential | 1171.2597 | 1877.7269 | 0.62 | 1053.43 | 0.0051 | 44.3653 | 45.1361 | 0.9833 |

- Nugget coefficient = nugget value/sill: reflect the level of data spatial correlation, the value is smaller and the correlation is stronger;
- Structural factors: soil parent material, topography and landform, altitude, climate, etc;
- Random factors: farming system, fertilization status, distance from residential areas, etc;

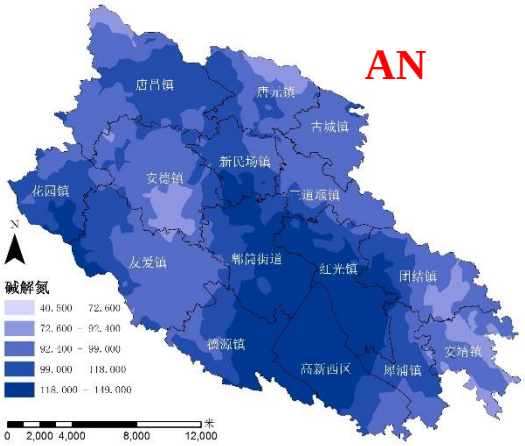
- SOM(0.39): structural factors play an important role in its spatial distribution;
- AK(0.62): structural factors and random factors are combined;
- TN, AN and AP: random factors play a decisive role.

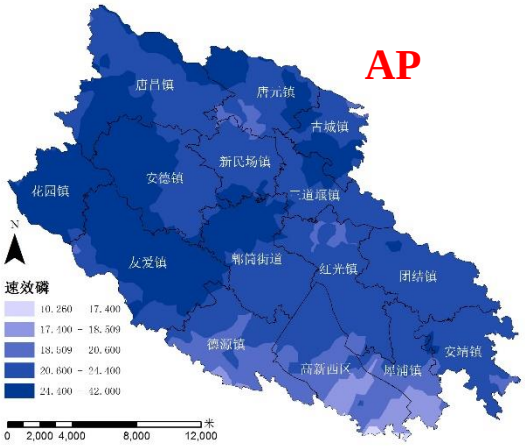
# 3 Spatial distribution

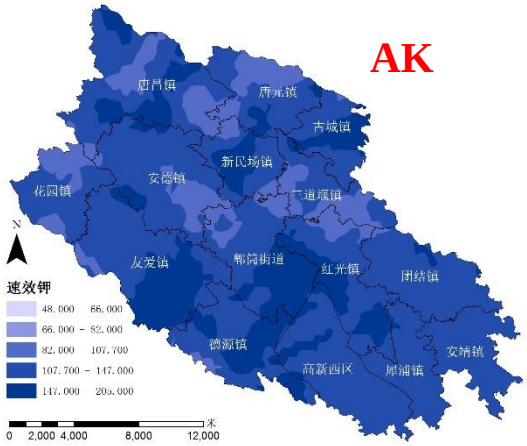


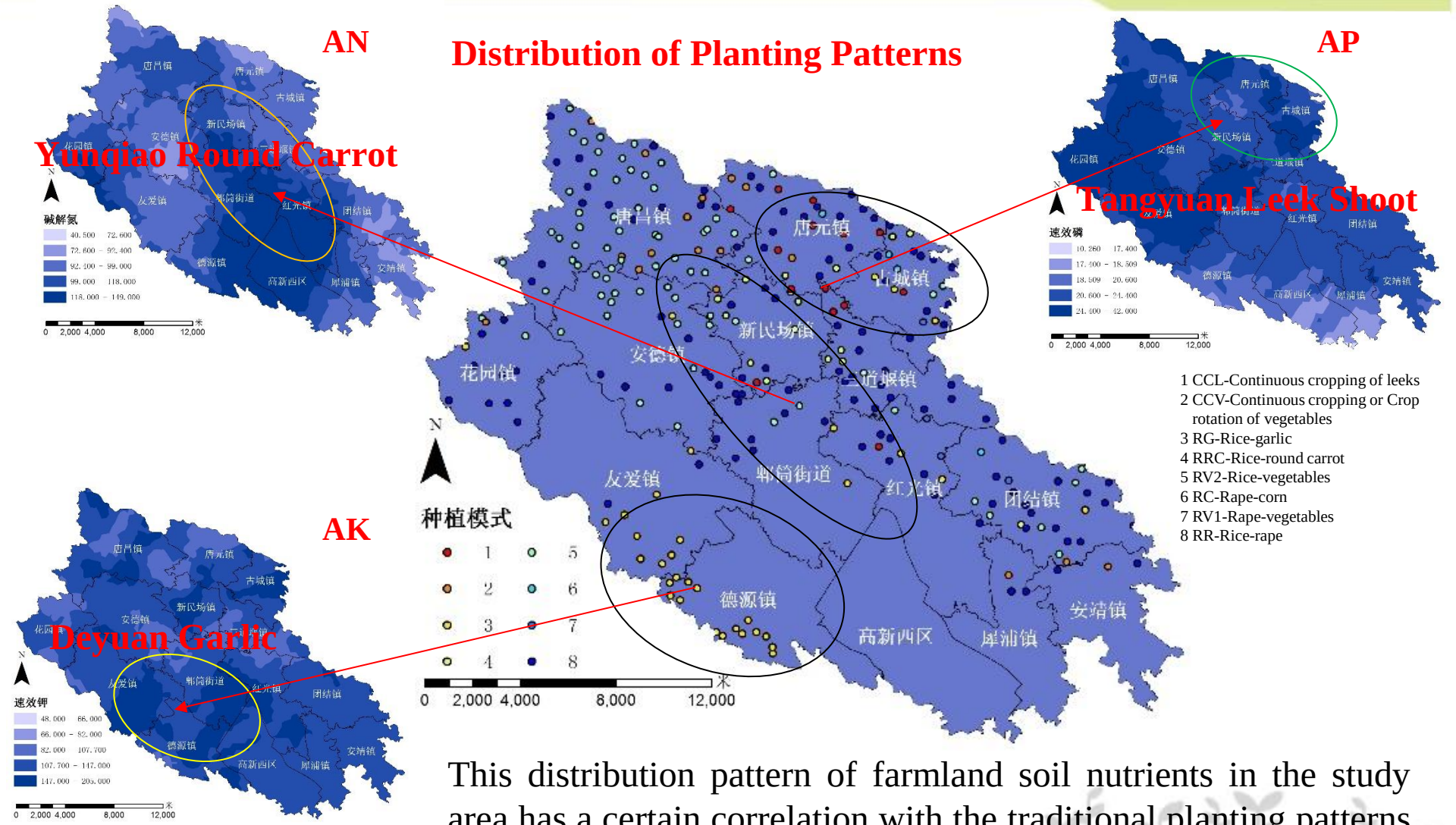

- The spatial distribution of SOM and TN is generally similar, with some higher areas;
- The south part of AN is higher;
- The north part of AP is higher;
- Part area of AK is higher.



It can be seen that the AN in Xinminchang Town has a good correspondence with the radish plantation in this area; it is same with the AK in Deyuan Town with the garlic plantation and AP in Tangyuan Town with the leek plantation.

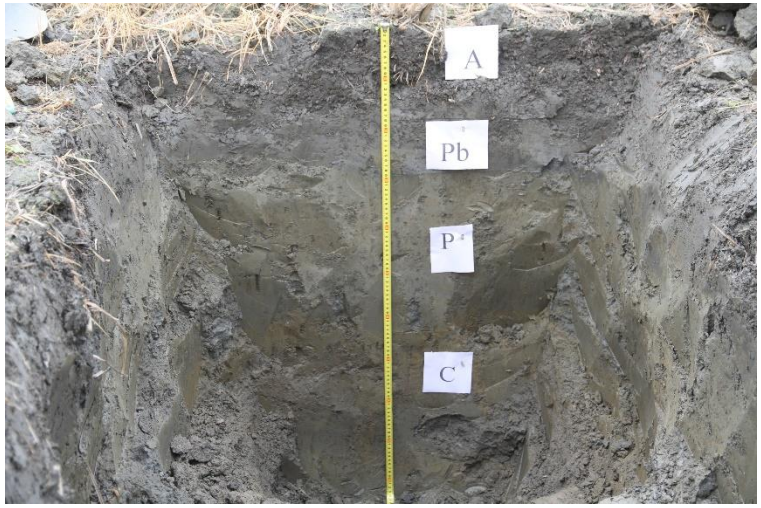



This distribution pattern of farmland soil nutrients in the study area has a certain correlation with the traditional planting patterns of the towns and villages in the Pidu District.

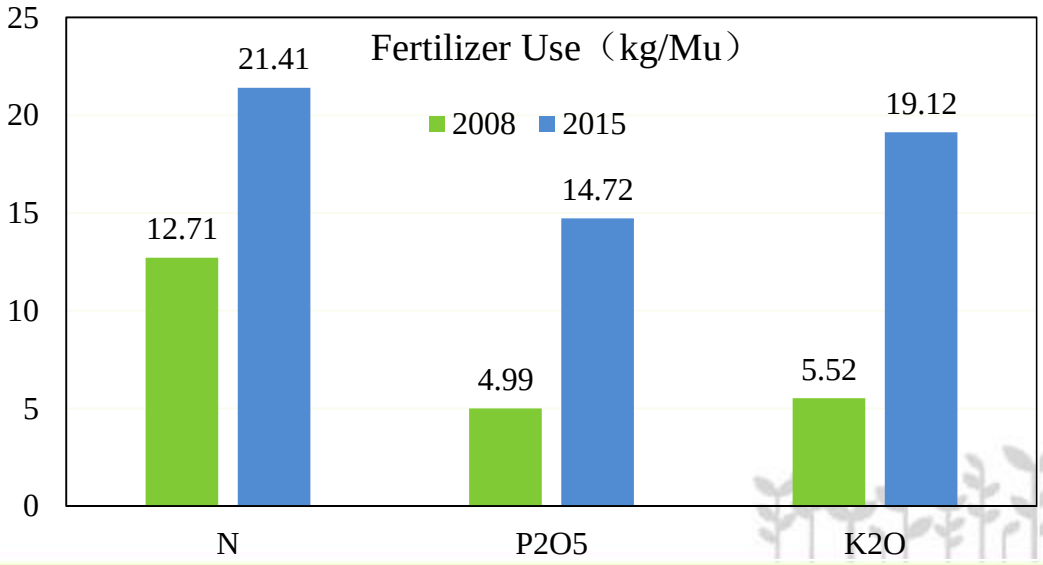
# V. Discussion

## 1 Characteristics of Soil Nutrients in Farmland

① The analysis of variance showed that the soil nutrient content difference of different soil types and different planting patterns in Pidu District was small in general, indicating that the soil nutrient content of farmland in Pidu District was relatively consistent due to the high-intensity human production activities.




② The soil nutrient content is common, and AK is relatively deficient, which has a certain relationship with the unique soil parent material, long-term paddy-upland rotation and high multiple crop index in this area. In order to maintain the soil fertility of the farmland, the use of fertilizer in the Pidu District has shown a significant uptrend in recent years. The use of $P_2O_5$ and K2O has increased by 3-4 times in the past 10 years. We can see that the high production of farmland in the Pidu District currently is based on the large use of fertilizer.



# 2 Spatial Distribution of Soil nutrients

① According to the results of different research, the nugget coefficient of SOM in the farmland of Pidu district showed a declining trend, while TN, AN and AP showed an increasing trend.

② This change maybe related to the changes of planting patterns such as vegetable-based dry farming instead of traditional paddy-upland rotation and compound fertilizer instead of farmyard manure.

| Item | Year | Content | Nugget/sill | Reference |
|---|---|---|---|---|
| SOM | 1982 | 25.65 | 0.810 | 杨刚，2012 |
| | 2004 | 15.60 | 0.640 | 秦鱼生，2008 |
| | 2007 | 33.04 | 0.720 | 杨刚，2012 |
| | 2015 | 22.35 | 0.390 | This research |
| TN | 2002 | 1.29 | 0.436 | 陈肖，2007 |
| | 2016 | 1.94 | 0.524 | 张浩，2018 |
| | 2015 | 1.15 | 0.870 | This research |
| AN | 2002 | 72.20 | 0.377 | 陈肖，2007 |
| | 2016 | 138.70 | 0.639 | 张浩，2018 |
| | 2015 | 95.38 | 0.940 | This research |
| AP | 1982 | 7.10 | 0.700 | 肖鹏飞，2005 |
| | 2002 | 14.30 | 0.790 | 肖鹏飞，2005 |
| | 2004 | 8.23 | 0.633 | 秦鱼生，2008 |
| | 2015 | 21.01 | 0.970 | This research |
| AK | 2004 | 72.20 | 83.600 | 秦鱼生，2008 |
| | 2015 | 104.58 | 0.620 | 本研究 |

③ In addition, the spatial distribution of different soil nutrient contents in the study area has a certain correlation with the spatial distribution of different planting patterns in the area, which shows that the demand of farmland crops for nutrients also affects the spatial distribution pattern of soil nutrients in some way.


Thanks !