# Supplementary Material

## Assessing the Alignment between Naturally Adaptive Grain Crop Planting Patterns and Staple Food Security in China

Zhang et al.

# Figures

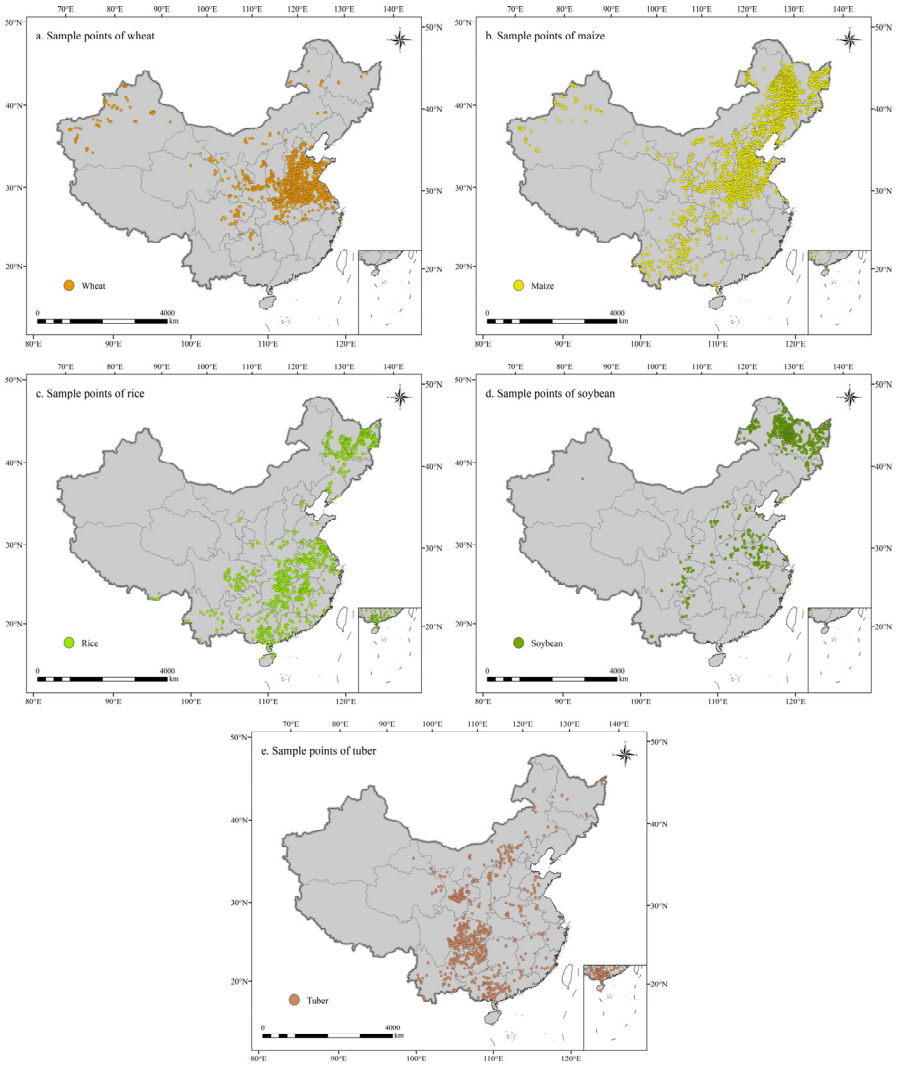



**Figure.S1 Distribution of planting sample points for wheat (a), maize (b), rice (c), soybean (d), and tuber (e) crops.**

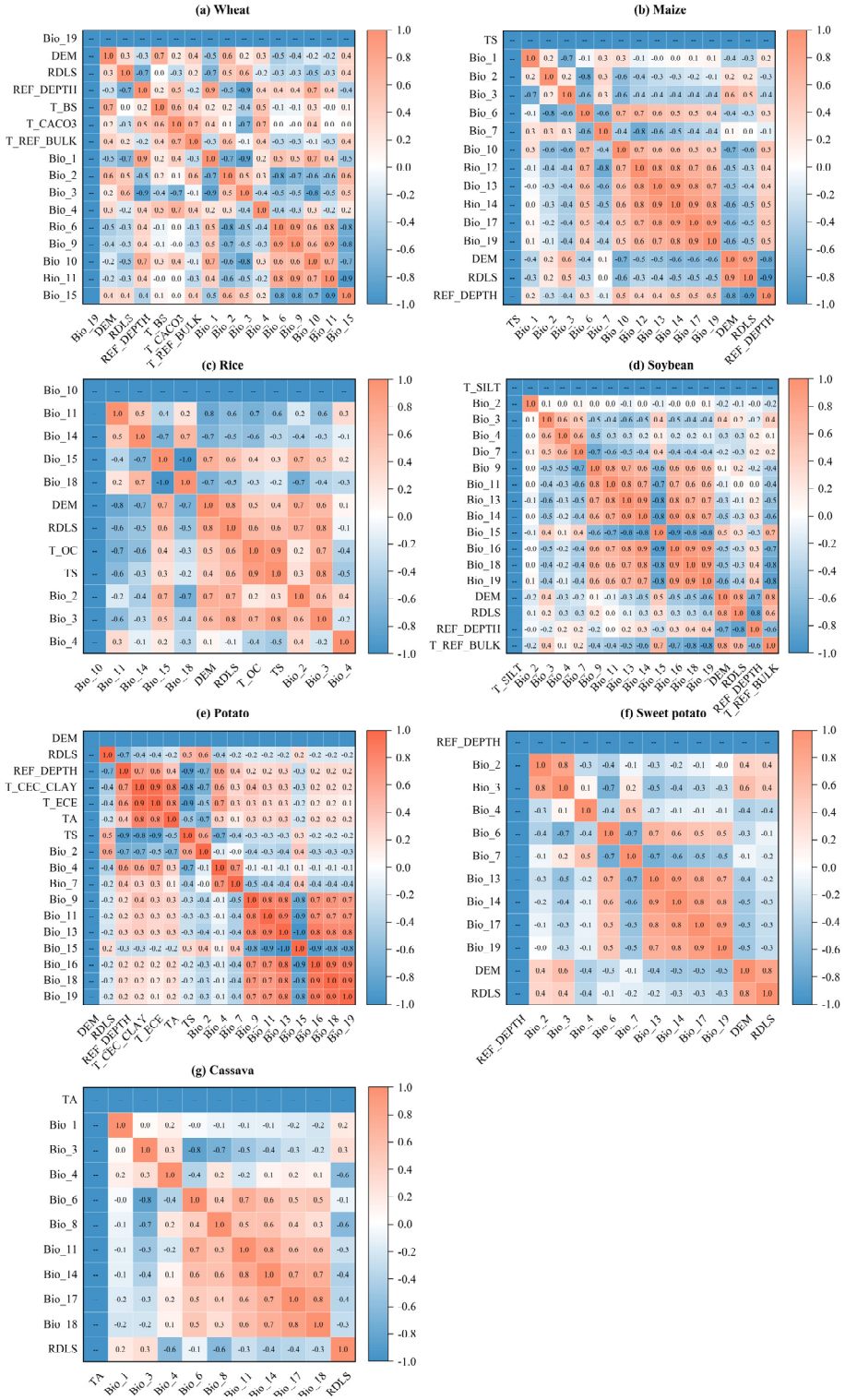



**Figure.S2 Correlation analysis of the major environmental variables related to the planting suitability of wheat (a), maize (b), rice (c), soybean (d), potato (e), sweet potato (f), and cassava (g).**

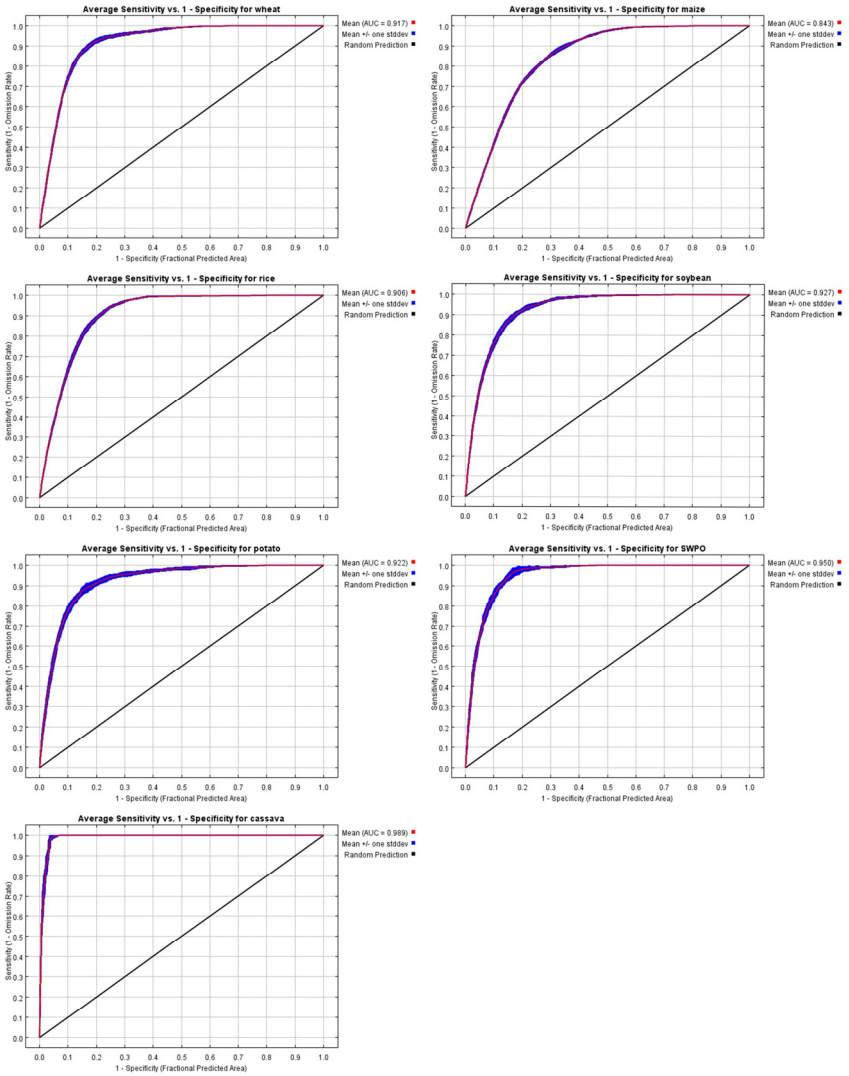



**Figure.S3 The AUC values obtained in the models for wheat (a), maize (b), rice (c), soybean (d), potato (e), sweet potato (f), and cassava (g). Data are means ± standing deviation (n=10).**

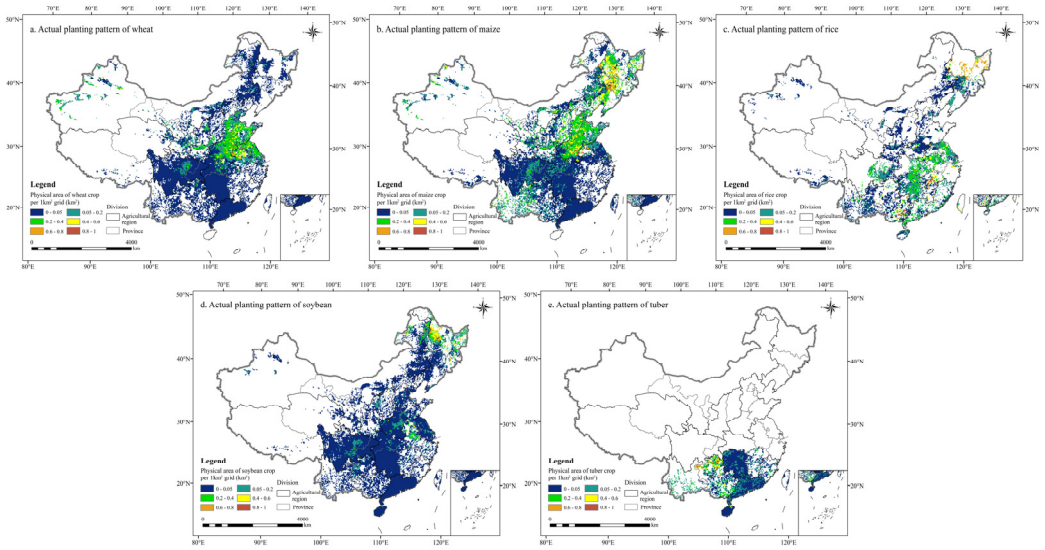



**Figure.S4 Actual planting patterns of wheat (a) , maize (b), rice (c), soybean (d), and tuber (e) in China.**

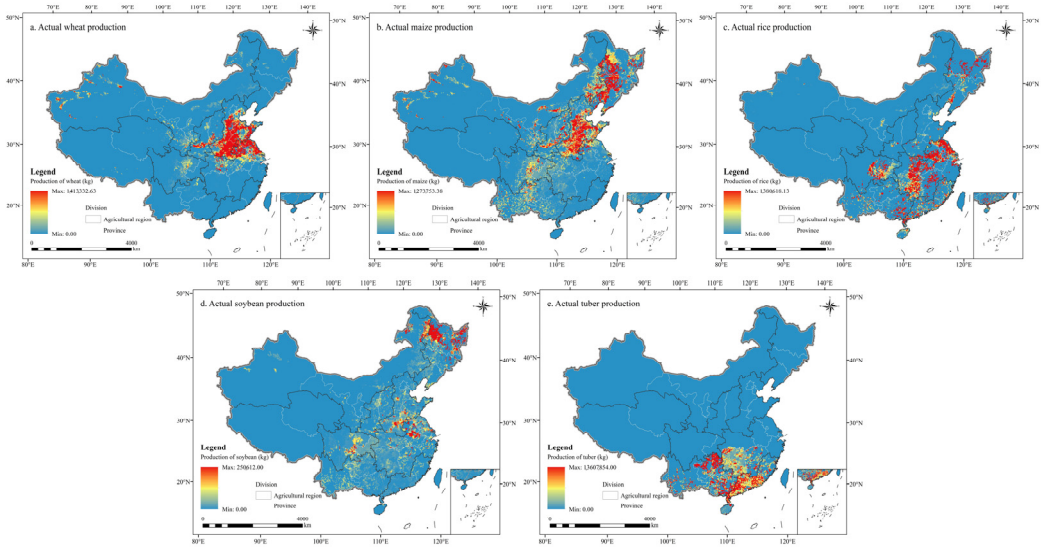



**Figure.S5 The distribution map of the production of wheat (a), maize (b), rice (c), soybean (d) and tuber (e) in China under the actual condition.**

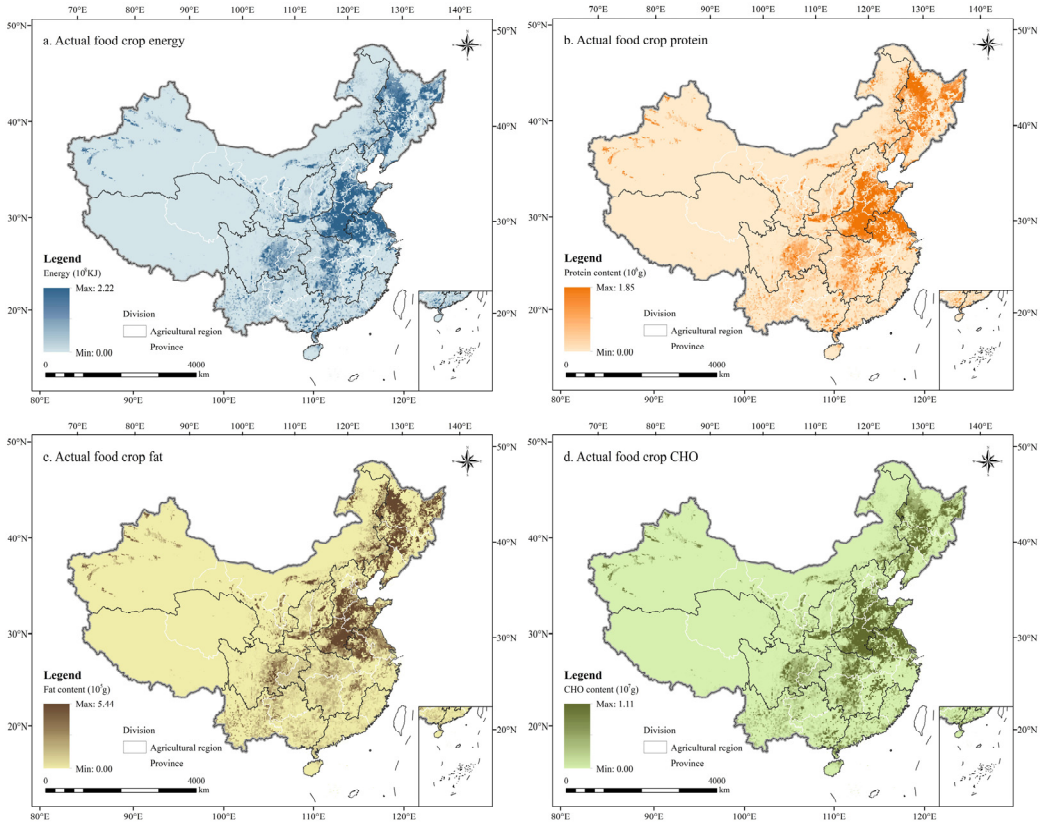



**Figure.S6 The distribution map of energy (a), protein (b), fat (c), and carbohydrate (d) contents provided by major grain crops in China under the suitable condition (rice as the standard food).**

## Tables

**Table.S1 Environment variables used in the MaxEnt model and their descriptions.**

| Type | Environment variable | Description | Unit |
|---|---|---|---|
| Bioclimate factors (19) | Bio1 | Average annual temperature | ℃ |
| | Bio2 | Average daily temperature difference | ℃ |
| | Bio3 | Isothermal | - |
| | Bio4 | Coefficient of seasonal variation of temperature | - |
| | Bio5 | Maximum temperature in the hottest month | ℃ |
| | Bio6 | Minimum temperature in the coldest month | ℃ |
| | Bio7 | Annual difference in temperature | ℃ |
| | Bio8 | Average temperature of the wettest quarter | ℃ |
| | Bio9 | Average temperature of the driest quarter | ℃ |
| | Bio10 | Average temperature of the warmest quarter | ℃ |
| | Bio11 | Average temperature of the coldest quarter | ℃ |
| | Bio12 | Annual precipitation | mm |
| | Bio13 | Precipitation in the wettest month | mm |
| | Bio14 | Precipitation in the driest month | mm |
| | Bio15 | Seasonal variations in precipitation | mm |
| | Bio16 | Precipitation in the driest quarter | mm |
| | Bio17 | Wettest quarterly precipitation | mm |
| | Bio18 | Warmest quarter precipitation | mm |
| | Bio19 | Coldest quarterly precipitation | mm |
| Topography factors (4) | DEM | Altitude | m |
| | TS | Terrain slope | ° |
| | TA | Terrain aspect | azimuth |
| | RDLS | Relief amplitude | — |
| Soil factors (19) | REF_DEPTH | Reference soil depth | code |
| | DRAINAGE | Drainage level | code |
| | AWC_CLASS | Range of effective soil water content | code |
| | T_GRAVEL | Topsoil gravel content | %vol |
| | T_SAND | Topsoil sand content | %weight |
| | T_SILT | Topsoil silt content | %weight |
| | T_CLAY | Topsoil clay content | %weight |

| | | |
|---|---|---|
| T_USDA_TEX_CLASS | Topsoil USDA Soil Texture Classification | name |
| T_REF_BULK_DENSITY | Reference bulk density of topsoil | $Kg/dm^3$ |
| T_OC | Topsoil organic carbon content | %weight |
| T_PH_H2O | Topsoil pH | $-log(H)^+$ |
| T_CEC_CLAY | Cation exchange capacity of topsoil clay layer soil | cmol/kg |
| T_CEC_SOIL | Topsoil cation exchange capacity | cmol/kg |
| T_BS | Topsoil subgrade saturation | % |
| T_TEB | Topsoil exchangeable salt base | cmol/kg |
| T_CACO3 | Topsoil carbonate or lime content | %weight |
| T_CASO4 | Topsoil sulphate content | %weight |
| T_ESP | Topsoil exchangeable sodium salt | % |
| T_ECE | Topsoil conductivity | Ds/m |

**Table.S2 Major environmental variables for evaluating wheat planting suitability (before screening).**

| Variable | Percent contribution | Permutation contribution |
|---|---|---|
| RDLS | 44.7 | 10.2 |
| Bio_19 | 9.2 | 5.7 |
| Bio_4 | 8.4 | 9.6 |
| T_CACO3 | 5.0 | 0.8 |
| DEM | 3.6 | 20.6 |
| Bio_3 | 2.5 | 2.3 |
| Bio_11 | 2.3 | 3.2 |
| T_BS | 2.2 | 0.8 |
| Bio_6 | 2.1 | 8.5 |
| Bio_2 | 1.9 | 3.3 |
| REF_DEPTH | 1.8 | 0.5 |
| Bio_9 | 1.8 | 1.1 |
| Bio_15 | 1.7 | 1.7 |
| Bio_10 | 1.6 | 0.2 |
| T_REF_BULK | 1.3 | 0.4 |
| Bio_1 | 1 | 1.1 |

**Table.S3 Major environmental variables for evaluating wheat planting suitability (after screening).**

| Variable | Percent contribution | Permutation contribution |
|---|---|---|
| RDLS | 50.2 | 25.9 |

| | | |
|---|---|---|
| Bio_11 | 14.7 | 18.7 |
| Bio_19 | 12.6 | 18.5 |
| T_CACO3 | 7.8 | 0.5 |
| Bio_4 | 6.9 | 19.3 |
| Bio_3 | 1.6 | 2.7 |
| Bio_2 | 1.5 | 8.3 |
| Bio_15 | 1.4 | 3.7 |
| T_REF_BULK | 1.1 | 0.2 |
| T_BS | 0.9 | 0.9 |
| REF_DEPTH | 0.7 | 0.9 |
| Bio_10 | 0.5 | 0.6 |

**Table.S4 Major environmental variables for evaluating maize planting suitability (before screening).**

| Variable | Percent contribution | Permutation contribution |
|---|---|---|
| RDLS | 36.0 | 21.5 |
| Bio_19 | 13.2 | 14.5 |
| Bio_12 | 7.8 | 8.1 |
| REF_DEPTH | 7.2 | 1.4 |
| TS | 4.7 | 5.0 |
| Bio_10 | 4.3 | 12.1 |
| DEM | 3.9 | 2.2 |
| Bio_14 | 3.2 | 2.2 |
| Bio_13 | 3.1 | 0.5 |
| Bio_1 | 2.3 | 14.5 |
| Bio_2 | 2.0 | 1.9 |
| Bio_17 | 1.7 | 2.8 |
| Bio_6 | 1.5 | 0.3 |
| Bio_3 | 1.3 | 0.5 |
| Bio_7 | 1.2 | 1.0 |

**Table.S5 Major environmental variables for evaluating maize planting suitability (after screening).**

| Variable | Percent contribution | Permutation contribution |
|---|---|---|
| RDLS | 37.5 | 15 |
| Bio_19 | 17.5 | 18.5 |
| Bio_12 | 14.6 | 16.1 |
| Bio_10 | 9.2 | 30.5 |
| REF_DEPTH | 7.7 | 0.6 |
| TS | 6.1 | 7.9 |
| Bio_2 | 3.2 | 5.4 |
| Bio_1 | 2.3 | 4.1 |

| | | |
|---|---|---|
| Bio_3 | 1.4 | 0.8 |
| Bio_7 | 0.6 | 0.9 |

**Table.S6 Major environmental variables for evaluating rice planting suitability (before screening).**

| Variable | Percent contribution | Permutation contribution |
|---|---|---|
| RDLS | 64.3 | 7.3 |
| DEM | 4.5 | 4.2 |
| Bio_18 | 4.0 | 3.4 |
| Bio_2 | 2.9 | 3.3 |
| Bio_3 | 2.8 | 1.1 |
| T_OC | 2.3 | 1.2 |
| Bio_11 | 2.1 | 2.3 |
| Bio_4 | 2.1 | 1.2 |
| TS | 1.6 | 3.2 |
| Bio_14 | 1.4 | 2.0 |
| Bio_15 | 1.1 | 1.7 |
| Bio_10 | 1.0 | 37.7 |

**Table.S7 Major environmental variables for evaluating rice planting suitability (after screening).**

| Variable | Percent contribution | Permutation contribution |
|---|---|---|
| RDLS | 66.3 | 41.3 |
| Bio_18 | 11.6 | 22.3 |
| Bio_4 | 4 | 4.8 |
| TS | 3.5 | 7.4 |
| T_OC | 3.2 | 1.1 |
| Bio_3 | 2.9 | 2.5 |
| Bio_15 | 2.9 | 2 |
| Bio_11 | 2.4 | 11.8 |
| Bio_14 | 1.9 | 3.2 |
| Bio_2 | 1.4 | 3.7 |

**Table.S8 Major environmental variables for evaluating soybean planting suitability (before screening)**

| Variable | Percent contribution | Permutation contribution |
|---|---|---|
| Bio_4 | 31.6 | 1.1 |
| RDLS | 23.5 | 6.7 |
| DEM | 6.3 | 4.6 |
| Bio_13 | 5.4 | 2.7 |
| Bio_9 | 4.9 | 2.6 |
| Bio_18 | 4.1 | 13.1 |

| | | |
|---|---|---|
| REF_DEPTH | 2.9 | 0.3 |
| Bio_11 | 2.3 | 11 |
| Bio_14 | 1.8 | 8.1 |
| Bio_7 | 1.4 | 1.1 |
| Bio_3 | 1.4 | 0.3 |
| Bio_16 | 1.2 | 7.1 |
| Bio_15 | 1.1 | 1.1 |
| T_REF_BULK | 1.1 | 0 |
| Bio_2 | 1.1 | 0.4 |
| T_SILT | 1.0 | 0.6 |
| Bio_19 | 1.0 | 0.5 |

**Table.S9 Major environmental variables for evaluating soybean planting suitability (after screening)**

| Variable | Percent contribution | Permutation contribution |
|---|---|---|
| Bio_4 | 33.4 | 6.7 |
| RDLS | 28.7 | 49.3 |
| Bio_13 | 14.8 | 16.8 |
| Bio_9 | 6.4 | 8.7 |
| Bio_3 | 4.9 | 0.8 |
| Bio_14 | 4.3 | 13.1 |
| REF_DEPTH | 2.1 | 0.3 |
| Bio_15 | 1.7 | 2.1 |
| Bio_2 | 1.6 | 0.7 |
| T_SILT | 1.2 | 0.7 |
| T_REF_BULK | 0.9 | 0.6 |

**Table.S10 Major environmental variables for evaluating potato planting suitability (before screening)**

| Variable | Percent contribution | Permutation contribution |
|---|---|---|
| DEM | 16.9 | 10.4 |
| Bio_13 | 14.8 | 14.9 |
| RDLS | 13.1 | 9.1 |
| Bio_2 | 8.7 | 2.8 |
| Bio_19 | 7.1 | 8.3 |
| REF_DEPTH | 4.6 | 0.8 |
| Bio_4 | 4.3 | 0.4 |
| Bio_11 | 4.3 | 0.1 |
| Bio_16 | 3 | 2.3 |
| T_ECE | 2.3 | 1.3 |
| Bio_18 | 2.2 | 1.3 |
| TS | 2.1 | 3.0 |

| | | |
|---|---|---|
| Bio_7 | 1.4 | 1.7 |
| Bio_9 | 1.3 | 2.1 |
| TA | 1.1 | 1.1 |
| Bio_15 | 1.1 | 3.3 |
| T_CEC_CLAY | 1.0 | 1.9 |

**Table.S11 Major environmental variables for evaluating potato planting suitability (after screening)**

| Variable | Percent contribution | Permutation contribution |
|---|---|---|
| DEM | 29.9 | 39.1 |
| Bio_16 | 13.5 | 15.9 |
| Bio_2 | 10.9 | 6.9 |
| Bio_19 | 10.1 | 9.2 |
| Bio_13 | 9.8 | 13.5 |
| Bio_4 | 7.3 | 0.8 |
| REF_DEPTH | 5.1 | 0.4 |
| Bio_11 | 4.9 | 3.1 |
| TS | 2.7 | 3.6 |
| T_ECE | 2.2 | 1.0 |
| Bio_15 | 2.1 | 4.0 |
| T_CEC_CLAY | 0.9 | 2.0 |
| TA | 0.6 | 0.5 |

**Table.S12 Major environmental variables for evaluating sweet potato planting suitability (before screening)**

| Variable | Percent contribution | Permutation contribution |
|---|---|---|
| Bio_14 | 39.8 | 16.1 |
| Bio_2 | 16.6 | 3.0 |
| Bio_13 | 7.4 | 15.7 |
| Bio_3 | 7.1 | 5.4 |
| Bio_17 | 3.6 | 4.8 |
| Bio_6 | 3.5 | 5.9 |
| RDLS | 2.4 | 2.4 |
| Bio_4 | 1.9 | 2.8 |
| Bio_19 | 1.7 | 3.3 |
| DEM | 1.5 | 6.4 |
| Bio_7 | 1.1 | 0.2 |
| REF_DEPTH | 1.0 | 6.3 |

**Table.S13 Major environmental variables for evaluating sweet potato planting suitability (after screening)**

| Variable | Percent contribution | Permutation contribution |
|---|---|---|
| Bio_14 | 42.3 | 10.9 |
| Bio_2 | 24.9 | 7.6 |
| Bio_13 | 11.5 | 31.8 |
| Bio_3 | 9 | 6 |
| Bio_6 | 6.7 | 30.2 |
| RDLS | 3 | 3.7 |
| Bio_4 | 1.6 | 8.4 |
| REF_DEPTH | 1.1 | 1.5 |

**Table.S14 Major environmental variables for evaluating cassava planting suitability (before screening)**

| Variable | Percent contribution | Permutation contribution |
|---|---|---|
| Bio_17 | 36.9 | 0.2 |
| Bio_1 | 25.4 | 24.8 |
| Bio_3 | 5.9 | 4.2 |
| Bio_18 | 4.3 | 1.7 |
| Bio_14 | 3.7 | 1.2 |
| RDLS | 3.3 | 8.8 |
| Bio_11 | 2.4 | 0.6 |
| Bio_4 | 2.4 | 4.6 |
| Bio_8 | 2.1 | 13.2 |
| Bio_6 | 2.0 | 1.1 |
| TA | 1.0 | 1.5 |

**Table.S15 Major environmental variables for evaluating cassava planting suitability (after screening)**

| Variable | Percent contribution | Permutation contribution |
|---|---|---|
| Bio_17 | 41.8 | 0.7 |
| Bio_1 | 39.4 | 35.9 |
| Bio_18 | 5.3 | 6.9 |
| Bio_3 | 4.7 | 3.4 |
| RDLS | 3.6 | 18.8 |
| Bio_8 | 3.1 | 10.9 |
| Bio_4 | 1.1 | 22.5 |
| TA | 1.0 | 0.9 |

**Table.S16 Food equivalent coefficient of grain crops**

| | Wheat | Maize | Rice | Soybean | Tuber |
|---|---|---|---|---|---|
| FEU | 1.03 | 1.01 | 1.00 | 1.45 | 0.25 |

| FEU' | Wheat | Maize | Rice | Soybean | Tuber |
|---|---|---|---|---|---|
| | 1.07 | 1.01 | 1.00 | 1.51 | 0.06 |

**Table.S17 Comparison of actual planting SDI and suitable planting SDI of grain crops by province**

| Province | SDI | | Province | SDI | |
|---|---|---|---|---|---|
| | Actual | Suitable | | Actual | Suitable |
| Beijing | 0.40 | 0.64 | Hubei | 0.71 | 0.79 |
| Tianjin | 0.57 | 0.70 | Hunan | 0.54 | 0.62 |
| Hebei | 0.49 | 0.69 | Guangdong | 0.58 | 0.56 |
| Shanxi | 0.47 | 0.71 | Guangxi | 0.64 | 0.61 |
| Inner Mongolia | 0.60 | 0.69 | Hainan | 0.06 | 0.59 |
| Liaoning | 0.26 | 0.69 | Chongqing | 0.64 | 0.70 |
| Jilin | 0.36 | 0.68 | Sichuan | 0.69 | 0.74 |
| Heilongjiang | 0.66 | 0.68 | Guizhou | 0.61 | 0.69 |
| Shanghai | 0.42 | 0.63 | Yunnan | 0.60 | 0.64 |
| Jiangsu | 0.65 | 0.75 | Tibet | 0.24 | 0.72 |
| Zhejiang | 0.62 | 0.63 | Shaanxi | 0.62 | 0.73 |
| Anhui | 0.70 | 0.77 | Gansu | 0.60 | 0.70 |
| Fujian | 0.57 | 0.59 | Qinghai | 0.31 | 0.67 |
| Jiangxi | 0.39 | 0.46 | Ningxia | 0.56 | 0.68 |
| Shandong | 0.55 | 0.75 | Xinjiang | 0.54 | 0.61 |
| Henan | 0.61 | 0.76 | | | |

**Table.S18 The difference between the per capita nutrient content of grain crops under suitable condition and actual condition (rice as the standard food)**

| Province | The difference between suitable and actual per 10,000 people nutrient content of food crops | | | |
|---|---|---|---|---|
| | energy ($10^8$KJ) | protein ($10^6$g) | fat ($10^6$g) | CHO ($10^7$g) |
| Beijing | 14.24 | 10.65 | 3.41 | 7.18 |
| Tianjin | 16.60 | 8.53 | 2.47 | 5.21 |
| Hebei | 46.56 | 129.18 | 35.87 | 79.43 |
| Shanxi | 47.64 | 57.92 | 15.95 | 38.74 |
| Inner Mongolia | 343.51 | 314.65 | 127.98 | 178.55 |
| Liaoning | 72.37 | 109.62 | 38.45 | 68.57 |
| Jilin | 129.31 | 119.05 | 44.11 | 66.73 |
| Heilongjiang | 261.99 | 371.82 | 142.62 | 168.05 |
| Shanghai | 5.39 | 4.34 | 0.92 | 3.10 |
| Jiangsu | 37.58 | 115.02 | 26.76 | 72.43 |
| Zhejiang | 13.62 | 25.18 | 4.25 | 20.86 |
| Anhui | 49.80 | 103.39 | 22.81 | 70.40 |
| Fujian | 14.82 | 16.34 | 2.51 | 14.78 |
| Jiangxi | 29.93 | 35.63 | 4.95 | 32.51 |
| Shandong | 44.51 | 165.19 | 45.15 | 103.00 |
| Henan | 42.27 | 156.11 | 33.14 | 97.43 |

| | | | | |
|---|---|---|---|---|
| Hubei | 48.59 | 91.70 | 19.12 | 64.95 |
| Hunan | 27.60 | 52.52 | 9.17 | 43.35 |
| Guangdong | 11.00 | 36.08 | 5.18 | 33.46 |
| Guangxi | 24.38 | 32.95 | 5.86 | 29.22 |
| Hainan | 19.35 | 5.16 | 0.91 | 4.69 |
| Chongqing | 25.64 | 27.09 | 7.65 | 18.77 |
| Sichuan | 28.83 | 85.32 | 26.73 | 53.89 |
| Guizhou | 24.98 | 30.27 | 8.72 | 22.25 |
| Yunnan | 30.47 | 41.26 | 14.07 | 33.67 |
| Tibet | 48.44 | 9.13 | 3.60 | 3.39 |
| Shaanxi | 52.70 | 71.90 | 19.48 | 48.56 |
| Gansu | 47.32 | 38.62 | 11.36 | 27.80 |
| Qinghai | 24.39 | 5.28 | 1.64 | 3.27 |
| Ningxia | 42.79 | 9.95 | 2.96 | 7.30 |
| Xinjiang | 137.61 | 114.48 | 34.13 | 83.89 |