Spatial distribution of wetland vegetation biomass in the Longhu area using GF-2 data

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Abstract. Wetland Plant biomass is a key biophysical parameter required for understanding ecological systems. In this paper, an above-ground biomass map at 1-m resolution for Longhu wetland was created by using GF-2 data and field measurements. *Typha angustifolia, Imperata cylindrical, Arundo donax, Typha angustifolia- Phragmites australis and Phragmites australis* were collected in the spring of 2018. The model of vegetation index and biomass was established and applied to the study of the distribution characteristics of vegetation biomass in the study area. Additionally, using the measured soil organic matter, available potassium data and GF-2 data, the organic matter content and available potassium content were mapped. The results showed that a significant correlation relationship existed between vegetation index and above-ground biomass, and the power function model based on NDVI(y=828770x^5.489, R^2=0.5317) was the most suitable one. The above-ground biomass map showed an overall trend that the biomass increasing was relevant to the distance from water surface. The *Phragmites australis* with the highest biomass was farthest from the water. The distribution of soil organic matter and available potassium was similar to that of plant biomass. The level of available potassium directly affected the level of biomass, and the organic matter content can predict the change of biomass.

1. Introduction

Wetland vegetation biomass assessment is an important basic research to describe the material cycle and energy flow processes of the wetland ecosystem, evaluate the ecological function value and the health status of wetland ecosystem[1]. Biomass is one of the factors that indicate the productivity of ecosystems. It directly reflects the material production of ecosystem producers and has always been valued by ecologists[2-3]. As a key factor in environmental calculations, there are various methods for measuring biomass, and various measurement accuracy. The traditional biomass methods have high precision, but they are extremely destructive to the local ecological environment, and it is difficult to collect data because of some factors such as topography and hydrology[4-5].

Nowadays, domestic and foreign scholars generally use remote sensing tools and assist in the measured data of the sample biomass to estimate the biomass by fitting simulation, and the effect is significant[6-12]. Wetland vegetation biomass research is developing rapidly. In the existing research, most of the large-scale wetlands are used as research objects, and there are few studies on biomass...
measurement in small wetland. Therefore, this research focuses on the small wetland - Longhu Wetland and mainly to study the vegetation distribution of small wetlands, the establishment and estimation of biomass models and the spatial distribution pattern of biomass, and it provides references for the protection and rational utilization of small wetlands.

2. Study area and data sources

2.1. Study Area.
This study was undertaken in the area of Longhu wetland(36°43' 57" N, 116°51' 35"E- 117°01’ 36"E), which is located in Jinan city, Shandong province, north of the Yellow River. The terrain here is gentle, with a slight tilt from west to east, and the average elevation ranges from 23.2 m to 24.8 m. There is a plenty of groundwater, which depth is of 30 ~ 50 m and PH value of about 7.8 ~ 8.0. The area experiences warm temperature zone monsoon climatic conditions, with hot and rainy summers, cold and dry winters. An average annual rainfall of about 666mm and an average annual temperature of about 14.3 °C.

2.2. Data sources

2.2.1. Remote sensing data
The research area and object of this study required high spatial resolution of remote sensing data. Therefore, GF-2 images used in this study were acquired in the spring of 2018, which consisted of multi-spectral data and full color data with spatial resolutions of 4m and 1m, respectively. The cloud amount was 1%.

2.2.2. Biomass data
In order to ensure time synchronization of the remote sensing data, the measured data of biomass were collected on Apr. 30, 2018. According to the investigation, the wetland organisms at this time were mainly Typha angustifolia, Imperata cylindrical, Arundo donax and Phragmites australis. According to different vegetation types and vegetation growth, 19 sampling points(1m×1m) were sampled uniformly and the data were collected for the fitting model study (figure 1) [13]. The latitude, longitude, coverage and vegetation types of each quadrats were recorded.

The above-ground vegetation was harvested to measure the fresh weight immediately, and the dry weight was determined by bagging back to the laboratory.

2.2.3. Soil physical and chemical data
The soil physical and chemical properties determined in this study were mainly soil organic matter, ammonium nitrogen, available phosphorus, and available potassium. The soil organic matter reflects the potential fertility of the soil, which can predict the trend of wetland biomass in this region to some extent by fitting the model. Ammonium nitrogen, available phosphorus and available potassium reflect the degree of mineralization of the soil, and the spatial distribution characteristics of biomass can be explained according to the status of available fertilizers in different regions[14].

In order to determine the physical and chemical properties of soil, 1kg soil from the center of the biomass sample plot in the range from 0 to 20cm was taken, which should be guaranteed not to carry too many animals and plant roots. The soil samples were brought back to the laboratory with black plastic bags, dried, ground and sieved for use.

2.3. Data processing

2.3.1. Remote sensing data processing and interpretation
(1) Image pretreatment. GF-2 images used in this paper required image preprocessing of multi-spectral image and panchromatic image and image fusion. Firstly, radiometric calibration, atmospheric
correction and orthophoto correction were carried out for multispectral images, radiometric calibration and orthorectification were performed for panchromatic images. After that, multi-spectral images were image-fused with panchromatic images, through the experimental comparison of various image fusion methods, the NNDiffuse pan sharpening for image fusion was chose in the end.

(2) Information acquisition. The classification map of wetland vegetation is an essential reference for the study of spatial distribution characteristics of biomass. In this research, the wetland vegetation classification map was obtained by using the object-oriented classification method and combining with the fixed-point measurement data.

(3) Vegetation index calculation. The fitting simulations of biomass, organic matter and available nitrogen, phosphorus and potassium in this study were based on the vegetation index, so the vegetation index needed to be calculated. Considering the purpose of this study and consulting a large number of documents, NDVI(normalized difference vegetation index), RVI(ratio vegetation index), EVI(enhanced vegetation index), SAVI(soil-adjusted vegetation index), DVI(difference vegetation index), RED(red band) and NIR(near-infrared band) were selected for use.

2.3.2. Determination of biomass
Biomass data consist of dry weight and wet weight. Wet weight was obtained immediately when collecting biomass data. The acquisition of dry weight should first retrieve from the field, dry after partial into the oven, under the temperature of 105 °C drying for two hours, take out of the weighing, and then dry at the same temperature, until the quality have no obvious change, record data as dry weight at this time.

2.3.3. Determination of soil physical and chemical properties. Using soil available nitrogen, phosphorus and potassium determination instrument(DP-TPY-6A), the content of organic matter(‰) and available potassium(mg/kg) were obtained, and all test data were analyzed by Excel and SPSS statistical software.

3. Data analysis

3.1. Biomass estimation based on GF-2 data

3.1.1. Vegetation index calculation
Using fusion GF-2 images and the corresponding measured sites, various vegetation indexes and band operation data of 19 sampling points were obtained (table 1).

It can be seen from the table that NDVI values of the study samples are between 0.25 and 0.41, which is lower than the farmland and the protection forest and higher than the bare land and water area in the whole study area. DVI values are between 694 and 1401. RVI values are concentrated on values 1 and 2, which range from 0 to 5 for the entire study area. EVI values range from 0.7 to 2.2, and SAVI values are between 0.38 and 0.60.

3.1.2. Measured biomass calculation
Using the plants collected in the field, dry and fresh biomass data of 19 samples were obtained (table 2) According to table 2, the fresh weight of the samples is between 313.95g and 4769.06g, and its average value is 2549.66g. The dry weight is between 135.62g and 3779.96g, and the average value is 2134.77g. The difference between dry weight and fresh weight ranges from 178.33g to 1039.99g, and the ratio is of 43% to 90%.

3.1.3. Correlation analysis
Image vegetation indexes and spectral bands were combined to analyze dry weight biomass. Pearson correlation analysis was performed on 7 indexes including wetland biomass, NDVI, DVI, RVI, EVI,
SAVI, red reflectivity and near-infrared reflectivity. Two-tailed test and the relative coefficients test were selected for significance test, as shown in table 3.

Table 1. Vegetation index

| Number | Vegetation type         | NDVI  | DVI  | RVI  | Red  | NIR  | EVI  | SAVI  |
|--------|-------------------------|-------|------|------|------|------|------|-------|
| 1      | Typha angustifolia      | 0.2579| 1047 | 1    | 1506 | 2553 | 0.7342| 0.3869|
| 2      | Typha angustifolia      | 0.2699| 738  | 1    | 998  | 1736 | 1.422 | 0.4048|
| 3      | Typha angustifolia      | 0.3055| 828  | 1    | 940  | 1768 | 1.402 | 0.4586|
| 4      | Typha angustifolia      | 0.3423| 1092 | 2    | 1049 | 2141 | 1.4174| 0.5134|
| 5      | Arundo donax           | 0.3108| 1135 | 1    | 1384 | 2519 | 0.7846| 0.4361|
| 6      | Arundo donax           | 0.3373| 846  | 2    | 831  | 1677 | 2.2112| 0.5059|
| 7      | Arundo donax           | 0.3422| 1214 | 2    | 1167 | 2381 | 1.0505| 0.5132|
| 8      | Phragmites australis   | 0.3755| 1178 | 1    | 1339 | 2517 | 0.8885| 0.4582|
| 9      | Phragmites australis   | 0.406 | 694  | 1    | 787  | 1481 | 3.4945| 0.4589|
| 10     | Phragmites australis   | 0.3907| 1318 | 1    | 1334 | 2652 | 0.9389| 0.4959|
| 11     | T angustifolia- P australis | 0.3516| 1077 | 2    | 993  | 2070 | 1.3221| 0.5273|
| 12     | Phragmites australis   | 0.3684| 1401 | 2    | 1201 | 2602 | 1.0665| 0.5525|
| 13     | T angustifolia- P australis | 0.3743| 1297 | 2    | 1084 | 2381 | 1.3229| 0.5614|
| 14     | Phragmites australis   | 0.4009| 1314 | 2    | 982  | 2296 | 1.826 | 0.6012|
| 15     | Imperata cylindrica    | 0.3015| 1175 | 1    | 1361 | 2536 | 0.835 | 0.4522|
| 16     | Imperata cylindrica    | 0.3026| 1183 | 1    | 1363 | 2546 | 0.8114| 0.4539|
| 17     | Imperata cylindrica    | 0.3189| 1148 | 1    | 1226 | 2374 | 1.0138| 0.4783|
| 18     | Imperata cylindrica    | 0.3214| 1224 | 2    | 1292 | 2516 | 1.0195| 0.4821|
| 19     | Arundo donax           | 0.3542| 1312 | 2    | 1196 | 2508 | 1.1559| 0.5312|

The spectrum of vegetation has two obvious absorptive valleys in the vicinity of 0.45μm and 0.65μm, and the reflectivity of 0.7-0.8μm increases sharply. The vegetation index, based on the characteristics of the absorption valley and reflection peak of vegetation spectrum, carries out different algebraic combination of red band and near-infrared band reflectivity to reflect some useful information about the vegetation cover state and vegetation structure, among which the biomass has a good correlation with the three vegetation indexes. Correlation analysis shows that the above-ground biomass of wetland vegetation has the highest correlation with NDVI, the next is SAVI, both of which are significantly correlated at the 0.01 level.

3.1.4. Establishment of biomass fitting model

Through correlation analysis, it was determined to establish fitting models by using NDVI, SAVI and measured biomass, in which the vegetation index in the remote sensing data was taken as the independent variable and the biomass was used as the dependent variable. Linear model, exponential model, quadratic polynomial model, cubic polynomial model and power model were selected to compare.

By comparing different fitting models, the models with better simulation results were determined, which were the power function model \( y = 89377x^{5.4862} \) of SAVI and biomass(figure 1), and the power function model \( y = 938140x^{5.7939} \) of NDVI and biomass(figure 2), their \( R^2 \) were 0.5309 and 0.7672, respectively. In this study, the power function model of NDVI and biomass was the best one.
Table 2. Measured values of biomass

| Number | Vegetation type          | Fresh weight (g) | Dry weight (g) | Difference * | Ratio b |
|--------|--------------------------|------------------|----------------|--------------|---------|
| 1      | *Typha angustifolia*     | 313.95           | 135.62         | 178.33       | 0.43    |
| 2      | *Typha angustifolia*     | 987.38           | 771.11         | 216.27       | 0.78    |
| 3      | *Typha angustifolia*     | 899.53           | 615.33         | 284.2        | 0.68    |
| 4      | *Typha angustifolia*     | 4317.8           | 3779.96        | 537.84       | 0.88    |
| 5      | *Arundo donax*           | 1943.07          | 1659.64        | 283.43       | 0.85    |
| 6      | *Arundo donax*           | 2910.41          | 2173.38        | 737.03       | 0.75    |
| 7      | *Arundo donax*           | 1745.14          | 1523.96        | 221.18       | 0.87    |
| 8      | *Phragmites australis*   | 4711.22          | 3671.23        | 1039.99      | 0.78    |
| 9      | *Phragmites australis*   | 3401.28          | 2933.36        | 467.92       | 0.86    |
| 10     | *Phragmites australis*   | 4767.06          | 3755.11        | 1011.95      | 0.79    |
| 11     | *Ty angustifolia- P australis* | 3337.32   | 2926.17        | 411.15       | 0.88    |
| 12     | *Phragmites australis*   | 4024.11          | 3559.31        | 464.8        | 0.88    |
| 13     | *Ty angustifolia- P australis* | 2707.45   | 2359.88        | 347.57       | 0.87    |
| 14     | *Phragmites australis*   | 2089.54          | 1746.73        | 342.81       | 0.88    |
| 15     | *Imperata cylindrica*    | 1221.35          | 879.15         | 342.2        | 0.72    |
| 16     | *Imperata cylindrica*    | 1200.62          | 937.07         | 263.55       | 0.78    |
| 17     | *Imperata cylindrica*    | 1877.71          | 1692.16        | 185.55       | 0.9     |
| 18     | *Imperata cylindrica*    | 1681.27          | 1488.47        | 192.8        | 0.89    |
| 19     | *Arundo donax*           | 2507.4           | 2262.93        | 244.47       | 0.9     |

*a* Difference means fresh weight minus dry weight.

*b* Ratio means dry weight divided by fresh weight.

Table 3. Correlation analysis

| Factor      | Variable | Correlation coefficient | Significance |
|-------------|----------|-------------------------|-------------|
| Vegetation index | NDVI      | 0.865 b                  | 0.000       |
|             | DVI       | 0.350                   | 0.142       |
|             | RVI       | 0.458 a                  | 0.049       |
|             | EVI       | 0.275                   | 0.254       |
|             | SAVI      | 0.646 b                  | 0.003       |
| Spectral band | Red       | -0.458                  | 0.053       |
|             | NIR       | 0.286                   | 0.829       |

*a* When confidence level (double test) is 0.05, the correlation is significant.

*b* When confidence level (double test) is 0.01, the correlation is significant.

It was found that fitting results of some vegetation models were better and $R^2$ was significantly higher when the biomass and vegetation index fitted according to different vegetation types, which were due to the particularity of wetland vegetation. In the environment where the wetland vegetation was located, the water had a greater influence on the brightness value of the image, and the wetland vegetation type with high biomass had high vegetation coverage, so the pixel values recorded by the satellite sensor were mainly vegetation reflection. On the contrary, the vegetation of surface biomass...
was greatly affected by background information such as soil and water, so that the pixels were not pure.

3.1.5. Remote sensing inversion of biomass
A mathematical model was established between the brightness information of the pixels received by satellite sensors and the measured biomass. Based on this model, the vegetation biomass of wetland was estimated and the biomass inversion map was obtained (figure 3).

3.2. Wetland vegetation classification
Using the object-oriented classification method and the actual vegetation type of the measured samples, vegetation classification map of the study area (figure 4) was created.

It can be seen from figure 5 that the wetland vegetation presented an obvious zonal distribution along the water to the periphery. With the increase of distance from the water, vegetation types were also different, and there were differences in the number of layers and vegetation types between north and south, east and west.

(1) North Shore (except for the concave bank): There were four layers, from the first to the fourth, respectively Typha angustifolia, T angustifolia- P australis symbiosis, Phragmites australis and Imperata cylindrica. Among them, three vegetation types of Typha angustifolia, T angustifolia- P australis symbiosis and Phragmites australis had the same bandwidth and were parallel to the shore, while the distribution of Imperata cylindrica was wider, the farthest distance of the distribution was not related to the shore, but affected by the protection forest and the hard surface.

(2) Concave bank on the north shore: On the west side, there were three layers which in order were Typha angustifolia, T angustifolia- P australis symbiosis, and Phragmites australis. Bandwidth of Typha angustifolia was the widest in the entire study area, the coverage and plant height of Typha angustifolia and Phragmites australis were high. The east side had two layers, of which the first layer was T angustifolia- P australis symbiosis, and the second layer was Arundo donax, which both had wide bandwidth and slightly lower than the west side in coverage and plant height.
Figure 4. Vegetation classification map

(3) East side of the south shore: Four layers of this area, which always appeared in the same order, were *Typha angustifolia*, *T. angustifolia- P. australis* symbiosis, *Phragmites australis* and *Imperata cylindrica*. *Imperata cylindrica* was distributed in the outlying area, and the symbiosis of *T. angustifolia - P. australis* was most obvious. Bandwidth distribution was uneven, generally showing a trend of gradual widening from east to west, and with the increase of vegetation bandwidth, *Typha angustifolia*, *T. angustifolia- P. australis* symbiosis and *Phragmites australis* bandwidth increased accordingly.

(4) West side of the south shore: The first layer was *Typha angustifolia*, the second was *T. angustifolia- P. australis* symbiosis, the third was *Phragmites australis*, and the fourth was *Imperata cylindrica*. Different from the east side of the south shore, the second layer of the *T. angustifolia- P. australis* symbiosis type on the west side was not continuous, which had many discontinuities and no symbiosis. The bandwidth of the *Phragmites australis* was wider, and plaque size of the *Imperata cylindrica* was significantly higher than the east side.

3.3. Organic matter inversion

Using NDVI of the study area and the measured soil organic matter content, a fitted model (figure 5) was built, \( y = 276.43x^{3.5823} \), \( R^2 = 0.7277 \), and an inversion map of organic matter (figure 7) can be made.

![Figure 5. Fitting model of NDVI and organic matter content](image)

3.4. Available potassium inversion

Using the NDVI of the study area and the measured soil available potassium content to calculate the fitting model (figure 6), \( y = 4516.6x^{3.2428} \), \( R^2 = 0.6633 \). The map of the available potassium (figure 8) was obtained.

![Figure 6. Fitting model of NDVI and available potassium](image)
4. Discussion

4.1. Spatial distribution characteristics of biomass

From the biomass inversion map (figure 3), the high, medium and low biomass of wetland vegetation was distributed in a strip shape, and the biomass increasing was relevant to the distance from water surface.

(1) East side of the north shore (except for the concave bank): Biomass of this study area was divided into four layers along the water, the first layer was of low biomass type, and the second was mainly of medium and low biomass type, which also contained some medium biomass types, the third was dominated by medium biomass and the fourth was high biomass type.

(2) West side of the north shore (except for the concave bank): Biomass was divided into three layers along the water, which were low biomass type, medium and low biomass type and medium biomass type.

(3) Concave bank on the north shore: The first layer was medium and low biomass type and the second was medium biomass type, which had a large area of high biomass on the northwest side.

(4) East side of the south shore: Low biomass type dominated the whole area, the middle and low biomass type appears only in the wide vegetation bandwidth of wetland, while there was high biomass type in the widest area of wetland vegetation.

(5) Central and west side of the south shore: There were three layers which in order are low biomass type, medium and low biomass type and low biomass type. In addition to the low biomass type in the near water area, there were also a large number of distributions in the far water area, and the middle biomass type appeared in some areas in patch form.
4.2. Correlation analysis of biomass and vegetation types

According to the biomass inversion map (figure 3) and vegetation classification map (figure 4), the low biomass part had a high coincidence with the distribution of *Typha angustifolia*. Both of them showed zonal distribution in the near water area with narrow bandwidth. Meanwhile, the *Phragmites australis* area on the east side of the south shore had a good coincidence with low biomass. In conclusion, both *Typha angustifolia* and *Phragmites australis* on the east side of the south shore belonged to low biomass type, of which *Typha angustifolia* was the most typical.

The middle and low biomass of the north shore was concentrated in the concave bank on the north side of the water, and there were differences between east and west. The middle and low biomass on the east side was mainly related to *Imperata cylindrica* and *Arundo donax* which has a small range of distribution. While the west side had a wide range of distribution, most of which were *Phragmites australis* vegetation types. The middle and low biomass types on the south shore were the most widely distributed, mainly including three types of vegetation: *Phragmites australis*, *T angustifolia* - *P australis* symbiosis and *Imperata cylindrica*.

Among the biomass types, the most widely distributed was the eastern side of the north shore, which had a high degree of coincidence with the *Phragmites australis* vegetation type, and the west side of the north shore mainly coincided with some *Phragmites australis* vegetation types. The distribution of the south shore was not extensive and no obvious laws had been found. The *Imperata cylindrica* and *Phragmites australis* on the south bank were the middle of the biomass.

There were three main types of high biomass. First, the northwest side of the concave bank on the north side of the water was phragmites australis, which height and coverage were higher than other *Phragmites australis* samples. Second, high biomass type on the east side of the north shore had a high degree of coincidence with the protection forest. Third, the east side of the south shore were mainly *Typha angustifolia* and *T angustifolia* - *P australis* symbiosis, which vegetation zone in the region was the widest.

4.3. Correlation analysis between biomass and organic matter

The organic matter content of the soil reflects potential fertility of the area. If soil organic matter content is high, the potential fertility of the area is high, too. After a period of time, the growth of the plant will be better and the biomass will increase to some extent, but if it is low, biomass, plant height and coverage will be reduced after a period of time.

According to the analysis of biomass inversion map (figure 3) and soil organic matter inversion map (figure 7), the coincidence degree between high biomass area and high organic matter content area, and the area with medium, low and low biomass type also had a high degree of coincidence with the corresponding area with medium, low and low organic matter content.

However, the difference was that the area with high organic matter content was larger than that with high biomass, and the part beyond was medium biomass. The area with medium organic matter content was larger than that with medium biomass, and the part beyond was medium and low biomass, and the area with low organic matter content was also the same. Only low organic matter content area was smaller than the low biomass area.

4.4. Correlation analysis of biomass and available potassium

The content of soil available potassium reflects the degree of mineralization and directly affects the biological status of plants in this area. If the content of soil available potassium is high, the biomass of this area is high, whereas if it is low, the biomass is low.

It can be seen from the available potassium inversion map (figure 8) that the soil available potassium content on the north shore was higher than that in the south, and the east side was higher than the west. On the north shore from the near water to the far water, the soil available potassium content changed from low to high.

The correlation analysis of soil available potassium inversion map (figure 8) and biomass inversion map (figure 3) showed that the low available potassium content area had a high degree of coincidence
with the low biomass, and the high available potassium content area had a high degree of coincidence with the high biomass.

4.5. Influencing factors and prediction of typical vegetation biomass

Taking *Phragmites australis* as an example, there were different biomass in different areas. *Phragmites australis* on the east side of the south shore was of low biomass type, the west side of the south bank was of medium and low biomass type, the east side of the north shore was of medium biomass type, and the concave bank on the north side of the water area was of high biomass type. The corresponding organic matter content was low, medium, high and extremely high, and their corresponding available potassium content was low, medium, high, extremely high.

The content of available potassium and organic matter in soil directly affect the biomass of vegetation. Based on this, we can predict that the biomass of the concave bank on the east side of the south bank and the north side of the water area will maintain its original biomass type, namely the low biomass type and the high biomass type, while the biomass of the west side of the south bank and the east side of the north bank will increase.

5. Conclusion

In this paper, the inversion results of biomass, organic matter and available potassium, and the classification of wetland vegetation were obtained effectively by using GF-2 data and measured data.

(1) According to the measured biomass data, the dry weight of *Typha angustifolia* was generally less than 1000g, *Imperata cylindrica* was between 800g and 1800g, *Arundo donax* was between 1500g and 2500g, *T angustifolia- P australis* symbiosis was between 2000g and 3000g, and *Phragmites australis* was between 2800g and 4000g.

(2) Using different vegetation indexes and biomass to establish a fitted model for comparison, and finally chose the power function model of NDVI and biomass as the best one, \( y = 828770x^{5.489} \), \( R^2 = 0.5317 \).

(3) According to the vegetation classification map(figure 4), except for the concave bank on the north side of the water, the vegetation types were *Typha angustifolia*, *Phragmites australis*, and *I cylindrica- A donax* symbiosis. Among them, there were obvious *T angustifolia- P australis* symbiosis in the wider vegetation area between *Typha angustifolia* and *Phragmites australis*.

(4) According to the correlation analysis between organic matter inversion map(figure 7) and biomass inversion map(figure 3), it was known that the biomass of vegetation in high, medium and low was predicted to increase due to their high potential fertility in the growing environment, and the biomass of *Typha angustifolia* in low will increase to medium and low biomass type, while the biomass of aquatic will decrease.

(5) The correlation analysis between soil available potassium inversion map(figure 8) and biomass inversion map(figure 3) showed that the vegetation biomass was low when the soil available potassium content was low. On the contrary, the soil available potassium content was high, which corresponded to the high biomass type.

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