Study on spatiotemporal difference and influencing factors of grassland yield in sunan county of Gansu province

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Abstract: Grassland ecosystem is the most important terrestrial ecosystem. Only by accurately estimating grassland yield and productivity can we effectively protect the ecosystem. This thesis is based on 323 monitoring data and MODIS-NDVI and MODIS-EVI vegetation index corresponding to the same period from 2012 to 2016, Based on the establishment of grassland yield estimation model, the grassland yield of Sunan County was estimated. The results show that: (1) After validating the model equations corresponding to the five production areas through the reserved precision verifying points, the model accuracy is higher than 90%, and it is feasible to estimate production by remote sensing. (2) From 2012 to 2016, the average yield of grass in Sunan County was 89.92 million tons, and the average yield per unit area was 524.12 kg/m². (3) Grass yield in Sunan County decreased from southeast to northwest during 2012-2016, and the overall grass yield showed a slow downward trend. (4) The annual grass yield in the study area is directly proportional to the annual precipitation and average annual temperature, and the annual precipitation has a greater impact on the annual grass yield.

1. Introduction
Grassland aboveground biomass is an important material basis for maintaining grassland ecosystem. With the progress of science and technology, more and more attention has been paid to the natural and social economic value of grassland[1]. However, due to overgrazing, mineral exploitation, environmental pollution, deforestation and many other factors, the sustainable development of grassland ecology has been affected. Grassland ecosystem is the largest terrestrial ecosystem in China. How to develop grassland ecological function and modern animal husbandry is very important. Only by accurately estimating grassland yield and productivity can we coordinate the relationship between them and better manage grassland resources[2]. Therefore, grassland yield has gradually become the focus of scholars' research.

After decades of development, grassland remote sensing technology combines the advantages of remote sensing technology with geographic information system and global positioning system to simulate the growth and yield estimation models under different growth conditions[3]. However, in the current estimation of grassland yield, the direct sample acquisition method is suitable for small-scale
single grassland monitoring. When estimating large-scale and cross-regional grassland yield, the number and uniformity of sample monitoring point data have a great impact on the accuracy of large-scale estimation. A statistical model method needs abundant, continuous and detailed data to support, but some research areas are inconvenient in traffic, which has become a restrictive factor for large-scale cross-regional research\cite{4}. In summary, most of the studies on the ground monitoring data are few, and the accuracy and reliability of the model are difficult to guarantee. Moreover, the grass yield in a growing season of grassland is greatly affected by the climate at that time. In addition, the monitoring points are not fixed and the sample plots are not representative, which will also cause errors. Therefore, only when the observation time is basically synchronized with the field measurement time and the observation time is long enough can the consistency between the estimation results and the spatial distribution trend of grassland yield in the study area be guaranteed. In the study area of this paper, Sunan County officially sets up 40 fixed-point monitoring areas in 2012, and 120 sample plots for accurate measurement, and combines with MODIS-NDVI and MODIS-EVI vegetation\cite{5} to establish yield estimation model, which has the characteristics of strong timeliness, high accuracy, and easy space-time comparison.

Therefore, based on 323 monitoring data and grassland survey monitoring data from July to August, 2012 to 2016, in Sunan grassland, combined with MODIS-NDVI and MODIS-EVI vegetation index corresponding to the same period\cite{6,7}, this paper establishes the relationship model between ground sample monitoring points and satellite remote sensing data, and establishes the estimation model of grassland yield of NDVI and EVI. Meanwhile, the spatial and temporal distribution pattern of grassland yield in the study area was studied by using yield estimation model, which provided the scientific basis for rational utilization and sustainable development of grassland, as well as the theoretical basis for ecosystem protection and grassland remote sensing monitoring in Qilian Mountains.

2. Materials and Methods

2.1. Survey of the Research Area

Sunan County is located in E97 21 102 02 and N37 35 39 20'. The length from northwest to southeast is about 650 km, and the width from northeast to southwest is about 120-200 km. The terrain is high in the South and low in the north, high in the West and low in the east. The altitude ranges from 1327m to 5564m, with a relative height difference of 4237m. The total land area of the county is 23800km$^2$, which is mainly located in the middle and eastern part of Qilian Mountain, the north slope of Hexi Corridor, and extends from southeast to northwest.

2.2. Ground Sample Data

The acquisition of ground survey data is very important in this study. The quality of ground data determines the accuracy of the production estimation model in the study area. However, the acquisition of ground data is very difficult. In order to achieve the consistency of time-effectiveness between ground data and spatial data objectively, the acquisition of ground data must be completed from late July to mid-August. In order to obtain near-real biomass, the unused areas should be selected as yield measurement samples as far as possible\cite{8}.

Nine grassland types in the study area are all distributed, and the distribution should be as uniform as possible. At the same time, 323 sample data combined with the normal monitoring points from 2012 to 2016 with high quality and credibility are finally obtained through data screening and sorting out, which provides sufficient basic preparation for the establishment of grass yield estimation model in the future. In the process of collecting and sorting out ground data, we should first select representative plots of nine grassland types in the study area, and select a certain number of plots for each plot. The spacing of each plot should be more than 250 m, and the area of grassland is 1 m$^2$, and the area of shrubs is 25 m$^2$. At the same time, the quadrat should be located in the center of the flat and wide terrain, and the distribution should be as uniform as possible. In each sample measurement, the
coordinates of the sample box should be accurately recorded and the image shooting should be done well. Secondly, the height, coverage, frequency, density and quality of vegetation should be measured in the sample box, and the names of the plants appearing should be recorded in the register. The poisonous weeds should be weighed separately when measuring the grass yield in the sample box, and then packed into sample bags and brought back to the room for drying and weighing. Because there are many samples, it is necessary to weigh and record them in time after drying indoors.

The grassland classification in Sunan County is divided into the following nine types according to the grassland classification in China\(^9\): lowland meadow, temperate desert, temperate desert grassland, temperate grassland, mountain meadow, alpine meadow, alpine grassland, Alpine desert grassland and alpine deserts.

![Fig.1 Distribution map of various grasslands in Sunan County](image)

2.3. Remote Sensing Data and Processing

The data to be downloaded is selected according to the row number of the study area. The numbers in the global sinusoidal projection SIN system are h25v04, h25v05 and h26v05, covering the entire study area with a spatiotemporal resolution of 16d and 250m. According to the research needs, MODIS data products from 2012 to July 15, July 30, and August 15 will be acquired, with a total of 45 remote sensing images. The remote sensing data used in this paper is MODIS13Q1, the format is EOS-HDF, and the data has been processed by atmospheric correction, radiation correction and cloud removal. In order to facilitate data processing, the MRT tool is used to process the MODIS data. According to the research needs, the NDVI value and EVI value corresponding to the monitoring points are sequentially extracted.

2.4. Climatic Data

The climatic data are derived from the precipitation and temperature data of 7 stations in 8 townships from 2012 to 2016 provided by Sunan county meteorological station. The annual precipitation and average annual temperature of every township in Sunan county are calculated by using meteorological data. The relationship between climatic factors and the temporal and spatial variation of grass yield in Sunan County was analyzed.

2.5. Modeling and Validation

When modeling by grassland type, the ground sample data is divided into two parts, one for remote sensing modeling and the other for model verification. In order to ensure the reliability of the estimated model, the sample of the grassland is large, especially in the process of modeling\(^10\). In order to verify the accuracy of the yield estimation model, the model accuracy verification was performed by using the reserved random samples. This study will establish a linear regression model and a nonlinear regression model (logarithmic function, exponential function, power function) between NDVI and EVI and grass yield, respectively, and select the optimal model from it\(^11-12\).
Tab1 The temperature of desert grassland of Sunan different vegetation index and grassland herbage yield regression model

| Model                  | Vegetation Index Type | Model Equation | R   | R²   | F      | Sig |
|------------------------|-----------------------|----------------|-----|------|--------|-----|
| Temperate Desert Steppe Area | NDVI                 | y= 577.087x-54.627 | 0.736 | 0.544 | 121.678 | 0.00 |
|                        | EVI                   | y=1016.232x-72.788 | 0.677 | 0.458 | 86.337 | 0.00 |
| Temperate Steppe Area   | NDVI                 | y=11.497e^{0.679x} | 0.775 | 0.600 | 414.426 | 0.00 |
|                        | EVI                   | y=14.127e^{0.482x} | 0.744 | 0.554 | 343.454 | 0.00 |
| Meadow                 | NDVI                 | y=10.911e^{0.045x} | 0.711 | 0.505 | 169.643 | 0.00 |
|                        | EVI                   | y=16.206e^{0.742x} | 0.691 | 0.478 | 152.069 | 0.00 |
| Alpine Steppe Area     | NDVI                 | y=270.325x-22.998  | 0.764 | 0.583 | 62.928  | 0.00 |
|                        | EVI                   | y=501.454x-36.223  | 0.735 | 0.540 | 52.844  | 0.00 |
| Lowland Meadow Steppe Area | NDVI             | y²=096.774x-207.733 | 0.814 | 0.663 | 82.779  | 0.00 |
|                        | EVI                   | y²=714.472x-184.639 | 0.819 | 0.670 | 85.332  | 0.00 |

In the formula, Y represents the grass yield, R is the model correlation coefficient, and R² refers to the proportion of the total squared deviation. It can be explained by the regression line. The size reflects the closeness of the sample data and the estimated model, that is, the R² Close to 1, indicating the better the fit.

It can be seen from Table 1 that the correlation coefficient between NDVI and the grass yield (dry weight) in the monsoon linear region and the alpine grassland region is significant, and the correlation between NDVI and the grass yield (dry weight) at the monitoring site is significant. The sex is higher than the EVI in the similar function type, indicating that the NDVI linear function in the warm desert steppe area and the alpine steppe area is more suitable for the establishment of the estimation model. However, the correlation coefficient between NDVI and the grass yield (dry weight) in the low-lying meadow steppe area is significant, but the correlation between NDVI and the monitoring grass yield (dry weight) is lower than that of EVI in the same function type. It is indicated that the EVI unitary linear function of the lowland meadow steppe area is more suitable for the establishment of the estimation model. The correlation coefficient between NDVI and the grass yield (dry weight) of the monitoring point in the expansive function of the warm steppe area and the meadow steppe area is significant. At the same time, the correlation between NDVI and the grass yield (dry weight) of the monitoring point is higher than that of the same type. EVI in the function type indicates that the NDVI exponential function in the warm steppe area and the meadow steppe area is more suitable for the establishment of the estimation model.

The error analysis of the estimated production model is carried out by comparing the measured value with the predicted value. The accuracy of the analyzed model is above 90%, indicating that the estimated production model is available.

3. Result and Analysis

3.1. Spatial Distribution of Grassland Yield

Five optimal yield estimation models corresponding to five research areas in Sunan County were used to estimate the grass yield from 2011 to 2016 based on the grassland type map of the study area. It can be seen from Table 2 that grassland grass yield in Sunan County decreases from southeast to northwest in general. In the southeast of China, where the grass yield is high, the foothills and valleys with flat terrain and abundant water sources have low grass yield. In the north, the warm desert steppe area of Minghua County is the main area, while in the northwest, the alpine desert steppe area of Qifeng County is the main area.
| County (Town)       | Grassland area (%) | Hay yield (%) | Hay yield per unit area (kg/hm²) | Grassland type                                                                 |
|---------------------|--------------------|---------------|----------------------------------|--------------------------------------------------------------------------------|
| Huangcheng Town     | 12.00              | 22.00         | 949.58                           | Mountain meadow, Alpine meadow, Temperate grassland                           |
| Horseshoe County    | 7.00               | 11.00         | 873.09                           | Alpine meadow, Mountain meadow, Temperate grassland, Temperate desert grassland |
| Kangle county       | 9.00               | 11.00         | 606.34                           | Temperate desert grassland, Mountain meadow, Alpine meadow, Alpine desert      |
| Baiyin County       | 2.00               | 2.00          | 707.28                           | Temperate grassland, Temperate desert grassland, Temperate desert, Mountain    |
| Dahe County         | 17.00              | 18.00         | 564.84                           | Temperate grassland, Temperate desert grassland, Alpine meadow, Alpine desert  |
| Minghua County      | 7.00               | 9.00          | 688.61                           | Temperate desert, Lowland Meadow                                              |
| Qifeng County       | 46.00              | 27.00         | 307.39                           | Temperate desert, Temperate desert steppe, Alpine steppe, Alpine desert steppe |
| Total               | 100.00             | 100.00        | 4697.13                          |                                                                                |

From Table 2, we can see that the grassland area of Huangcheng Town accounts for 12% of the total grassland area of Sunan County, and the grassland yield accounts for 22% of the total grassland output of the county. The hay yield per unit area is the highest. We can see that the grassland quality and productivity level of Huangcheng Town ranks first in the county. The grassland area of Horseshoe County accounts for 7% of the total grassland area of Sunan County, and the grassland yield accounts for 11% of the total grassland output of the county. It can be seen that the grassland quality and productivity level of Horseshoe County ranks second. The grassland area of Baiyin County accounted for 2% of the total grassland area of Sunan County, and the grassland yield accounted for 2% of the total grassland output of Sunan County. The hay yield per unit area reached 707.28 kg/hm. It can be seen that the grassland quality and productivity level of Baiyin County ranked third in the county. The grassland area of Minghua County accounted for 7% of the total grassland area of Sunan County, and the grass yield accounted for 9% of the total grassland output of Sunan County. The hay yield per unit area reached 688.61 kg/hm. It can be seen that the grassland quality and productivity level of Minghua County ranked fourth in the county. The grassland area of Kangle County accounts for 9% of the total grassland area of Sunan County, and the grassland yield accounts for 11% of the total grassland output of Sunan County. The hay yield per unit area reaches 606.34 kg/hm. It can be seen that the grassland quality and productivity level of Kangle County ranks fifth in the county. The grassland area of Dahe County accounts for 17% of the total grassland area of Sunan County, and the grassland yield accounts for 18% of the total grassland output of Sunan County. The hay yield per unit area reaches 564.84 kg/hm. It can be seen that the grassland quality and productivity level of Dahe County ranks sixth in the county. The grassland area of Qifeng County accounts for 46% of the total grassland area of Sunan County, and the grass yield accounts for 27% of the total grassland yield of the county. It can be seen that although the grassland yield of Qifeng County ranks first in the county, the hay yield per unit area of the county is the lowest.
Tab 3 Annual yield per plant of 2012-2016 in different grassland types in the study area

| Grassland type          | Area (km²) | 2012 year | 2013 year | 2014 year | 2015 year | 2016 year | Average kg/hm² | Coefficient of variation |
|-------------------------|------------|-----------|-----------|-----------|-----------|-----------|----------------|--------------------------|
| Lowland Meadow          | 544.68     | 1413.7    | 1519.9    | 1531.9    | 1575.4    | 1710      | 1550.18        | 7%                       |
| Temperate Desert        | 1370.57    | 297.2     | 311.3     | 168.2     | 165.8     | 315.9     | 251.68         | 31%                      |
| Temperate Desert Steppe | 1371.28    | 763.8     | 890       | 644.4     | 584.8     | 946.9     | 765.98         | 20%                      |
| Temperate Steppe        | 4451.29    | 624.1     | 603       | 623.5     | 541       | 665.3     | 611.38         | 7%                       |
| Mountain Meadow         | 745.59     | 912.6     | 897.9     | 917.7     | 861.2     | 913       | 900.48         | 3%                       |
| Alpine Meadow           | 6607.47    | 524.6     | 524.2     | 522.8     | 494.3     | 540       | 521.18         | 3%                       |
| Alpine Steppe           | 723.13     | 497.7     | 432.6     | 518.7     | 543.3     | 553.7     | 509.20         | 9%                       |
| Frigid Alpine           | 1721.85    | 110.6     | 114.3     | 116.4     | 108.8     | 112.9     | 112.60         | 3%                       |

From Table 3, it can be seen from the yield per unit area of different grassland types from 2012 to 2016 that Lowland Meadow is the unique grassland type in Minghua County, and the highest grass yield grassland type in Sunan County, followed by mountain meadow, temperate desert grassland, temperate grassland, alpine meadow, Alpine desert grassland, temperate desert and alpine desert.

The coefficient of variation of mountain meadow, alpine meadow and lowland meadow in the middle and east of Sunan County and Minghua County in the North ranges from 3% to 7%. These grassland types belong to recessive vegetation. The water condition of this type of grassland is better, and the climate has little influence on the grassland vegetation. Especially in the case of abnormal drought, the grassland's ability to maintain grassland yield is better than that of other grassland types. The interannual variations of the grassland type are very small[13]. The coefficient of variation of temperate grassland, temperate desert grassland and temperate desert in Qilian Piedmont region is between 7% and 31%, and the coefficient of variation is higher. Because most of the vegetation in these grasslands are xerophytic, strongly xerophytic shrubs and perennial grasses, the stability of the ecological environment is poor, the anti-interference ability is weak, the grassland is sensitive to changes in external conditions, and the grassland yield is weak[14].

3.2. Dynamic Changes of Grassland Yield

3.2.1. Grass yield and livestock carrying capacity of grassland

![Fig.2 The amount of change in Sunan County Grassland 2012-2016 map](image)

It is reflected in Fig 2 that the grassland in the Sunan County grassland has fluctuated greatly during the five years from 2012 to 2016. The total average grass yield in the five years was 890,200 tons, and
the average yield was 524.12 kg/hm². Among them, the average value in 2012, 2013 and 2016 is higher than the average in 2014 and 2015, indicating that the grass yield in Sunan County is decreasing year by year.

3.2.2. Grass-storage balance area and forbidden pasture area

(1) Grass storage balance zone

The demarcation of the grass storage balance area first considers that the grassland quality in the county is relatively good, and the grassland areas widely used are mostly warm grassland and meadow grassland. The area of grass and livestock balance area delineated by the county is 1,407,700 mu, accounting for 53% of the total grassland area in Sunan County. The grazing area is mainly defined by the low grassland yield, the small utilization value and the fragile ecological environment, most of which are desert grasslands. By paying grassland compensation to herders (12.9 yuan per mu), ecological protection can be achieved without reducing the living standards of herders. At present, the area of forbidden pastoral areas designated by the county is 6.842-million mu, accounting for 26% of the total grassland area.

![Fig.3 Sunan County in 2012-2016 grass storage balance area variation of hay yield (kg/hm²)](image)

The broken line in Fig.3 is the fitting line of the interannual variation of hay yield in the grass storage balance area of Sunan County. It can be seen that the hay yield in this area in the five years is basically consistent with the change trend of the total grass yield in the whole county in Figure 5, and the combination map It can be seen from the carrying capacity of 5 that the carrying capacity has a great influence on the grass yield in the grass storage balance area, and the carrying capacity in the same year is inversely proportional to the hay yield in the grass storage balance area.

(2) Exclosure

![Fig.4 The hay yield changes in grazing area 2012-2016 map of Sunan County (kg/hm²)](image)

Fig.4 Shows that hay yield in forbidden pastoral areas increased from 2011 to 2012, decreased from 2012 to 2014, and increased significantly from 2014 to 2016.

(3) Influence factor

Climatic factors and human factors are the main factors affecting the grassland yield. It can be seen from Fig. 6 that the hay yield of the grass storage balance area in Sunan County decreased by 0.7kg/hm² from 2012 to 2013, but the grassland total grass yield in Sunan County and the grassland hay yield in the grazing area of Sunan County are increasing. The grass yield of pasture grassland is only affected by one factor of climatic conditions, so it can be seen that the reason for the decline in
grass yield in the grass storage balance area of Sunan County in 2012 to 2013 is due to human factors. As can be seen from Figure 5, In 2012 to 2013, the stocking capacity increased by 70,000 units. In 2013 to 2014, the total hay yield of hay in the county decreased by 33,000 tons, and the hay in the grass storage balance area decreased by 6.9 kg per hectare. In the grazing area, the yield per hectare was reduced by 42.1 kg. It can be seen that the grassland in the pastoral area fluctuates greatly and is affected by climatic factors. Due to its superior geographical position, the grass storage balance area has been affected by both human and climatic factors, but the yield per hectare has not changed much. The main reason is that the stocking capacity has decreased during the year.

The total hay production of the county decreased by 66,100 tons in 2014 to 2015, and the output of hay per hectare decreased by 48 kg in the balance area. The yield of dry grass decreased by 25.3 kg/ha in the forbidden area. It can be seen that the unit yield reduction in the balanced area of grass storage is twice as that in the forbidden area, the main reason is that the livestock carrying capacity has increased by 80,000 units. The results showed that the grassland degradation was caused by human factors such as overgrazing although the grassland balance area had better natural environment conditions.

In 2015 to 2016, the total grass yield of hay in the county increased by 135,900 tons, and the hay in the grass storage balance area increased by 105 kg per hectare. The perennial hay in the grazing area increased by 90.3 kg. The hay yields in the grass storage balance area and the grazing area have reached the highest value in the past five years. The main reason is that the climatic conditions in Sunan County in 2016 were better than the previous year, and the stocking capacity decreased.

Therefore, most of the grazing areas are close to the Qilian Mountain in the Hexi Corridor. Due to the small amount of precipitation, most of them are desert grasslands, and the grass storage balance areas are better than the grazing areas. The amount of grass yield in the grass storage area is affected by both natural environmental factors and human factors. Therefore, if the grass yield per grazing area is increased compared with the previous year, the grass growing area with better conditions will produce grass. It is reasonable to increase more yields, and if it is not increased, it will decrease, indicating that there is overgrazing and overgrazing in the grass storage area.

### 3.3. Spatial and Temporal Variation of Grassland Yield

![Graph](image)

**Fig. 5** The relationship between the interannual variation of Sunan County grass yield and annual precipitation and annual mean temperature

It can be seen from figure 5 that there is an obvious positive correlation between grass yield and annual precipitation. There was also a positive correlation between the yield of grass and the annual mean temperature, and the restriction of heat on plant growth still had a definite effect. In 2012-2013, the total grass yield of Sunan County increased from 912,100 t to 922,500 t, the precipitation in 2013 also increased from 200 mm to 220 mm, and the annual mean temperature also increased from 4.79°C to 6.04°C. Under the dual influence of precipitation and temperature, the total yield of grass increased to 922,500 tons.

In 2012-2013, the total grass yield of Sunan County increased from 912,100 t to 922,500 t, the precipitation in 2013 also increased from 200 mm to 220 mm, and the annual mean temperature also
increased from 4.79℃ to 6.04℃. Under the dual influence of precipitation and temperature, The total yield of grass increased to 922500 tons.

In 2014-2015, the grass production in Sunan County decreased by 66100 tons, reaching the lowest value of 81.98 million tons in the past five years in the study area, while the precipitation decreased by 33.6ml, making it the year in which the precipitation in the study area declined the most in the past five years. The average annual temperature increased by 0.1C, and it can be seen that the precipitation has a great influence on the grass yield in the study area.

In 2015-2016, the total grass yield in Sunan County increased from 819800 t up to 955700 tons, the yield of grass increased by 135900 tons, which is the largest increase in grass production in the past five years. The annual precipitation has also risen from 190mm to 238 mm, which is also the year with the most precipitation in the past five years. The annual mean temperature has also risen by 0.5C, reaching the highest average temperature in the past five years. It can be seen that the water and heat matching has an important influence on the space-time variation of grass yield in the study area. In particular, the change of precipitation plays a key role in the change of grass yield[15].

The relationship between grass yield, annual precipitation and annual mean temperature of 2012-2016 years in the study area has been found that the yield of grass in the study area fluctuated greatly with the influence of temperature and precipitation. The daily forage amount of forage was 1.8kg, and the annual grazing amount was 657kg. If the amount of grass production in the study area is reduced by 10,000 tons per year due to the change of precipitation and temperature, and the unutilized rate of 35% is deducted, then the theoretical livestock load should be reduced by 9800 sheep units in that year[16]. From 2015 to 2016, due to abundant precipitation, rising temperature, grass production. It rose by 135900 tons, equivalent to the theoretical capacity of the year. It rose by 135000 units. Therefore, we should take into account the fact that the annual fluctuation of grass yield in Sunan County should be taken into account in the formulation of scientific stocking capacity.

By comparing grass yield with annual precipitation and annual mean temperature (Tab.4), it was found that there was a significant positive correlation between grassland grass yield and annual precipitation ($r^2=0.60$, $p < 0.01$) in Sunan County. The precipitation of different towns in Sunan County is different, and the precipitation decreases from east to west, which is similar to the spatial distribution of grassland grass production.

The annual mean temperature of each township in Sunan County was between 2.28 ℃- 10.51℃, geographical location and altitude had a great influence on the annual mean temperature, and different township annual mean temperature had different correlation with annual grass yield. This mainly depends on the proportion of different grassland types in the township. If the proportion of hidden grassland type is large, it is inversely proportional, and vice versa.

Huangcheng town is located in the eastern part of Qilian Mountains, the terrain is low and flat by the eastern monsoon climate, the precipitation is rich, and the meadow steppe is relatively large, so the hay yield per unit yield is the highest in the whole county. MaTi township precipitation is the highest

| The villages and towns | Huangcheng town | Mati township | Kangle township | Baiyin township | Dahe township | Qifeng township | Minghua township |
|------------------------|-----------------|---------------|-----------------|-----------------|---------------|-----------------|-----------------|
| Hay yield (kg/hm²)     | 948.59          | 873.09        | 606.34          | 707.28          | 564.80        | 307.59          | 688.61          |
| Annual precipitation (mm) | 241.00        | 359.00        | 166.00          | 165.00          | 283.00        | 96.0            | 112.0           |
| Annual average temperature (℃) | 2.02          | 2.71          | 8.19            | 8.30            | 7.02          | 5.96            | 10.89           |

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in the county, hay per unit yield is the second in the county. The position of Kangle Township and Baiyin Township is connected, the annual precipitation and annual mean temperature are similar, but the yield of grass in Baiyin Township is obviously higher than that in Kangle Township, the main reason is that Baiyin Township has banned all grazing, and the vegetation has recovered better. The annual precipitation of Dahe Township was the second, but the yield of grass was low, mainly because the desert steppe accounted for more in the grassland type. The annual mean temperature of Minghua Township is the highest, the precipitation is less, but the yield of hay is higher. The main reason is that it is located in the middle of the Hexi Corridor, the groundwater level is higher, and the meadow area of the lowland is large, most of the grassland is planted as artificial grassland. Qifeng Township has the lowest yield of hay per unit, although the grassland area accounts for the whole county-half, the average altitude is also the highest in the county. Due to the scarcity of precipitation and the lack of high altitude heat, vegetation generation is subject to dual constraints. Thus hay yield per unit of the county is the lowest.

4. Conclusion and Discussion
(1) Based on the grassland type map of the study area, it is estimated that the grass yield decreased from southeast to northwest in Sunan County from 2012 to 2016, and the areas with high grass yield were concentrated in Huancheng town in southeast China. The average yield of hay in this area was 949.58kg/hm. The low yield of grass was mainly distributed in the temperate desert steppe of Minghua Township in the north and the alpine desert steppe in Qifeng Township in the northwest of China. The average yield per hectare of hay in this area was less than that in 150kg/hm.

(2) In the study area, the average total grass yield was 899200 t during the period of 2012-2016, the coefficient of variation was 5.6, the average yield per unit yield was 524.12kg/hm, and the total yield of grass decreased slowly.

(3) According to the average annual grass production in the grasslands of Sunan County from 2012 to 2016, the yield of hay per unit in Huancheng town was the highest, followed by Mabou, Baiyin, Minghua, Kangle, Dahe, Qifen and Qifen. Judging from the structure and productivity of grassland types in Sunan County, lowland meadow is the most productive grassland type, followed by mountain meadow, temperate desert steppe, temperate steppe, alpine meadow, alpine steppe, alpine desert steppe. Temperate desert and alpine desert are the lowest grassland types in Sunan County.

(4) The annual precipitation and annual mean temperature in the grassland of Sunan County from 2012 to 2016 had a significant effect on the grass yield, especially on the grassland in the study area. The change trend of forage yield in forage area and forage storage balance area in recent five years is basically consistent with that in research area.

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