Cloud Grazing Management and Decision System Based on WebGIS

Dong Li[1,2,3], Chuanjian Wang[1,2,3](✉), Tianying Yan[1], Qilei Wang[1], Ju Wang[1], and Wanlong Bing[1]

[1] College of Information Science and Technology, Shihezi University, Shihezi 832000, China
wcj_inf@shzu.edu.cn
[2] Geospatial Information Engineering Research Center, Xinjiang Production and Construction Corps, Shihezi 832000, China
[3] Geospatial Information Engineering Laboratory, Xinjiang Production and Construction Corps, Shihezi 832000, China

Abstract. In order to improve the information level of animal husbandry and solve the problems of unreasonable utilization of grassland resources, this study was based on 3S technology, making full use of the advantages of GIS information processing and Cloud computing resources. A cloud grazing management and decision system based on WebGIS was developed. The system took the mainstream Web browser as the client platform. The functions of displaying the real-time position of the herd, querying historical trajectory, monitoring grassland growth and estimating situation of grassland utilization were achieved by the system. For the server side, the spatial management technology of spatial data engine ArcSDE and SQL Server 2012 was applied to store data. Tomcat 7.0 was used as the Web server and ArcGIS Server 10.3 was used as GIS Server. The automation of data processing was realized by calling ArcPy package through Python script. The results were published automatically to the ArcGIS Server for client display. The system can provide decision-making basis for ranchers and grassland livestock management departments to manage grazing and grassland. It enables ranchers to make reasonable and effective grazing plans, so as to make balanced utilization of grassland resources and promote the sustainable development of grazing animal husbandry.

Keywords: WebGIS · Grazing management · Monitor · Perception · Cognition

1 Introduction

Grassland is not only an important ecological barrier for the earth, but also the material basis for the livestock production in pastoral areas [1]. China's natural grassland is about $4 \times 10^8 hm^2$. It accounts for 41.7% of the country's land area [2], 90% of which has different extent of degradation [3]. However, overgrazing is one of the important causes of grassland degradation [4–7]. Due to the backwardness of infrastructure construction in pastoral areas and the poor communication conditions, it is difficult for ranchers

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and grassland livestock management departments to control effectively herders' grazing behavior and grassland utilization. To a great extent, it has affected the scientific decision-making of grassland construction projects, such as rotational grazing [8, 9], light grazing [10], grassland ecological compensation [11], and fence enclosure [12, 13]. Therefore, it is necessary to develop a cloud grazing management and decision system for rapid and large-scale monitoring of grazing behavior, herd feeding, grassland growth and grassland utilization. The system can provide decision-making basis for ranchers and grassland livestock management departments to manage grazing and grassland. It is of great practical significance to promote the sustainable development of animal husbandry and grassland ecology.

In recent years, domestic and foreign scholars have applied 3S technologies to their studies. In terms of GPS location perception, Pérez et al. and McGranahan et al. used GPS and GPRS technology to monitor the captive animals and provide information such as walking distance and herd behavior in the study area [14, 15]. The daily walking distance of the animal was obtained by the analysis. Liao et al. used the GPS collar to track and monitor the cattle herds in the African grassland. The relationship between the behavior types of cattle and the statistical parameters of the movement was established [16]. They analyzed and predicted the temporal and spatial distribution of the cattle movement behavior and resource selection patterns. Bailey et al. used GPS and accelerometer motion sensing device to monitor the behavioral changes of the cattle and predict the health of the animals [17]. In terms of RS perception, Ali et al. obtained experimental farm grass biomass by using the raw spectral bands of the satellite sensing. ANN(artificial neural network) was found to provide significant improvements in biomass estimation by them [18]. Ancin-Murguzur et al. used remote sensing satellites and a portable spectrometer (ASD FieldSpec 3) to perceive the spectrum of forage crops in high latitudes. The multivariate models were used to predict crop yields in high latitudes [19]. Pérez-Ortiz et al. used super-high spatial resolution UAV images and ground sampling data to perceive ground weed distribution. They used classification techniques to find the optimal machine learning model and developed a weed positioning system [20]. Pavel Propastin used the SPOT-VGT satellite to perceive the spectral information of the study area. The monitoring system was developed to quantify the link between climatic conditions and disaster risk [21]. Punalekar, et al. used optical remote sensing data (proximal hyperspectral and Sentinel 2A) to perceive experimental field spectra. The precision of estimated biomass was increased by the radiative transfer model [22]. In terms of environmental cognition, the relevant scholars mainly use RS and GIS to achieve the environment monitoring [23–27]. However, there are still few mature biomass estimation systems.

The above study work mainly used 3S technology to achieve the trajectory monitoring of the herds and grassland monitoring. These studies have the following limitations:

- Existing grazing management systems have few functions of monitoring feed intake of herds. Therefore, it is unable to meet the higher requirements on pasture monitoring for grassland livestock management departments.
- Although existing grassland monitoring systems have achieved the monitoring function of various grassland resources, there are few systems that achieved the function of grassland utilization estimation.

The purpose of this study is to develop a cloud grazing management and decision system. The specific objectives are to 1) to calculate the situation of feed intake, grassland growth and grassland utilization, and 2) to publish automatically the results to ArcGIS Server.

2 Methods

2.1 System Requirement Analysis

2.1.1 System Functional Requirements

Although the relevant grazing management systems had realized functions such as real-time location monitoring of herds, historical trajectory query and fence alarm, it still couldn't meet the requirements of ranchers and grassland livestock management departments, such as the situation of feed intake, grassland growth and grassland utilization. Therefore, in addition to the basic functions of herd real-time location monitoring and historical trajectory query, the system should also include the functions of feed intake of the herd, grassland biomass and grassland utilization estimation.

2.1.2 System Data Requirements

The trajectory data of the herd was collected by the GPS device. In terms of the number of data, the number of devices would determine the quality of the data. Appropriate increase in the number of devices would result in more trajectory data. It would improve the fault tolerance and representativeness of the data, and it enabled the data to more accurately describe the herd trajectory.

In terms of data quality, high-quality trajectory data was an important data guarantee for monitoring grazing behavior and estimating grassland utilization situation. Akasbi, et al. shows that the shorter the data recording time interval, the closer the recorded trajectory is to the actual grazing trajectory [28]. Therefore, the recording interval of data should be as short as possible.

Remote sensing image data were needed for grassland growth monitoring and grassland utilization estimate. Satellite remote sensing technology can provide large-scale image data with small geographical constraints, but it has low resolution, long acquisition period and poor timeliness. UAV (Unmanned aerial vehicle) remote sensing image has high resolution and high timeliness, but its work is limited by its endurance. It limits the acquisition of image data. Therefore, the system needed to combine two data acquisition methods. According to the requirements of different regions, the appropriate remote sensing image data was selected to accurately monitor the grassland biomass in the corresponding area.

2.1.3 User Requirements

The users had different functional requirements in various application scenarios. In practical applications, after the herdsmen login to the system, the system automatically assigned them to the corresponding ranch. The herdsmen could query the herd information and their working status. They could also view the location of all the current herds in the pasture. For the ranchers and grassland livestock management departments could view the real-time location, the historical trajectory, the feed intake distribution of the herd, and the situation of grassland utilization.

2.2 System Design

2.2.1 System Architecture Design

The architecture of the system was mainly divided into four layers (Fig. 1). They were application layer, presentation layer, business logic layer and data layer.

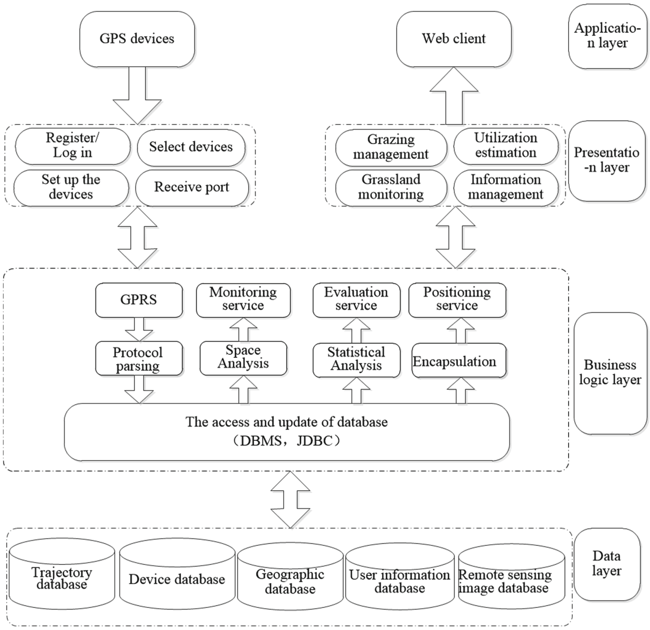

Fig. 1. System architecture diagram

The application layer consisted mainly of GPS devices and Web browsers (client). GPS devices were used to collect the trajectory data of herds. Web browsers were used to provide interface of data visualization to users.

In the presentation layer, we could select or add GPS devices, and set the communication mode, address and port of the GPS devices. According to different types of users, the system provided corresponding functions such as grazing management, grassland monitoring, grassland utilization estimation and information management.

In the business logic layer, GPS devices used GPRS technology to communicate with the GServer of the exlive platform. The GServer parsed the GPS protocol and stored the trajectory data into the database. The data was encapsulated into JSON format data to achieve the location service by calling the interface of GServer. Other functions of the business logic layer used the Python script to read the relevant data from the database and call the API of ArcGIS or ENVI to automatically process the relevant data at a fixed time. The results were published automatically to the ArcGIS Server. The thematic maps need a lot of historical GPS data, traditional servers need too much time to process large-scale data. Therefore, the spatial analysis server of this system was built on the cloud server by Hadoop, which improved the computing power of the traditional server, and the results were provided to users in time.

The data layer included a trajectory database, a device information database, a remote sensing image database, a geographic information database, and a user information database, which were respectively used to store GPS trajectory information, GPS device information, remote sensing images, geographic information, and user information.

2.2.2 Design of Client Function

After related functional requirements and user requirements were analyzed, the client function diagram was designed (Fig. 2).

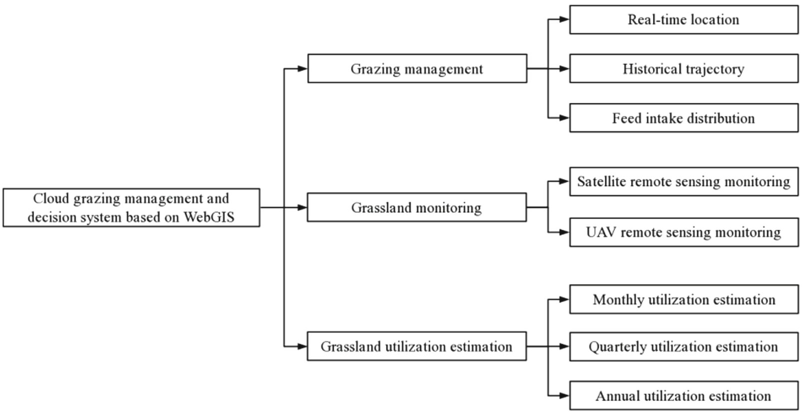

Fig. 2. System client function diagram

2.2.2.1 Grazing Management

Real-time location, historical trajectory, and feed intake distribution functions were included in the grazing management module. The user could set the GPS positioning time interval and the pasture boundary range. The real-time location function could locate the position of herds. The feeding route was displayed by the historical trajectory function according to the retrieval period. The feed intake distribution function could query the distribution of feed intake during the retrieval period, so that the herdsmen and ranchers grasped the feeding situation of the herds in time.

2.2.2.2 Grassland Monitoring

The grassland monitoring function obtained grassland growth situation by satellite remote sensing and UVA remote sensing. It displayed the spatiotemporal distribution map of grassland growth situation on the client side for livestock management.

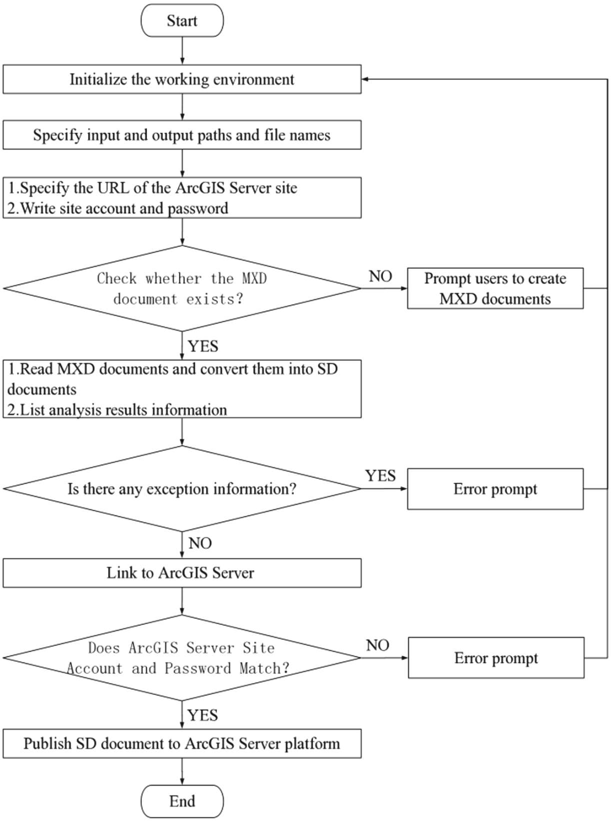

Fig. 3. Automatic publishing flowchart

2.2.2.3 Grassland Utilization estimation

When the client sent a grassland utilization query request to the server, the server found the corresponding estimation result and sent it to the client. The client provided user with a spatiotemporal distribution thematic map and a pie chart of the grassland utilization estimation.

2.2.3 Design of Server Function

The server was in charge of the storage of the trajectory data, the processing of remote sensing images, and the publishing of the results. When the server received the GPS trajectory data, it began data parsing, stored the valid field in the location information database, and used the spatial data engine (SDE) to manage the location information database, which can effectively save time and space.

The server used Python scripts to calculate the feed intake of the herd and grassland biomass, and used two kinds of grassland estimation models to estimate the grassland utilization. The estimation results of feed intake of the herd, grassland biomass and grassland utilization were stored into SQL database by ArcSDE. The processing results would be automatically published to ArcGIS Server in the time (such as 12:00 p.m.) when the system was accessed less frequently. When the server received the client's query request, it called ArcGIS API for JavaScript to respond to the client's request quickly and sent the relevant results to the client.

2.3 Core Function Realization and Testing

2.3.1 Trajectory Data Acquisition

The position information was collected by collars with GPS devices. It was encapsulated according to the data transmission standard and sent to the server through the data communication link. The data information was parsed and stored in the SQL Server database.

2.3.2 Realization of Data Processing Function

2.3.2.1 Feed Intake Distribution Module

The feed intake distribution module called ArcPy package to process the data of the herd trajectory. By creating a grid and using the model of the feed intake distribution of the herds, the feed intake in different regions was calculated. The distribution maps of the feed intake in different regions were obtained.

In terms of the normal grazing, there is no significant difference in the daily feed intake of the herd [28]. The greater the number of GPS points, the greater the feed intake. In this paper, the fishnet tool of ArcGIS was used to grid the study area. According to the proportion of GPS points in each grid to the total GPS points in the study area, the feed intake of the herd in each cell was calculated:

$$\sum I = F \cdot N \cdot \frac{A_i}{\sum A_i} \cdot \frac{1}{S} \tag{1}$$

Where $\sum I$ is the feed intake of the herd for N days (g/m^2), A_i is the number of GPS trajectory points in the i-th cell of the feed N days, $\sum A_i$ is the total GPS trajectory points of the feed N days for herd.

The projection of trajectory data, grid analysis and frequency distribution statistics of trajectory points were the cores of the calculation of feed intake. They were achieved by calling the related functions of ArcPy package, such as Project_management() function, CreateFishnet_management() function, Spatial Join_analysis() function, AddField_management() and CalculateField_management() functions of ArcPy package.

2.3.2.2 Grassland Monitoring Module

- Estimation of Grassland Biomass Based on Satellite Remote Sensing

Zhang et al. used Landsat 8 OLI remote sensing data and ground measured biomass data to build grassland estimation model through statistical analysis [29]. The result showed that the grassland biomass of the sunny slope and shady slope had a good fitting effect with the soil-adjusted vegetation index (SAVI) (sunny slope $R^2 = 0.703$, shady slope $R^2 = 0.712$). The grassland biomass was calculated:

$$f(x) = \begin{cases} 178.71 \cdot x^2 + 97.199 \cdot x + 37.794, & \text{sunny slope} \\ 112.01 \cdot x^2 + 305.36 \cdot x - 59.296, & \text{shady slope} \end{cases} \tag{2}$$

Where x is the value of RVI, and f(x) is grassland biomass.

- Estimation of Grassland Biomass Based on Remote Sensing of UAV

Shize, et al. used the UAV multi-spectral image ground measured biomass data to build grassland estimation model through statistical analysis [30]. The result showed that the grassland biomass of the sunny slope and shady slope had a good fitting effect with the ratio vegetation index (RVI) (sunny slope $R^2 = 0.781$, shady slope $R^2 = 0.813$). The grassland biomass was calculated:

$$f(x) = \begin{cases} 2.659 + 12.583 \cdot x, & \text{sunny slope} \\ 36.951 + 16.589 \cdot \text{x}, & \text{shady slope} \end{cases} \tag{3}$$

Where x is the value of RVI, and f(x) is grassland biomass.

The data of the images was processed and analyzed by calling Radiometric Calibration, FLAASH Atmospheric Correction and BandMath module. The distribution map of grassland biomass was obtained.

2.3.2.3 Grassland Utilization Estimation Module

- Grassland Utilization Estimation Using Trajectory and Remote Sensing

The utilization process of natural grassland is a process of continuous interaction between grazing behavior and grass growth. The grass growth and grazing behavior should be considered when estimating the utilization situation of natural grassland. Grassland biomass wouldn't change significantly in a short period of time. If the estimated period was short, the grassland utilization estimation could be based on the compensatory growth principle of the grassland. If the grassland biomass level was the same as the feed intake level, the grassland utilization was moderate utilization. If the grassland biomass level was less than the feed intake level, the grassland was over utilization. If the grassland biomass level was greater than the feed intake level, the grassland was light utilization (Eq. 4):

$$y = F(A,\ B,\ T) = \begin{cases} B_T > I_T, & \text{light utilization} \\ B_T = I_T, & \text{moderate utilization} \\ B_T < I_T, & \text{over utilization} \end{cases} \tag{4}$$

Where A is the trajectory data, B is the remote sensing image data, T is the grazing cycle, I_T is the feed intake classification level, and B_T is the biomass classification level.

The function was achieved by calling the relevant functions, such as ExtractMultiValuesToPoints() function, AddField_management(), CalculateField_management() functions of ArcPy package and jenks_breaks() method of Jenkspy package.

• Using Fuzzy Mathematics for Grassland Utilization Estimation.

The grassland biomass has changed significantly over a long period of time, so it is necessary to build a membership function for evaluating the quarterly or annual grassland utilization [31]. The membership function was based on the descending half trapezoid, the rising half trapezoid and the intermediate symmetry in fuzzy mathematics. Taking the feed intake as the domain, the membership functions of the fuzzy comment set V = {good, moderate, poor} are given. The poor utilization of grassland is divided into two different membership functions: one is light utilization (Eq. 5) and the other is over utilization (Eq. 6).

$$\mu_{11}(x) = \begin{cases} 1 & (x < b_1) \\ \frac{b_2 - x}{b_2 - b_1} & (b_1 \le x \le b_2) \\ 0 & (x > b_2) \end{cases} \tag{5}$$

$$\mu_{12}(x) = \begin{cases} 0 & (x < b_4) \\ \frac{-b_4 + x}{b_5 - b_4} & (b_4 \le x \le b_5) \\ 1 & (x > b_5) \end{cases} \tag{6}$$

The intermediate symmetrical distribution function is used to estimate moderate utilization and good utilization of grassland (Eq. 7, Eq. 8, and Eq. 9).

$$\mu_{21}(x) = \begin{cases} \frac{x - b_1}{b_2 - b_1} & (b_1 \le x \le b_2) \\ \frac{b_3 - x}{b_3 - b_2} & (b_2 < x \le b_3) \\ 0 & (x < b_1 \text{ or } x > b_3) \end{cases} \tag{7}$$

$$\mu_{22}(x) = \begin{cases} \frac{x - b_3}{b_4 - b_3} & (b_3 \le x \le b_4) \\ \frac{b_5 - x}{b_5 - b_4} & (b_4 < x \le b_5) \\ 0 & (x < b_3 \text{ or } x > b_5) \end{cases} \tag{8}$$

$$\mu_{3}(x) = \begin{cases} \frac{x - b_2}{b_3 - b_2} & (b_2 \le x \le b_3) \\ \frac{b_4 - x}{b_4 - b_3} & (b_3 < x \le b_4) \\ 0 & (x < b_2 \text{ or } x > b_4) \end{cases} \tag{9}$$

Where b_i is the boundary of different feed intake, i = 1, 2,…, 5; x is the feed intake, g/m^2.

2.3.3 The Achievement of Automatic Publishing Result Function

The results were automatically published to ArcGIS Server platform by Python script. The map documents in folders were automatically published to ArcGIS Server. Automatic publishing process is shown (Fig. 4).

id	VehicleID	UserID	gpstime	recvtime	lng	lat	alt	veo	direct	av	istate
10655	9363485	0	2017-06-13 08:45:04.000	2017-06-13 08:45:06.000	85.777271	44.001484	0	4	72	1	5120
10656	9363485	0	2017-06-13 08:45:09.000	2017-06-13 08:45:11.000	85.777333	44.001462	0	3	123	1	5120
10657	9363485	0	2017-06-13 08:45:14.000	2017-06-13 08:45:16.000	85.777413	44.00144	0	4	120	1	5120
10658	9363485	0	2017-06-13 08:45:19.000	2017-06-13 08:45:21.000	85.777493	44.00144	0	4	109	1	5120
10659	9363485	0	2017-06-13 08:45:24.000	2017-06-13 08:45:26.000	85.777582	44.001453	0	4	94	1	5120
10660	9363485	0	2017-06-13 08:45:29.000	2017-06-13 08:45:31.000	85.777644	44.00148	0	4	78	1	5120
10661	9363485	0	2017-06-13 08:45:34.000	2017-06-13 08:45:36.000	85.777689	44.001516	0	4	42	1	5120
10662	9363485	0	2017-06-13 08:45:39.000	2017-06-13 08:45:41.000	85.777716	44.001569	0	3	32	1	5120
10663	9363485	0	2017-06-13 08:45:44.000	2017-06-13 08:45:47.000	85.777742	44.001604	0	2	18	1	5120
10664	9363485	0	2017-06-13 08:45:49.000	2017-06-13 08:45:51.000	85.77776	44.001604	0	0	18	1	5120
10665	9363485	0	2017-06-13 08:45:54.000	2017-06-13 08:45:57.000	85.77776	44.001604	0	0	18	1	5120
10666	9363485	0	2017-06-13 08:45:59.000	2017-06-13 08:46:02.000	85.77776	44.001604	0	0	18	1	5120
10667	9363485	0	2017-06-13 08:46:04.000	2017-06-13 08:46:06.000	85.77776	44.001604	0	0	18	1	5120
10668	9363485	0	2017-06-13 08:46:09.000	2017-06-13 08:46:12.000	85.77776	44.001604	0	0	18	1	5120
10669	9363485	0	2017-06-13 08:46:14.000	2017-06-13 08:46:16.000	85.77776	44.001604	0	0	18	1	5120
10670	9363485	0	2017-06-13 08:46:19.000	2017-06-13 08:46:21.000	85.77776	44.001604	0	0	18	1	5120
10671	9363485	0	2017-06-13 08:46:24.000	2017-06-13 08:46:26.000	85.77776	44.001604	0	0	18	1	5120
10672	9363485	0	2017-06-13 08:46:29.000	2017-06-13 08:46:31.000	85.77776	44.001604	0	0	18	1	5120
10673	9363485	0	2017-06-13 08:46:34.000	2017-06-13 08:46:36.000	85.77776	44.001604	0	0	18	1	5120

Fig. 4. Data acquisition results

3 Results

In this study, Ziniquan pasture, No. 151st regiment of the 8th division of Xinjiang production and Construction Corps was taken as an example. The experiment was carried out from April to August 2017. This experiment used the GT03C positioning devices produced by Shenzhen Gu Mi Electronics Co., Ltd. to obtain the real-time geographic location of the herd and upload it to the server. The uploaded data included device ID, latitude and longitude, transmission time, etc. (Fig. 3).

The spatial distributed map of the feed intake was obtained when the trajectory points as the input of the feed intake distribution model. The spatial distributed maps of grassland biomass were respectively obtained when satellite remote sensing image and UAV image as the input of the grassland biomass models.

The natural grassland biomass was estimated from April 20, 2016 to May 6, 2016 by satellite remote sensing image (Fig. 5). The area of human activity was in the northwest part of the study. Other areas with high biomass were due to the exuberant growth of grass during this period. At the same time, the weather was so cold that the herd rarely fed in circles. Therefore, the growth speed of grassland was higher than the feeding speed of the herd. The less biomass in the study area was mainly due to the terrain was not suitable for grass to grow.

Grassland utilization in the study area was estimated by fuzzy mathematics evaluation method in 2016. The thematic map of the grassland utilization evaluation was obtained (Fig. 6).

It could be seen from Fig. 6 that the over utilization area was mainly distributed in the southwest of the study area. The main reason for the over utilization was that the terrain of the area was flat, which was conducive to grazing and feeding of herds. And it was the area that herds often pass after they leave the sheepfold.

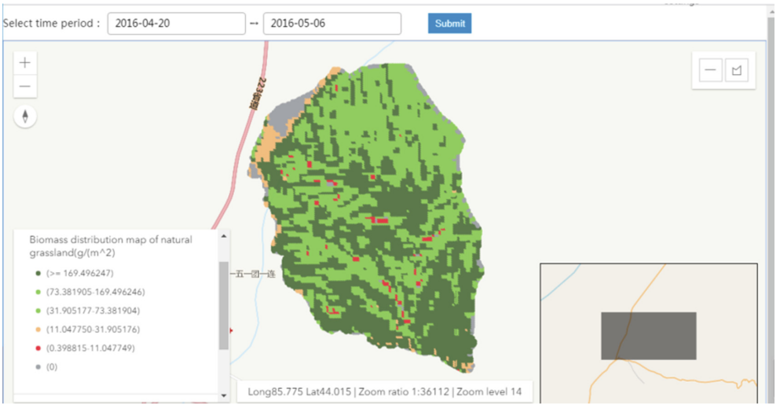

Fig. 5. Distribution of grassland biomass from April 20 to May 6, 2016

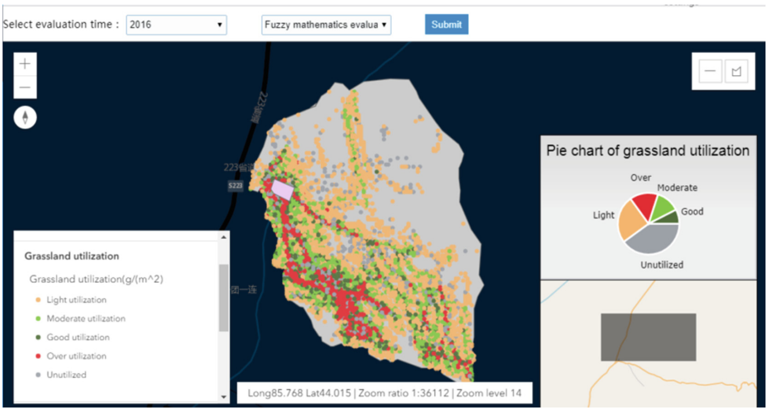

Fig. 6. Distribution of grassland utilization in 2016

4 Conclusions

- The system built the client and server modules. The server was composed of GIS server, Web server, GServer and database. The web browser was used as the client of the system. The GPS terminal uploaded the position information to the GPS server in time. When the client accessed the trajectory information, the web server returned data to the client by requesting GPS server. In addition, the spatial analysis server collected a large amount of GPS data periodically. The data was processed and packed intelligently through the cloud service platform. The result was published automatically to the ArcGIS server by Python. The GPS terminal server and client are combined and coordinated organically in system.
- The system achieved the functions of real-time monitoring of the herd, query of historical trajectory, distribution of feed intake, grassland growth monitoring and grassland utilization estimation. The system can deliver monitoring information and send warning messages to ranchers and animal husbandry management departments

in time, so as to guide relevant people to adjust grazing area. In short, it is meaningful to improve grassland productivity and achieve sustainable utilization of grassland. It also can balance grass and livestock, and promote the sustainable development of animal husbandry.

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Conflicts of Interest. The authors declare no conflict of interest.

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