Evaluation of the Township Proper Carrying Capacity over Qinghai-Tibet plateau by CASA model

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Abstract. The existing study of proper carrying capacity (PCC) has mostly focused on province or county administrative units, which can only macroscopically master the quantitative characteristics of PCC, but could not effectively take some animal husbandry management measures that are pertinent and operational. At town-scale, this paper used CASA model to estimate the PCC in Mongolian Autonomous County of Henan, Qinghai province, China, with serious grassland degeneration that mainly caused by overgrazing. The results showed that the PCC throughout the County was 950,417 sheep unit. For the township, the PCC of Saierlong and Duosong were the largest (247,100 sheep unit) and the smallest (82,016 sheep unit) respectively. This study will provide reference data for developing sustainable development of town-scale pasture policies and also will help to evaluate the health status of the alpine grassland ecosystem on Qinghai-Tibet plateau.

1. Introduction
Grassland degeneration is a serious problem of ecological economy, and overgrazing is the essential cause that leads to degeneration of grassland. Qinghai-Tibet plateau (QTP), with wide grassland areas of the world, is presently faced with a severe challenge on how to manage its vast and degenerating/degenerative grassland. Therefore, it is important to determine proper carrying capacity (PCC) at regional scales.

There are two kinds of existing methods for calculating PCC. The first is ground measurements of PCC [1], which is able to generate accurate point measurements, but is constrained by inefficiency, expense and inaccessibility; the second is estimating the PCC through net primary production (NPP). NPP is accumulation of carbon by plants, and it is defined as the accumulation of dry matters by green plants per unit time and space, and it is also very useful in many of the studies associated with terrestrial ecology such as estimating crop yield and forage yield [2, 3].

Estimation NPP through models is the focus of current NPP study at regional scales [4, 5]. Among the various existing models, the Carnegie-Ames-Stanford Approach (CASA) model is a simple and
mechanistic model and it is easily amenable to satellite-derived variables. The model has been successfully implemented by several workers to estimate regional NPP over the world.

In view of the current PCC research that focused on province or county administrative units, which can only macroscopically master the quantitative characteristics of PCC, so, it is difficult to take practical animal husbandry management measures, for example, for a given pasture, should it be whether rotational grazing or forbidden grazing? In addition, considering the sustainable livestock production is crucial for QTP pastoralists who rely on healthy rangelands for their livelihood benefits [6]. Therefore, this paper aims to use CASA model to estimate and analyze the PCC and serves the management of township animal husbandry over QTP [7].

2. Study area and data

2.1. Study area

Henan Mongolian Autonomous County is located in the eastern part of QTP (Fig.1), with a total population of 40,900, a total area of 6,997.45 km², and an average elevation of 3,600 m. Its climate is the plateau continental climate, with an average annual temperature ranging from 9.2 °C to 14.6 °C, and an annual rainfall ranging from 597.1 mm to 615.5 mm. This County has 913 million acres of available grassland that belongs to typical alpine meadow.

![Figure 1. Location and topography of Henan Mongolian Autonomous County, Qinghai province, China](image)

2.2. Data and processing

2.2.1. NDVI data. The MODIS Normalized Difference Vegetation Index (NDVI) is computed from atmospherically corrected bi-directional surface reflectance that has been masked for water, clouds, heavy aerosols, and cloud shadows. MOD13A1 data provides every 16 days NDVI product at 500-
meter spatial resolution [8]. We obtained the MOD13A1 NDVI data from LP DAAC (Land processes distributed active center).

2.2.2. Meteorological data. Meteorological data, including temperature, precipitation, sunshine percentage, relative humidity were obtained from China Meteorological Data Service Center (CMDC) and applied the spline interpolation method to produce grid cell data. Finally, we took these meteorological grid cell data and MODIS NDVI data as CASA model parameters.

3. Methods

3.1. CASA model

The CASA model, proposed by Potter in 1993, is determined by two variables of absorbed photosynthetically active radiation (APAR) and light utilization efficiency ($\varepsilon$).

$$NPP(x,t) = APAR(x,t) \times \varepsilon(x,t)$$  \hspace{1cm} (1)

Where $NPP$ is the amount of dry organic matter on the grid cell $x$ in time $t$; $APAR$ is the fraction of photosynthetically active radiation intercepted by green vegetation on grid cell $x$ in time $t$; and $\varepsilon$ is the light utilization efficiency on grid cell $x$ in time $t$. The parameter calculation method uses refers to literatures [9, 10].

3.2. Proper carrying capacity

According to the definition of the PCC from Ministry of Agriculture of the PRC [1], we defined the regional PCC, namely, the number of livestock, which can be normally growth in a certain area of grassland and a certain time (one year), under the conditions of moderate grazing and maintenance of sustainable grass, it defined as equation (2):

$$PCC = \frac{AREA \times NPP \times R_{biomass} \times Ru \times I_{intake}}{I_{intake} \times 0.45}$$  \hspace{1cm} (2)

Where $AREA$ is the township area calculated by ARCGIS10 software; $NPP$ is derived from CASA model; $R_{biomass}$ is the ratio of above-ground biomass to total biomass (including above-ground and below-ground biomass). $Ru$ is the rangeled utilization rate; $I_{intake}$ is the annual intake for one sheep unit; 0.45 is a conversion coefficient for converting plant carbon into biomass.

The parameters of $R_{biomass}$ (14.67%) [11], $Ru$ (70%,it ranged from 50% to 70%, taking into account the vulnerability of alpine grassland ecosystems, we took the highest value) [12] and $I_{intake}$(503.7 kg/a.sheep uint) [13] were substituted into equation(2).

4. Results and Discussion

4.1. Characteristics of NPP

We mapped the spatial distribution of NPP that derived from CASA model (Fig.2). Due to high altitude, low temperature, and slow growth grass, the NPP of southeastern Henan Mongolian Autonomous County was low; conversely, the NPP of its north was high.

We compared the results of this paper with other ones in related research on average annual NPP of alpine grassland on QTP. JQ Du [14] obtained the NPP of Huangnan State from 1981-2000 (71.51 gC/m².a), with AVHRR data and GLOPEM model. S Piao [9] used AVHRR data and TEM model and determined the NPP of QTP was 127.5 gC/m².a from 1982 to 1999. The averages annual NPP of this paper was similar to or different from those reported ones, which may be caused by data source, model, and study period and so on. On the other hand, the reliability of this paper was also verified.
Using the modules of zonal statistics analysis in ARCGIS 10 software, we obtained the mean NPP of six townships, that is NPP of Saierlong (308.18 gC/m^2.a), Youganning (298.68 gC/m^2.a), Tuoyema (283.59 gC/m^2.a), Duosong (283.36 gC/m^2.a), Ningmute (274.14 gC/m^2.a) and Kesheng (248.09 gC/m^2.a).

**Figure 2.** The spatial distribution of NPP derived from CASA model

**4.2. Proper carrying capacity**

We calculated the PCC of townships (Table 1). The Ningmute Township, with large area, moderate altitude, and extensive river systems, is suitable for forage growth, and thus its PCC is the largest among six townships. The PCC of Duosong township is the smallest because of complex terrain, hypsographic feature, widely distributed bare land.

| Serial number | Township   | Area(km^2) | PCC(sheep unit) |
|---------------|------------|------------|-----------------|
| 1             | Duosong    | 575.93     | 82,016          |
| 2             | Tuoyema    | 871.08     | 124,147         |
| 3             | Kesheng    | 1,073.72   | 133,895         |
| 4             | Saierlong  | 1,016.19   | 157,360         |
| 5             | Youganning | 1,371.88   | 205,899         |
| 6             | Ningmute   | 1,793.47   | 247,100         |

**5. Conclusion**

Using Meteorological data and MODIS NDVI data, we estimated NPP through CASA model and calculated town-scale PCC of Mongolian Autonomous County of Hainan, Qinghai province, China. This research obtained the following conclusions:
1) The NPP in the north of Mongolian Autonomous County of Henan was high and the southeastern was low, which mainly caused by terrain.

2) The PCC throughout the County was 950,417 sheep unit. For the township, the PCC of Saierlong and Duosong were the largest (247,100 sheep unit) and the smallest (82,016 sheep unit) respectively.

In this study, the estimation accuracy of PCC is determined by NPP derived from CASA model which has many parameters. So, in order to further improve estimation accuracy, we should measure locally some parameters.

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