Remote Sensing Survey of Grassland Resources and Study of Grass - livestock Balance in Hangjin Banner of Inner Mongolia

Terigele, Yanhong XU*, Ying LI, Quan WU

Land Survey and Planning Institute of Inner Mongolia Autonomous Region, Hohhot 010018, China

Abstract The data of this paper mainly include statistics, field survey data and MODIS remote sensing image data. This paper estimates the aboveground biomass of grassland and theoretical livestock carrying capacity of natural grassland in Hangjin Banner and draws a grass - livestock balance table in accordance with the actual and theoretical livestock carrying capacity of natural grassland. Studies have shown that the grass and livestock balance is good in Hangjin Banner, and the overloading rate is 1.5%; there was no overloading in 2010 and 2011.

Key words Remote sensing monitoring, Grass - livestock balance, Hangjin Banner

1 Introduction

As population grows and agricultural production technology improves, there are more and more livestock grazing in the grassland, and grassland is facing increasing grazing pressure[1]. In many areas, the number of livestock has far exceeded the number that grassland can carry, and there is even severe overgrazing case[2]. Especially due to seasonal overgrazing and irrational use of grassland, there are not only the phenomena of productivity decline and vegetation degradation in the grassland ecosystem, but also the phenomena of vegetation disappearance, soil desertification and frequent sandstorms[3-4]. The grass - livestock balance management is the key measure to rationally use grassland resources and achieve grassland ecosystem health and sustainable development of livestock[5]. The grass - livestock balance means the dynamic balance between amount of forage needed to fed livestock and total amount of available forage obtained by grassland users or contractors through grassland and other means within a certain time, in order to maintain virtuous cycle of grassland ecosystem[6-7]. In this paper, based on the actual data, we analyze and evaluate the balance between pastures and livestock in Hangjin Banner, Erdos City, Inner Mongolia, aimed at ensuring grass - livestock balance, improving the economic conditions of farmers and herdsmen and improving the ecological environment of pastoral grassland. On the basis of grass - livestock balance, this paper proposes the strategic thinking of sustainable development of animal husbandry in Hangjin Banner, to provide a reference for the sustainable development of animal husbandry.

2 Overview of study area and data sources

2.1 Overview of study area Hangjin Banner is a banner in the southwest of Inner Mongolia, People's Republic of China, bordering Dalad Banner to the east, Otog Banner to the southwest, and Bayan Nur to the north. It is under the administration of Ordos City. It extends across the Ordos Plateau and the Hetao Plain, and the Yellow River flows 242 km through the entire banner from west to east. Hobq Desert spans the banner from east to west, and divides the entire region into the northern area along the river and the southern area behind mountain[7]. The banner has seven townships, with a total area of 18900 square kilometers. It features a continental climate with long and cold winters but short and mild summers. The frost-free period is short and the sunlight is adequate; there is little precipitation and great evaporation. There are clear regional differences in sunlight, temperature and water[7].

2.2 Data sources The statistical data are from *Hangjin Banner Statistical Yearbook* (2007 - 2011)[8]; the field survey data are from the grassland productivity data of Agriculture and Animal Husbandry Bureau of Hangjin Banner; MODIS data are the MODIS13Q1 data (2007 - 2011) released by NASA.

3 Research methods

3.1 Remote sensing monitoring method for aboveground biomass and livestock carrying capacity of grassland

3.1.1 Remote sensing monitoring of aboveground biomass. The field survey data of grassland sample are the data of Hangjin Banner pasture in growing season. The data are the 28 sampling points selected from different types of grassland evenly distributed in Hangjin Banner during 2007 - 2011. The grassland sample data include grassland height, grassland coverage, average yield of grassland, different communities and types of grassland, utilization area of grassland, and edible forage biomass. We establish the remote sensing monitoring model for aboveground biomass of grassland vegetation, and perform the comprehensive evaluation of accuracy of remote sensing monitoring model. Remote sensing monitoring model is to use hay yields of grassland plots, the corresponding normalized vegetation index and enhanced vegetation index, and statistical software Excel to establish model, and then carry out the comparative analysis to select the final model. Using

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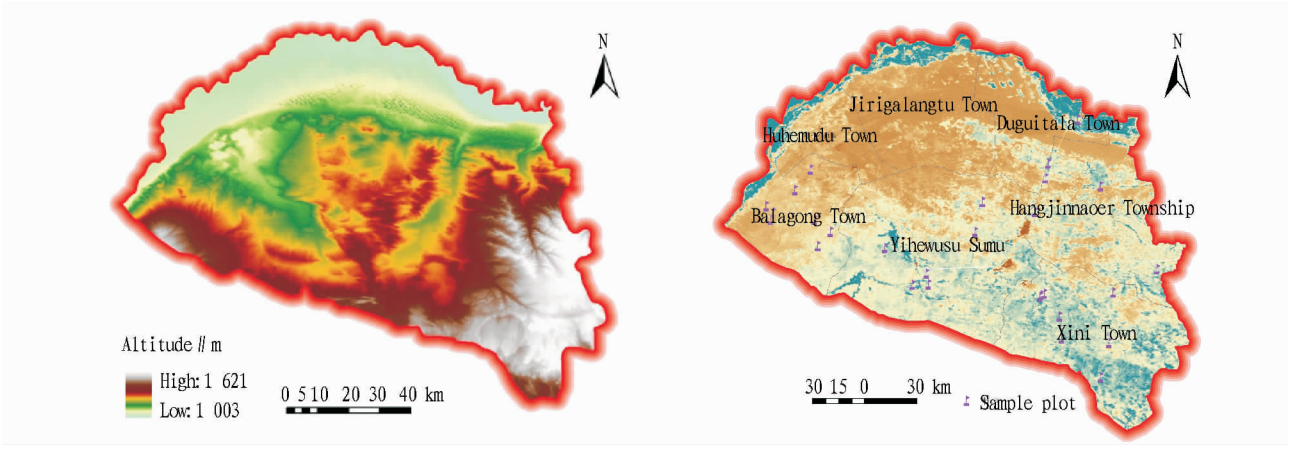
* Corresponding author. E-mail: 478327029@qq.com

the error statistical formula (1), we perform the accuracy evaluation of the model established.

$$P = 100 \times |L_{\text{measured value}} - L_{\text{inversion value}}| \div L_{\text{measured value}} \quad (1)$$

where P *is the average yield estimation error* (%); $L_{measured\ value}$ *and* $L_{inversion\ value}$ *represent the measured edible hay yields and the inversion value according to remote sensing monitoring model.*



(a) digital elevation model (b) natural grassland plots

Fig. 1 Grassland in Hangjin Banner

Table 1 *shows the remote sensing model established and the polynomial can better simulate the relations among normalized vegetation index, enhanced vegetation index and edible hay (Fig.* 2*). Studies have shown that the best model is as follows:*

$$y = 0.000\,4x^2 - 1.855\,5x + 2231 \quad (P < 0.001) \quad (2)$$

where y *is grassland aboveground biomass* (*kg/ha*); x *is the enhanced vegetation index of MODIS remote sensing image.*

Table 1 Grassland vegetation index and regression model of aboveground biomass in Hangjin Banner ($P < 0.001$)

Regression model	Vegetation index VI	Simulation equation	R^2
Linear model: $y = ax + b$	EVI NDVI	$y = 0.0605x + 119.16$ $y = 0.071x + 149.88$	0.103 0.059
Exponential model: $y = ae^{bx}$	EVI NDVI	$y = 87.314e^{0.0003x}$ $y = 188.59e^{0.0001x}$	0.066 0.029
Logarithm model: $y = a + b\ln x$	EVI NDVI	$y = 193.67\ln(x) - 1307.6$ $y = 134.76\ln(x) - 719$	0.087 0.042
Power model: $y = ax^b$	EVI NDVI	$y = 15.94x^{0.3452}$ $y = 38.905x^{0.2511}$	0.056 0.016
Polynomial model: $y = a + bx + cx^2$	EVI NDVI	$y = 0.0004x^2 - 1.8555x + 2231$ $y = 0.0001x^2 - 0.5804x + 864.91$	0.312 0.148

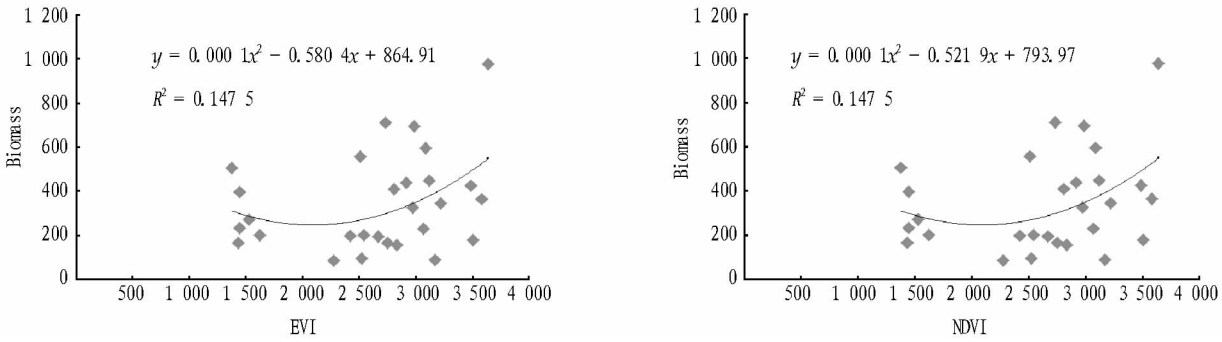


Fig. 2 Comparison between EVI, NDVI regression model and grassland aboveground biomass in Hangjin Banner

3.1.2 Estimation model for suitable livestock carrying capacity of grassland. The theoretical livestock carrying capacity is closely related to some indicators such as grassland area, pasture yields, available area coefficient of grassland, edible forage coefficient and grazing utilization rate. The calculation model is as follows:

$$C = \frac{\sum_{i-1}^{n}(A_i Y_i k_{i1} k_{i2} k_{i3})}{ID} \quad (3)$$

where C is the total livestock carrying capacity of various types of grassland in the region; i represents different types of grassland (i −1, 2, 3……, n); A is the annual forage yield of grassland i

(kg/ha); k_{i1}, k_{i2} and k_{i3} represent the usable area coefficient, edible forage coefficient and grazing utilization rate of grassland i; I is the standard daily intake of an adult sheep (kg) (5kg of fresh grass in this study); D is the days of grazing in grassland (day) (270 days in this research).

3.2 Grass – livestock balance analysis The natural grassland is the main food source for livestock in Hangjin Banner, and the livestock carrying capacity of natural grassland is a factor determining the animal husbandry production scale[9]. We use model (3) to calculate the appropriate livestock carrying capacity of grassland, and then use grass – livestock balance for analysis.

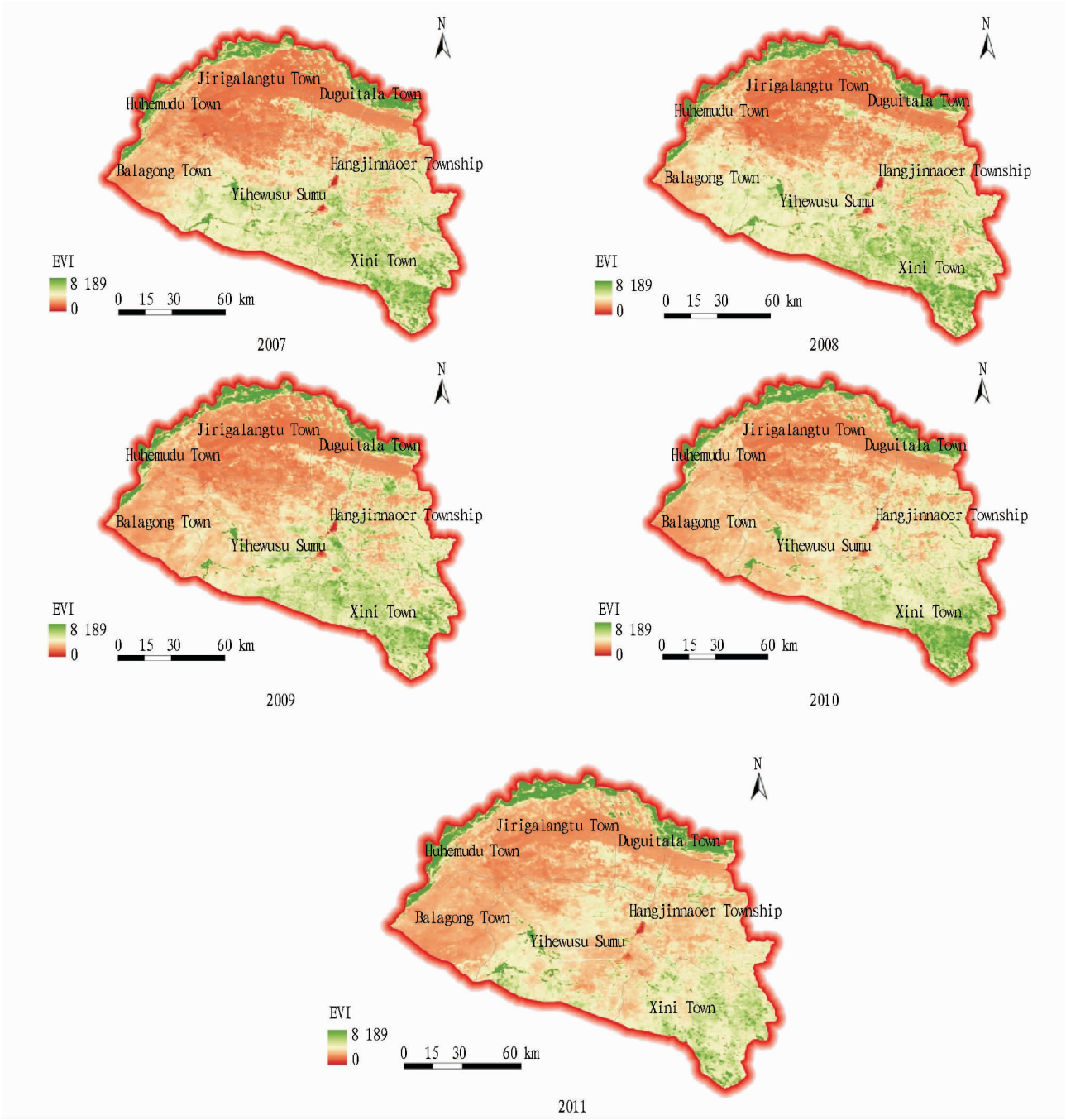


Fig. 3 Grassland EVI map of Hangjin Banner

4 Results and analysis

4.1 Estimation results of grassland aboveground biomass in Hangjin Banner According to changes in enhanced vegetation index of MODIS remote sensing image, the enhanced vegetation index is highest in the southern part, and the enhanced vegetation index in the central part is greater than in the western part. The enhanced vegetation index was highest in 2007 and lowest in 2011, because the less rainfall and droughts caused a decrease in

the total grass yield. From the townships in Hangjin Banner, the enhanced vegetation index was highest in Yihewusu and lowest in Huhemudu. From the data analysis, it is found that EVI value is corresponding to the grassland aboveground biomass.

Table 2 The calculation results of enhanced vegetation index in Hangjin Banner (10^7)

Area	2007	2008	2009	2010	2011	Average
Xini Town	16.66	14.61	14.79	15.63	9.55	14.25
Jirigalangtu Town	7.78	7.74	7.52	7.49	7.76	7.66
Huhemudu Town	4.08	4.07	3.96	3.89	3.93	3.99
Balagong Town	7.27	5.05	5.13	5.91	4.21	5.51
Duguitala Town	4.97	4.89	4.85	5.12	4.78	4.92
Yihewusu Sumu	19.38	14.65	16.50	18.62	9.43	15.71
Hangjinnaoer Township	11.76	11.31	11.31	11.74	8.87	11.00
Hangjin Banner	71.81	61.53	63.99	68.32	48.53	62.84

Table 3 Statistics of grassland biomass in Hangjin Banner Unit: 10^7 kg/ha

Area	2007	2008	2009	2010	2011	Average
Xini Town	26.66	24.61	24.79	25.63	19.55	24.25
Jirigalangtu Town	12.78	12.74	12.52	12.49	12.76	12.66
Huhemudu Town	9.08	9.07	8.96	8.89	8.93	8.99
Balagong Town	10.27	8.05	8.13	8.91	7.21	8.51
Duguitala Town	9.97	9.89	9.85	10.12	9.78	9.92
Yihewusu Sumu	29.38	24.65	26.50	28.62	19.43	25.71
Hangjinnaoer Township	11.76	11.31	11.31	11.74	8.87	11.00
Hangjin Banner	109.90	100.32	102.07	106.40	86.53	101.04

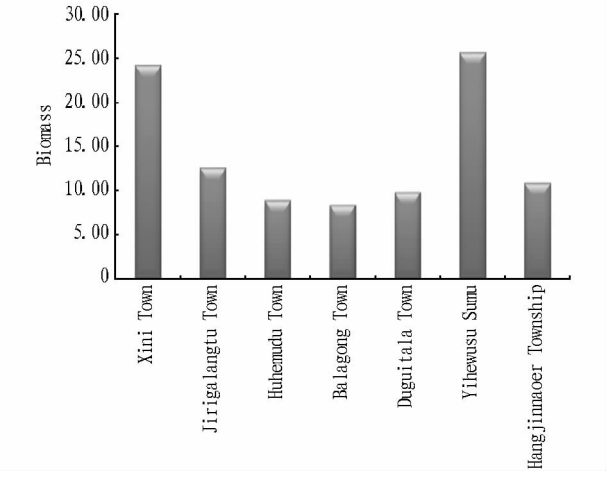


Fig. 4 Five-year average grassland aboveground biomass in Hangjin Banner (10^7 kg/ha)

4.2 Analysis of livestock carrying capacity of grassland

The data in the above table and chart of livestock carrying capacity of grassland show that there were changes in the theoretical livestock carrying capacity of grassland in Hangjin Banner during 2007 – 2011 due to a variety of weather and grazing conditions. The theoretical livestock carrying capacity of grassland was highest in 2007 but lowest in 2011. From various townships in Hangjin Banner, the appropriate livestock carrying capacity was highest in Yihewusu Sumu, and lowest in Huhemudu Town. Overall, the livestock carrying capacity of grassland in the northern part is low than in the southern part. This distribution is closely related to the local natural and geographical environment. And the eastern and western regions have a temperate continental climate and a continental steppe and desert climate, respectively. This analysis is consistent with the distribution of EVI and grassland biomass in Hangjin Banner.

Table 4 Statistical results of livestock carrying capacity of grassland in Hangjin Banner

Area	Statistics of livestock carrying capacity (10^4 sheep units)					Average
	2007	2008	2009	2010	2011	
Xini Town	33.83	20.78	21.03	31.76	8.73	23.22
Jirigalangtu Town	15.80	11.01	10.69	15.21	7.09	11.96
Huhemudu Town	8.29	5.79	5.63	7.89	3.59	6.24
Balagong Town	14.78	7.17	7.30	12.01	3.85	9.02
Duguitala Town	10.10	6.95	6.90	10.41	4.37	7.75
Yihewusu Sumu	39.36	20.83	23.46	37.81	8.62	26.02
Hangjinnaoer Township	23.88	16.08	16.08	23.85	8.11	17.60
Hangjin Banner	145.87	87.49	90.99	138.78	44.36	101.50

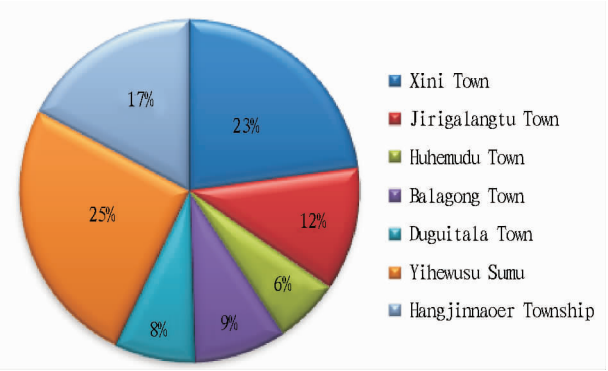


Fig. 5 Five-year average livestock carrying capacity structure of grassland in Hangjin Banner

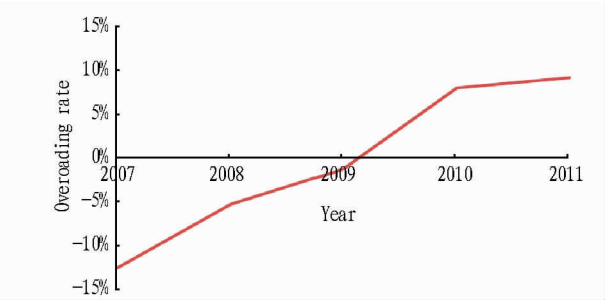


Fig. 6 The annual overloading in Hangjin Banner

4.3 Analysis of grass – livestock balance in Hangjin Banner

The above studies show that the grass and livestock balance in Hangjin Banner is good, and data show that there was no overloading in 2010 and 2011.

Table 5 Grass – livestock balance in Hangjin Banner

Year	Theoretical livestock carrying capacity 10^4 sheep units	Amount of big livestock on hand	Amount of sheep on hand	Actual livestock carrying capacity 10^4 sheep units	Theoretical livestock carrying capacity-actual livestock carrying capacity 10^4 sheep units	Proportion of overloading amount to theoretical livestock carrying capacity//%
2007	145.87	12169	1410553	163.9631	−18.0931	−12.40
2008	87.49	13113	1319561	91.9894	−4.4994	−5.14
2009	90.99	14401	1304728	92.0653	−1.0753	−1.18
2010	138.78	17963	1386676	127.6573	11.1227	8.01
2011	44.36	17953	1386598	40.2731	4.0869	9.21
Total	507.49	75599	6808116	515.9482	−8.4582	−1.50

5 Conclusions

(i) The grassland biomass in Hangjin Banner showed a decreasing trend in the study period. The grassland biomass in the northern part was lower than in the southern part, because the southern part was animal husbandry base with good natural conditions while the grassland biomass in the western part was lower than in the eastern part due to different climatic conditions. (ii) During 2007 – 2011, the theoretical livestock carrying capacity of grassland in Hangjin Banner was highest in 2007 and lowest in 2011. This indicates that the livestock carrying capacity of grassland is affected by climate and grazing conditions. Due to less rainfall and drought in 2011, both EVI value and grassland aboveground biomass were low in Hangjin Banner, so the livestock carrying capacity of grassland was also low. (iii) The grass and livestock balance in Hangjin Banner is good, and there was no overloading in 2010 and 2011. The reason why there is a good balance of grass and livestock lies in determining livestock number by grassland carrying capacity and protecting grassland in Hangjin Banner. Various towns in Hangjin Banner actively develop grass industry, regard the artificial growing of grass as an important part of farming structure adjustment, build high-yielding forage base, and encourage cultivating forage to raise livestock. Hangjin Banner ensures the grass – livestock balance by speeding up the internal restructuring of animal husbandry.

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