

Optimization Study of Space Utilization Rate of Lake Sheep Based on Spatial Planning Model

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Abstract. The article explores the issue of space utilization on a lake sheep farm and draws a series of conclusions through analysis and modeling. First, based on the allocation ratio of breeding rams to foundation ewes and the number of existing sheep pens, the number of breeding rams was determined to be 8, and the number of foundation ewes ranged from 386 to 392. Considering the limitation of 112 existing sheep pens, the enumeration method was used to solve the range of annualized number of sheep to be slaughtered to ensure not less than 1500 sheep, and the gap of the existing standard number of pens was determined to be 26 sheep. Next, on the basis of further optimizing the spatial planning model of lake sheep reproduction, the specific production plans of 112 standard sheep pens were enumerated, and the maximum value of the annualized number of sheep was determined. Finally, for the uncertainty factors of the time nodes such as the pregnancy period, a dynamic planning model was established, and the number of sheep pens allocated to the farm was calculated to be 115 with the objective of minimizing the expected loss. On this basis, the article proposed an optimal production planning scheme for space utilization in lake sheep farms to cope with various uncertainties in the breeding process, such as conception time, number of lambs, survival rate, etc., which provided specific guidance and reference for improving the turnover rate.

Keywords: Lake Sheep Breeding, Enumeration (Math.), Spatial Planning Model.

1. Introduction

Lake sheep is a high-quality breed of sheep that is easy to breed. Lake sheep have the advantages of short age, high fertility, four seasons of estrus, and easy to keep in captivity [1-2]. Lake sheep farms usually use standard pens for captive breeding, and the number of sheep in a standard pen is determined by the growth stage, sex and size of the sheep. Since space utilization is an important factor affecting reproductive efficiency, the number of sheep in a standard pen depends on the growth stage, sex and body size of the sheep. Therefore, it is important to reduce the number of unused pens while meeting the captive breeding needs of lake sheep [3-4]. The production process of lake sheep farming is mainly divided into basic ewe rearing and lamb fattening. At the time of mating, some ewes are kept in the same enclosure as a breeding ram and mated naturally for 3 weeks. At the end of the mating period, the pregnant ewes are separated from the rams. The gestation period of a pregnant ewe is usually about 5 months, and she usually gives birth to 2 lambs per litter. The lambs are usually suckled for about 6 weeks and after weaning are transferred to fattening pens where they are fattened for about 7 months. After the ewes stop lactating, they can breed again after a rest period of about 3 weeks. Generally, each ewe can produce 3 litters every two years [5-6]. The ratio of rams to ewes is generally not less than 1:50, assuming that rams are of equal reproductive ability, and rams and ewes should not be kept in the same pen during the non-breeding period.

In order to determine a reasonable number of breeding rams and foundation ewes, to estimate a range of annualized sheep numbers, and ultimately to be able to improve space utilization, this paper employs a number of methods in practice [7-10].

During the natural mating period, the ratio of breeding rams to foundation ewes in the same pen was only 1:14. Therefore, in this paper, the foundation ewes were divided into three rounds, with the same time interval between each round, in order to make full use of the breeding rams and improve the space utilization rate.

Secondly, observe the maximum number of sheep pens used during the breeding period. Make sure that the two conditions of using the maximum number of sheep pens and not exceeding the number of existing standard sheep pens are satisfied. Based on these relationships, a linear programming model between breeding rams and the number of sheep pens used was constructed in this paper.

Subsequently, the total number of breeding rams was calculated by counting them in the total number of pens used and determining whether the space utilization met the subject requirements. If the requirements were not met, the most appropriate total number of breeding rams was determined by adjusting the model parameters.

Eventually, this paper found that the planning model in which the foundation ewes are divided into three rounds is not universal. Therefore, this paper changed the base ewes to four stages. Calculations similar to the three rounds were carried out to finalize the extension model [11]. By optimizing the extension model, this paper can calculate the number of breeding rams and foundation ewes. Optimization was performed only for the number of foundation ewes in the fourth round, so as to determine the range of the annualized number of sheep to be fledged and to calculate the shortfall in the number of existing standard pens with no less than 1,500 sheep fledged per year.

2. Solving the spatial problem of reproduction in lake sheep

2.1. A spatial linear programming model for lake sheep reproduction

In order to determine a reasonable number of breeding rams and foundation ewes, the following conditions have been established.

- (1) the total ratio of breeding rams to foundation ewes is not less than 1:50.
- (2) the ratio of breeding rams to foundation ewes in the same pen (natural mating period) is 1:14.

In order to make the best use of the breeding rams, the foundation ewes are bred in three rounds. From the above conditions, the ratio of breeding rams to foundation ewes in the same pen in three rounds is 1:42, while the ratio in four rounds is 1:56, which is not in line with the above condition 1. Therefore, it is considered that the foundation ewes should be bred in three rounds. The breeding cycle of foundation ewes in each round was 229 days, so that up to three times of breeding could be accomplished in two years [7-10]. The data were obtained from http://www.mcm.edu.cn/html_cn/node/c74d72127066f510a5723a94b5323a26.html. The results are shown in Figure 1.

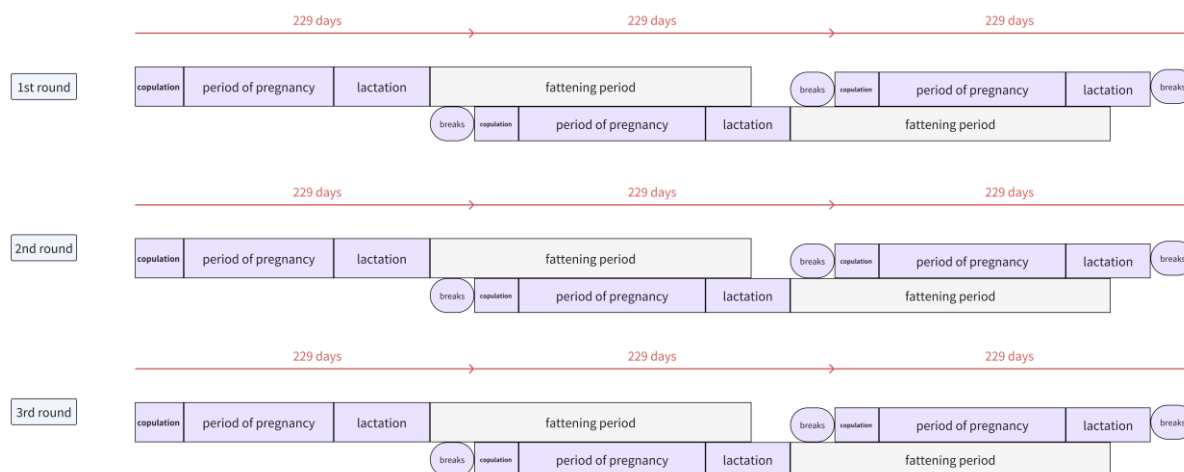


Figure. 1 Three reproductions in three rounds in 2 years

In order to improve the utilization of space on the farm, this paper appropriately adjusts the start time of each breeding round. Using the time period at the end of $T_{\text{fatten (animal before slaughter)}}$ of the first round of L_1 as the time point, the breeding start time of the last two rounds was nudged with the time

The figure illustrates the experimental design across three rounds. Each round begins with a 20-day period (marked by a red circle) before the first copulation. The timeline is divided into three 229-day intervals (T1, T2, T3). The first round shows a sequence of copulation, pregnancy, lactation, and fattening periods. The second and third rounds show similar sequences but with a 20-day delay in the start of the first copulation. A 'time interval' label points to the 229-day intervals.

According to the standard sheep pen specification, the weight of $T_{\text{lactation}}$ and $T_{\text{have conceived}}$ in the penned flock is relatively heavy, and it is observed that if two $T_{\text{copulation (esp. of animals)}}$ (40 days.) are moved in the last two rounds, the weight of $T_{\text{lactation}}$ and $T_{\text{have conceived}}$ can be changed when the overlapping period is the most. Therefore, the breeding time interval of basic ewes in each round is set as $k(20 \leq k < 40)$.

When $k = 20$, obtain the number of pens used in each period for breeding rams and foundation ewes in relation to the existing standard pens

α 、 β is a coefficient and $\alpha + \beta = 3$. When $\alpha = 2, \beta = 1$, the final result of the calculation $x_{\max} = 8$.

Adjust the value of k to fully utilize the available standard columns.

By the formula for the annualized number of sheep slaughtered:

Yields an annualized number of sheep out of the pen of 1071 when $x=8$. When $x=9$, the annualized number of sheep out of the pen is 1204.

378

2.2. Optimization of a spatial model of lake sheep reproduction

According to the results of the above model, there are still two pens left, in order to improve the space utilization, the extra two pens are added with a number of foundation ewes ($0 \leq \text{Number of ewes} \leq 7$) and breeder rams ($1 \leq x_{\text{increment}} \leq 3$). In order to maintain the continuous production of the foundation ewes, another breeder ram is added to mate only with the foundation ewes from the last round of these two pens, as shown in the figure3 below.

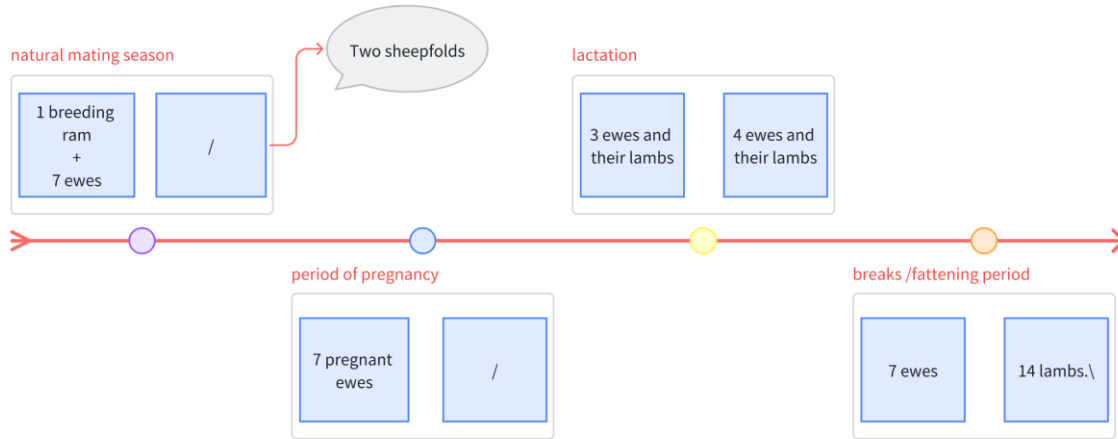


Figure. 3 Optimization process

In summary, when $x = 10$.

That is, the number of breeding rams is 10 and the number of foundation ewes is 385, which is a more reasonable number, and all of the existing 112 standard sheep pens are used, which improves the utilization of space on the farm.

At this point, the annualized number of sheep slaughtered is 1,227 when $x = 9 + 1$ from equation (2).

Ultimately, the range of annualized number of sheep slaughtered: 1071 to 1227.

2.3. Further optimization based on the spatial planning model for lake sheep reproduction

For the foundation ewe rounds discussed in 2.2, it was found that the planning model of dividing the foundation ewes into three rounds was not universal, and they were now bred in four rounds [11]. The first three rounds of $T_{\text{copulation (esp. of animals)}}$ breeding rams to foundation ewes in the ratio of 1:14, and the fourth round of $T_{\text{copulation (esp. of animals)}}$ breeding rams to foundation ewes in the ratio of 1:8, still meet the conditions described.

When $k = 21$, observe the case where the number of sheep pens is used the most (i.e., the case with the most overlapping periods). The results are shown in Figure 4.

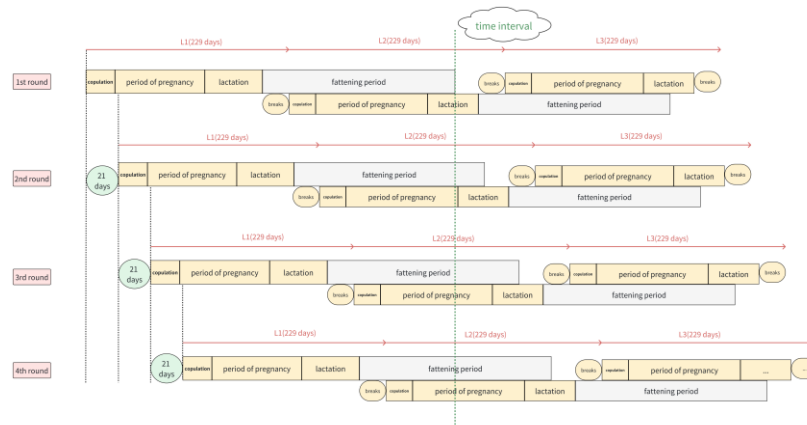


Figure. 4 Time nodes for time interval 21

The number of pens used in each period for breeding rams and foundation ewes was obtained in relation to the available standard pens:

$$\max(m): \left\lceil \frac{x}{4} \right\rceil + \left\lceil \frac{14x}{8} \times 2 \right\rceil + \left\lceil \frac{14x}{6} \right\rceil + \left\lceil \frac{8x}{8} \right\rceil + \left\lceil \frac{(3 \times 14x + 8x) \times 2}{14} \right\rceil \leq 112 \quad (3)$$

The final calculation is $x = 7$. At this point, the number of breeding rams is 7 and the number of foundation ewes is 350. At this point, there is a difference of $m = 2(\text{breeding ram}) + 100(\text{foundation ewe}) = 102$ from the existing standard number of pens by almost 9%, which is not in line with the efficiency of the manager of the farming production.

Adjusting the value of x , when $x = 8$, $m = 2(\text{breeding ram}) + 113(\text{foundation ewe}) = 115$, slightly exceeding the number of standard pens available. Therefore, the ratio of the fourth round of breeding rams to foundation ewes is scaled up appropriately.

If this is adjusted to 1:7, the number of sheep pens used is calculated to be exactly equal to the number of standard pens available. The results are shown in Table 1.

Table. 1 Comparison of Ratio 1:7 and 1:8

Ratio of breeding rams to ewes in the fourth round (at $x=8$)	Total number of breeding rams	Total number of foundation ewesf	Number of sheep pens used (including first three rounds)
1:8	8	400	115
1:7	8	392	112

At this time, the number of breeding rams is 8 and the number of basic ewes is 392, which is a more reasonable number and improves the space utilization of the farm.

At this point, the maximum annualized number of sheep to be fledged is derived from equation (3) for $x = 8$. The minimum annualized number of sheep to be fledged is derived using the enumeration method. The results are shown in Figure 5.

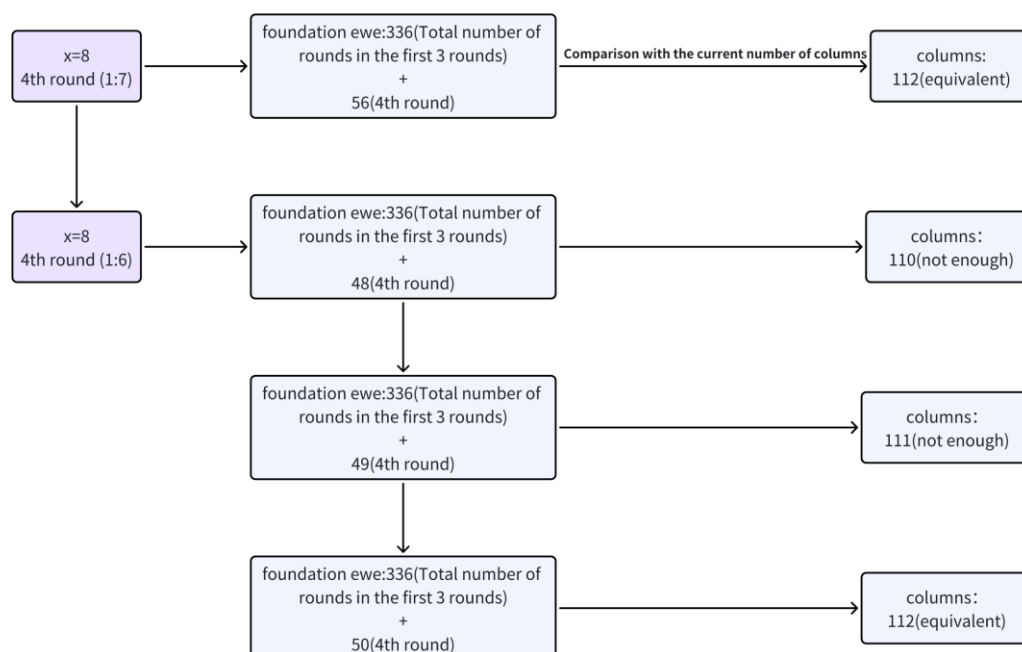


Figure. 5 Derivation of the minimum annualized number of sheep to be slaughtered

As we know from the above figure, at and the ratio of the fourth round of breeding rams to foundation ewes is 1:6, if the number of foundation ewes is 386, at this time, the minimum annualized number of sheep to be fledged is 1230.

Ultimately, the range of annualized number of sheep slaughtered: 1230 to 1249.

3. Results

In this paper, the foundation ewes were changed to four stages. Calculations similar to the three rounds were carried out to finalize the extension model. The optimization of the extension model resulted in the calculation of the range of the annualized number of sheep slaughtered: 1230 to 1249.

Finally, the paper enumerates 112 specific production plans for standard sheep pens and gives the maximum value of the annualized number of sheep to be slaughtered. The results are shown in Table 2.

Table. 2 Planned production schedule

timing	round	cyclicality	Number of sheep pens				(grand total)	
			ram (male)	fatten (animal)	have conceived	lactation		
T+(272~290)	1	1	0	16	0	0	...	102
	1	2	0	0	14	0		
	2	1	0	16	0	0		
	2	2	0	0	14	0		
	3	1	0	16	0	0		
	3	2	0	0	0	0		
	4	1	0	10	0	0		
	4	2	0	0	0	0		
T+(291)	1	1	2	16	0	0		110
	1	2	0	0	14	0		
	2	1	0	16	0	0		
	2	2	0	0	14	0		
	3	1	0	16	0	0		
	3	2	0	0	14	0		
	4	1	0	0	0	0		
	4	1	0	10	0	0		
.....								

4. Conclusions

The article discusses space utilization on lake sheep farms. This article follows the ratio of breeding rams to foundation ewes. Three rounds of foundation ewes are considered, and each round is spaced at the same time to make the best use of the breeding rams and to improve the space utilization. This paper ensures that the condition of not exceeding the existing standard number of sheep pens is met while using the maximum number of pens. Based on these relationships, this paper constructed a linear programming model between breeding rams and pen utilization.

Eventually, it was found that the planning model of dividing foundation ewes into three rounds was not universal. Therefore, in this paper, the foundation ewes were changed to four stages. Calculations similar to the three rounds were carried out to finalize the extension model. By optimizing the extension model, the number of breeding rams and foundation ewes was calculated.

At present, the model mainly focuses on the space utilization rate of lake sheep and the utilization efficiency of breeding rams. Future research could consider more objectives including economic benefits, reproductive efficiency, animal welfare, etc. to construct a multi-objective optimization model.

Although current linear planning models have been able to provide optimized solutions for the number of breeding rams and foundation ewes, there is still room for further optimization. Future research could explore more complex models, such as nonlinear or dynamic programming, to more accurately model the actual situation on the farm.

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