

Optimization Model for Captive Breeding of Lake Sheep Based on Space Utilization

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Abstract: Power Lake sheep have excellent characteristics such as fast early growth, early sexual maturity, four-season estrus and can be kept in captivity, etc. It is of great significance to explore the development of appropriate production plans to improve the space utilization of farms in order to increase the annual turnout of lake sheep. In this paper, under the condition of continuous production, in order to determine the reasonable number of breeding rams and basic ewes in the farm and estimate the range of the annualized number of sheep, we used a set of inequalities to depict the breeding cycle of the lake sheep from the spatial and temporal dimensions, and established a model to analyze the number of annualized number of sheep under the condition of deterministic factors, and based on the analytical model, we solved the gap between the number of standard sheep pens and the number of standard sheep pens in the existing one, under the requirement of the farms to have not less than 1500 sheep pens per year. gap in the number of standard sheep pens. On the basis of the above model, taking into account the influence of uncertain factors such as the success rate of mating, the number of lambs delivered and the mortality rate, an optimization algorithm for fluctuating reproduction of lake sheep was adopted to achieve the optimization of the production plan in order to maximize the economic benefits.

Keywords: Captive Breeding of Lake Sheep, Continuous Production, Fluctuating Reproductive Cycles, Spatio-Temporal Analysis.

1. Introduction

As a precious lamb breed in China, the lake sheep has a long history with excellent characteristics such as fast early growth, early sexual maturity, four seasons of estrus and can be raised in captivity. According to historical records, as early as 1126 AD, lake sheep began to be bred. In the early days, lake sheep were raised by the northern people, but as the northern immigrants migrated to the south, in the absence of natural pasture, they gradually changed from free-range to captive breeding. Under the constant cultivation of artificial captivity, the sheep eventually adapted to the southern climate and settled around Lake Taihu, forming the current lake sheep. Since the 14th Five-Year Plan for the development of animal husbandry, large-scale raising has become a trend in the breeding industry, through scientific methods can improve the survival rate and fertility of sheep, make full use of land for penning captive breeding, thus improving land utilization and saving more resources. The breeding of lake sheep mainly includes two key aspects: reproduction and fattening. Due to the high technical requirements of artificial insemination, the breeding of lake sheep is mostly carried out by natural mating of breeding rams and basic ewes, and the sheep need to be fed in different pens at different times. Under the premise of safeguarding the economic benefits of farm managers, the space utilization rate of the farm is improved by formulating the corresponding production plan, and the main production plan is used to determine the mating time of how many basic ewes can be mated, and by controlling the breeding time, the

space utilization of the sheep pens is improved in order to achieve the maximization of economic benefits [1, 2].

2. Model Analysis of The Annualized Number of Sheep Slaughtered Under Deterministic Conditions

2.1. Reproductive gestation cycle of lake sheep based on temporal analysis

In the actual production process, without considering the uncertainty factors and the elimination and renewal conditions of the breeding sheep, statistics found that the natural mating period of 20 days within the ewes can be conceived, gestation period of 149 days, 2 lambs per litter, the lactation period of 40 days, lamb fattening period of 210 days, the ewes are empty and resting period of 20 days. Now a lake sheep farm existing 112 standard sheep pen, in the realization of continuous production conditions, in order to determine the reasonable number of farm breeding rams and basic ewes and estimate the range of the annualized number of sheep, the establishment of 2. Determining factors under the conditions of the number of annualized number of sheep model analysis, and based on the analytical model for the farm each year, not less than 1,500 sheep under the requirements of the estimated solution to the existing standard sheep pen The gap in the number of sheep. In the process of modeling, the reproductive gestation cycle modeling process shown in Figure 1 was established by using the method of sequential analysis based on different times.

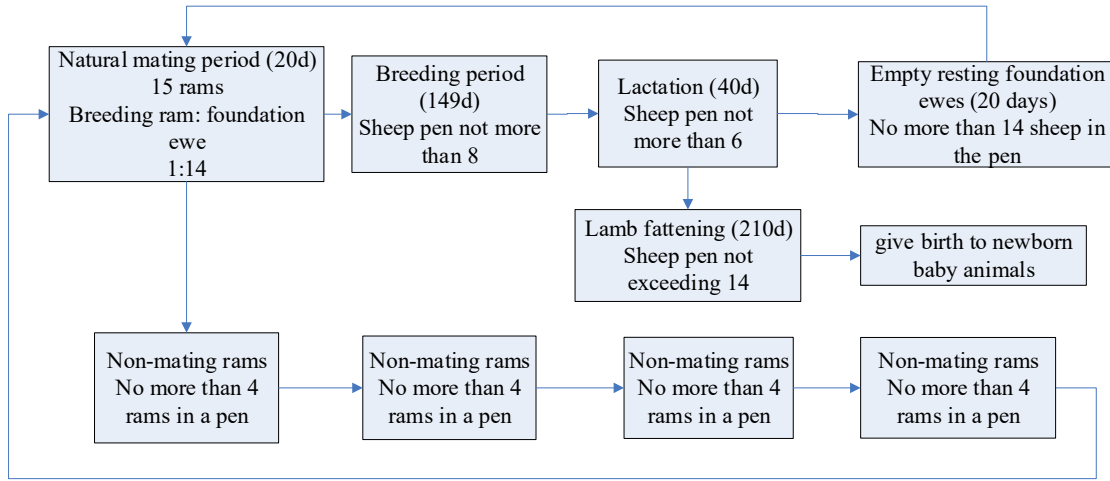


Figure 1. Breeding gestation cycle diagram

Let the number of breeding rams be x , the number of foundation ewes be $14x$, the number of lambs be $2 \times 14x = 28x$, and given the number of pens N , we have:

Modeling the natural mating period:

$$\frac{x+14x}{14} = \frac{15x}{14} \leq N \quad (1)$$

(2) Models of pregnancy:

$$\left\lceil \frac{x}{4} \right\rceil + \frac{14x}{8} \approx \frac{x}{4} + \frac{7x}{4} = 2x \leq N \quad (2)$$

(3) Models of lactation:

$$\left\lceil \frac{x}{4} \right\rceil + \frac{14x}{6} \approx \frac{x}{4} + \frac{7x}{3} = \frac{31x}{12} \leq N \quad (3)$$

(4) Modeling of the lambing and nulliparous conditioning period:

$$\left\lceil \frac{x}{4} \right\rceil + \frac{2 \times 14x}{14} + \frac{14x}{14} = \frac{13x}{4} \leq N \quad (4)$$

Based on the time analysis, it was found that the captive breeding of lake sheep was multi-batch, and each batch was further divided into two rounds of breeding, and the complete breeding process was analyzed by taking the first round of the first batch as an example, and the results were obtained as shown in Figure. 2.

The number of pens used in the second lactation period is the largest, because the lambs are fattened in the first round, and the second round of foundation ewes lactating with the non-mating period of the breeder rams will take up the pens, so according to Equation 3, we can calculate the breeder rams as 24 rams. Because the whole breeding cycle is 229 days, deducting a natural mating period there are only 209 days, but lamb fattening needs 210 days, so we will delay one day, in the second round of the second round of lactation period to open the new foundation ewes natural mating, so when the first batch of the first round of the nursing period is finished, at the same time start the second batch of lake sheep breeding, can be calculated to get the cumulative number of days of captivity under different breeding period as Table 1.

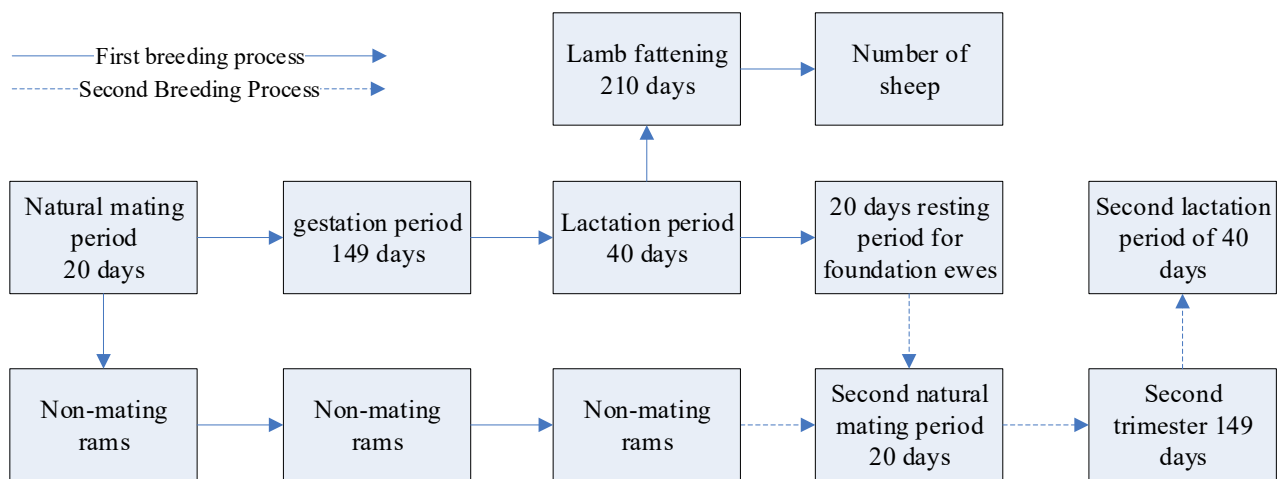


Figure 2. Diagram of the complete breeding process of the first round

Comparison of Table 1 reveals that the cumulative number of days corresponding to the number of breeding periods 3 is the closest to two years, whereas for leap year (366 days) and flat year (365 days) under two years the number of lower lake sheep was calculated to be 2,823 and 2,816, respectively.

Table 1. Number of Reproductive Stages

Number of breeding periods	Cumulative days
1	229
2	458
3	687
4	916

2.2. Solving a model for annualized sheep numbers in slaughter

With the premise of achieving continuous production, the first natural mating period of the second cohort ends at the end of the lactation period of the first cohort, so finding a second cohort to initiate the second cohort for natural mating at the stage of the first cohort HO is extremely important to maximize the benefits of captive breeding, so the following two scenarios were considered for the study [3]:

(1) The second batch is initiated at the end of the first gestation period of the first batch.

The time elapsed includes a natural mating period of 20 days and a gestation period of 149 days for the first batch, a natural mating period of 20 days for the second batch, a gestation period of 149 days for the second batch, a lactation period of 40 days for the second batch, and a cumulative time elapsed of 378 days to enter the fattening of the lambs, which takes 210 days. The first batch went through the first natural mating period of 20 days, 149 days of gestation, 40 days of lactation, 20 days of rest and recuperation in the empty womb, 20 days of natural mating period in the second batch, 149 days of gestation in the second batch, 40 days of lactation in the second batch, with a cumulative elapsed time of 438 days. At this time, the first batch of lambs have been reared for 229 days, the first batch of sheep out of the pen on the 419th day,

there is a time difference of 41 days, indicating that the second batch of lambs have been reared for only 60 days, 419 days before the first batch of lambs and the second batch of lambs need to be reared in the pen, that is, there is a lack of pens, at this point, we can draw two important conclusions:

Conclusion 1, the natural mating of the second batch of foundation ewes took place earlier and earlier, i.e. in the second case.

Conclusion 2, 48 pens kept by lambs after day 419, that is, days 420 to 438, were vacant.

(2) The second batch was started earlier than the end of the first pregnancy.

According to conclusion 2 of the first scenario, the first batch of lambs is fattened out on day 419. According to the analysis the time required for a complete breeding cycle is 229 days, with 50 free pens, i.e. the second batch is started on day 190 to enter the natural mating period. Starting earlier than 190 days will inevitably lead to an insufficient number of pens by day 419, i.e. the first case above. Starting the second batch on the 190th day is the earliest, with the highest number of lambs in the pen and more benefits.

Therefore, the breeding process of the first batch of the first round and the third batch of the second round of lake sheep as an example of solving the analysis, to obtain the breeding process shown in Table 2 and Table 3.

Table 2. Table of the first round of breeding process for the first batch

Natural mating season	Duration of pregnancy	Lactation period	Lamb fattening and resting period in empty wombs
	Foundation ewes require 42 pens	56 pens of foundation ewes	Lambs need 48 pens
	Breeding rams require 6 pens	Breeding rams require 6 pens	24 pens of foundation ewes
Total columns 24	Total columns 48	62 total columns	Breeding rams require 6 pens
			Total columns 78
88 remaining sheep pens	64 remaining sheep pens	50 remaining goat pens	34 remaining goat pens
Cumulative number of days 20d	Cumulative days 169d	Cumulative number of days 209d	Cumulative days 229d
24 breeding rams			672 lambs have been reared for 20 days
336 foundation ewes			

Table 3. Third second round of breeding process table

Natural mating season	Duration of pregnancy	Lactation period
Basic ewe lamb pens: 4	Basic ewe lamb pens: 6	Basic ewe lamb pens: 8
Lambing pens: 7	Lambing pens: 7	Lambing pens: 7
Cumulative number of days 249d, harmonized time 439d	Cumulative days 398d, harmonized time 588d	Cumulative days 438d, harmonized time 628d
96 + 28 lambs reared for 40d	96 + 28 lambs reared for 189d	96 + 28 lambs have been raised for 229 days and are out of the pen

Based on the results of solving for all batches, it can be seen that for the above two cases of second batch start-up time points the annual slaughter of lake sheep and the number of sheep pen gaps are calculated as follows:

(1) The second batch is initiated at the end of the gestation period of the first batch.

The first batch of lambs in the first round of complete fattening for the time of 419 days, the base ewes 336, the number of lambs out of the pen is 672, the annual output is 586; the second batch of lambs in the first round of complete fattening for the time of 439 days, the base ewes for 14, the

number of lambs out of the pen is 24, the annual output is 20; the third batch of lambs in the first round of complete fattening for the time of 609 days. With 62 base ewes and 124 lambs fledged, the annual number of lambs fledged in the third batch is 75; the total annual number of lambs fledged in the first round of all three batches is 618.

The number of pens is calculated when the first round of lambs in the third batch is fully fattened, so the first batch of lambs will require 48 pens and the foundation ewes 24 pens; the second batch of foundation ewes will require 1 pen and the lambs 1 pen; the third batch of foundation ewes will

require 8 pens and the lambs 7 pens; so the total number of pens required will be 89, and the number of shortfalls in the number of pens will be 23.

(2) The second batch is started earlier than the end of pregnancy of the first batch.

The first batch of the first round of lamb fattening start time is 209 days, the base ewes are 336, the number of lambs out of 672, then the first batch of the annual output is 1174; the second batch of the first round of lamb fattening start time is 229 days, the base ewes are 14, the number of lambs out of 24, then the second batch of the annual output is 38; the third batch of the first round of lamb fattening time is 399 days The first round of lambs for the third batch is 399 days, the foundation ewes are 62 and the number of lambs fledged is 124, so the annual lambing quantity for the third batch is 113; so the total annual lambing quantity for the first round of lambs for the three batches is 1325;

The number of sheep pens is calculated when the first round of lambs of the third batch are fattened, the first batch of lambs need 48 pens, the foundation ewes need 42 pens, the

breeder rams need 6 pens; the second batch of foundation ewes need 1 pen, the lambs need 1 pen; the third batch of foundation ewes need 5 pens, the lambs need 9 pens; so the total number of pens needed is 112, the number of shortfalls in the number of sheep pens is zero.

3. Optimization of A Fluctuating Reproduction Model for Lake Sheep Under Uncertainty Considerations

3.1. Analysis of fluctuating reproductive cycles of lake sheep under uncertainty

In the actual breeding process of lake sheep, there are still uncertain factors such as the success rate of breeding, the number of lambs delivered and the mortality rate, etc. Therefore, the fluctuating breeding cycle of lake sheep in captivity under the consideration of uncertain factors is shown in Figure 3.

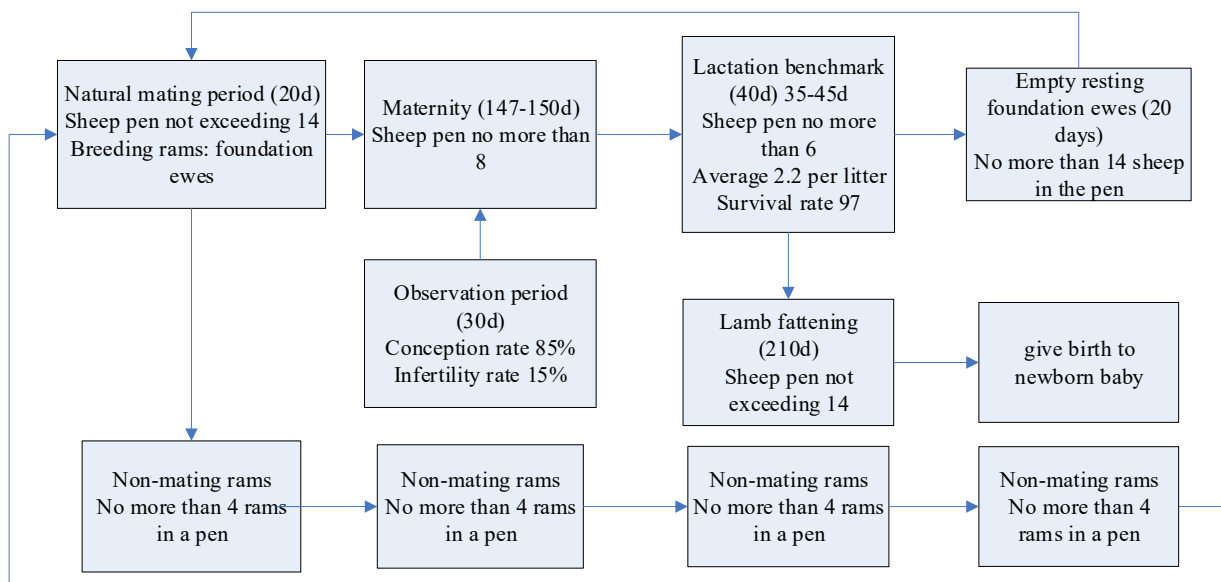


Figure 3. Fluctuating breeding cycles under uncertainty

Natural mating phase: The ram mates naturally with the foundation ewe for 20 days.

Gestation phase: the basic ewe's conception fluctuates from 147 to 150 days during the gestation phase, we need to generate multiple random integer values within this specified range and store the basic ewe's state records in the matrix, after the gestation period is over, the basic ewe enters into lactation state and gives birth to lambs.

Observation period: Since successful pregnancy can only be recognized 30 days after the end of the base ewe's mating period, the conception rate of the base ewe's natural mating is 85%.

Lactation period benchmark: the lactation period is based on 40 days, and the lactation period is controlled to be within 35 to 45 days, for every 1 day decrease in lactation period, the fattening period of the lambs decreases by 2 days, and vice versa for every 1 day increase in lactation period, the fattening period of the lambs increases by 2 days, and we need to generate multiple random integer values within this specified range of the status record of the breeding ram, the status record of the foundation ewe, the status record of the lambs,

the status record of the foundation ewe and the status record of the lambs. The status record of the breeding ram, the status record of the foundation ewe, the status record of the lamb, and the use of the sheep pen are put into the matrix variable for storage. At the end of the lactation period, the foundation ewes return to breeding status and the lambs enter the fattening period. Typically, foundation ewes produce an average of 2.2 lambs per litter with a survival rate of 97%.

Empty Rest Period: Foundation ewes require a minimum of 18 days in the empty rest period before they can be flexibly conditioned.

In addition, without taking other factors into consideration, we need to pen lactating ewes and lambs born with a difference of no more than 7 days between delivery dates, as well as allow fattening lambs with a difference of no more than 7 days between weaning dates to be penned together, and base ewes during the resting period to be penned together.

3.2. Optimization algorithm for fluctuating reproduction in lake sheep under consideration of uncertainties

To minimize the expected loss of the production plan under the consideration of uncertainty, there are the following two options:

(1) When the sheep pens are vacant, the value of loss per pen per day is 1, and want to minimize the expected loss value to each pen occupied, in each pen among the sheep pens in order to put one to the farm to occupy the pens.

(2) When the sheep pen is full, we need to rent an additional sheep pen, the rental fee is 3, as far as possible in the feasibility of the number of annualized number of sheep slaughtered under the conditions of the sheep pen full of farms, reduce the cost of renting the sheep pen, so that the loss of the expected value of the minimum.

Then the flow chart of the optimization algorithm used is shown in Fig. 4.

The constraints of the algorithm are as follows:

Sheep pen capacity: ensure that the capacity limit of each pen is not exceeded, including the number of sheep at different stages.

Availability of leased space: if leased, it is necessary to ensure that the leased space is available and has sufficient holding capacity.

Total farm space: Consider the total available space within the farm.

Rental cost: If renting, consider the cost of renting the

space to ensure it is within budget.

Movement and deployment restrictions between different sheep stages within the farm: consider the rules and restrictions on movement of sheep between different farming stages.

The specific implementation process of the algorithm is as follows:

Divide a number of sheep pens from the total number of pens and mark the use in these pens as 'natural mating' and the rest as 'idle'. The pens were divided into natural mating and idle pens, and the status of the breeding rams and foundation ewes, as well as the status of the lambs, were recorded, and all the pens on the farm were placed in breeding rams, resulting in a loss of 1 per pen per day.

The second step was to calculate the values of conceived and foundation ewes at 147-150 days of gestation, 30 days of observation, 85% conception rate and 15% non conception rate, arrange the pens for the breeding rams, put the non conceived ewes in the natural mating phase, number the breeding rams and arrange them in separate pens, and the remaining ones were arranged according to four. Observe whether the monitoring time is reached or not, if it has been reached, then output the result, if it has not been reached, we need to test and modify the foundation ewes in the natural mating period, observation period and lactation period, as well as checking and modifying the lambs in the fattening period and the foundation ewes in the empty resting period until the monitored time is reached and output the result [4, 5].

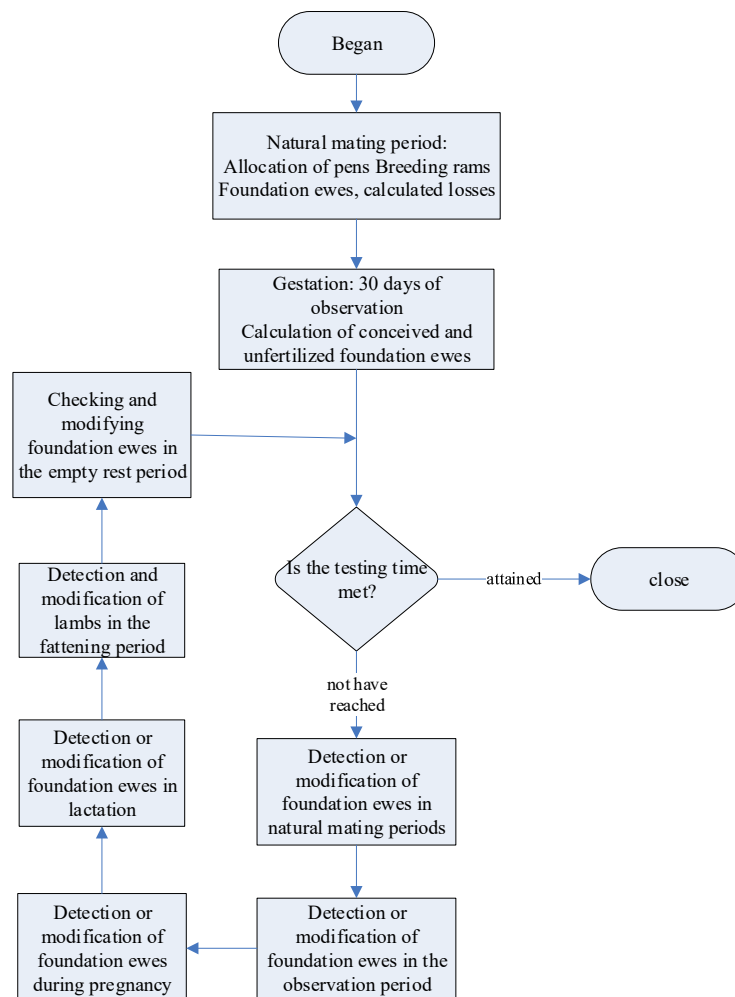


Figure 4. Flowchart of the fluctuating reproduction algorithm

4. Conclusions

In this paper, under the condition of realizing continuous production, in order to determine the reasonable number of breeding rams and basic ewes in the farm and estimate the range of the annualized number of sheep, the inequality group was used to portray the breeding cycle of lake sheep from the spatial and temporal dimensions, and an analysis of the model of the number of annualized number of sheep under the condition of determining the factors was set up, and based on the analytical model, the existing number of standardized sheep pens was solved for the requirement that the farms should produce no fewer than 1,500 sheep annually under the estimate. The shortfall in the number of standard sheep pens was estimated based on this analytical model. The results of the calculations showed that the number of standard pens used by the farm was 110 when there were 24 breeding rams and 336 foundation ewes in 112 standard pens. The farm has the highest number of lambs and benefits from adding an additional batch of foundation ewes in the second round, i.e. starting the second batch on day 190 to enter the natural mating period.

Finally, considering the effects of uncertain factors such as the success of mating, the number of lambs delivered and the mortality rate, an optimization algorithm for fluctuating

reproduction in lake sheep was used to achieve the optimization of the production plan in order to maximize the economic benefits.

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