RESEARCH

METHODOLOGY
CHAPTER 4

RESEARCH METHODOLOGY

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4. RESEARCH METHODOLOGY

4.1 Introduction

As regards to find out the optimum values of feeds and fodder, for minimizing the expenditure and to fulfill the requirement of all nutrients the linear programming technique was employed. This technique was used as an analytical tool to calculate the optimum feed combination under the available as well as without availability conditions of feeds and fodder. The optimization of linear function subject to linear constraints is simple in its mathematical structure, but powerful in its adaptability to a wide range of problem.

4.2 A scientific approach

Many business and economic situations are concerned with a problem of planning activity. In each case there are limited resources at our disposal and our problem is to make such a use of these resources so as to yield the maximum production or to minimize the cost of production or to give the maximum productivity as profits etc. Such problems are referred to as problems of constrained optimization. Linear programming is technique for determining an optimum schedule of inter dependent activities in view of the available resources. Programming is just another word for planning and refers to the
process of determining a particular plan of action from amongst several alternatives. The word linear stands for indicating that all relationships involved in a particular problem are linear.

In both developing and developed economics, Operations Research approach is equally applicable. In developing economics, there is a great scope of developing an Operations Research approach towards planning. The basic problem is to orient the planning so that there is maximum growth of per capita income and in the shortest possible time, by taking into consideration the national goals and restrictions imposed by the country.

Operations Research approach needs to be equally developed in agriculture sector on national or international basis with population explosion and consequent shortage of food. Every country is facing the problem of optimum allocation of land to various crops in accordance with climatic conditions and available facilities. The famous problems in Linear programming approach is to find the minimum cost diet that would supply to the body at least minimum requirement of each vitamin.

Operations research or Management science as the name suggests, is a science of managing. As known, management is most of the time making decisions. It is thus a decision science, which helps management to make better decisions. Decision in fact, a pivotal world in managing. Decision-
making can be improved and in fact, there is large-scale improvement the essential characteristics of all decisions are

i) Objectives

ii) Alternatives

iii) Influencing factor

Once these characteristics are known, one can think to improving the characters so as to improve upon the decision itself. It is thus scientific quantification used in operations Research, which helps management to make better decisions. Thus in Operations Research the essential features of decisions, namely, objectives, alternatives and influencing factors are expressed in terms of scientific quantifications or mathematical equations. This gives rise to certain mathematical relations, terms as a whole mathematical models. Thus the essence of operations Research is such mathematical models.

4.3 Phases of operations research

Operations research, like all scientific research, is based on scientific methodology, which proceeds along the following lines

1. Formulating the problem
2. Constructing a model to represent the system under study
3. Deriving a solution from the model
4. Testing the model and the solution derived from it
5. Establishing controls over the solution
6. Putting the solution to work i.e. implementation.

4.4 Assumptions in linear programming model

In other word to tackle the problem of attaining the optimum feed and fodder combination in the cattle farm for optimization of net returns and to increase the productivity of cattle a hypothesis is developed first. For this development, it will be worth while to lay down some assumption in the linear programming model, which are as follows:

i) The present problem is dealt with the cattle farm as whole and farm economics level as an industry.

ii) It is also assumed that the study area has limited resources, such as feeds and fodder. The study area is not in a position to expand the resources beyond certain limits.

iii) The other inputs such as labour, housing, management factors etc. are made available to the cattle farms as required.

iv) Linearity assumes constant proportionality between input and output given to cattle farm. This is the crucial assumption in the L.P. model under study. That all the activities in the model have linear characteristics i.e. any change in the level of feed and fodder will cause a similar change in the effect of that activity.
v) The relative price structure of study period will remain stable in study area.

vi) The farm owner, it is assumed will exert more and more to optimize the farm production needed as like in industry.

vii) All the input and output coefficients and variables are positive. This is mathematical requirement of model.

4.5 The Hypothesis

The hypothesis underlying the present problem is that “There exists a potential for increasing cattle farm production and opportunities by adjusting the existing resources of the farm with the present technique of management.” This hypothesis is placed under a strong height of evidence and empirical facts for the validity. This is tested by employing linear programming model in the present study.

4.6 Logic of the constraints and objective functions

To obtain the optimum combination of feeds and fodder with minimum cost a very simple linear programming model is used in this research work. The objective functions of the present study are as follows.

a) To minimize the feeding cost and to obtain the optimal feeds and fodder combinations, which will satisfy the
constraints of requirement of all types of nutrient for a Gir crossbred cattle breeding farm in the availability of feeds and fodder conditions in different months and seasons.

b) To minimize the feeding cost and to obtain the same optimal feeds and fodder combinations without the availability conditions in different month and season for the Gir crossbred cattle farm.

c) To estimate the optimum productivity of crossbred cattle in selection to same economic traits by utilizing various expenditure resources.

4.7 Nutritional system

The non-protein nitrogenous compounds play important role in ruminants system, almost an identical role as the true protein (Sen and Ray, 1971). So the protein requirements of the animals were made available in terms of digestible crude protein (DCP) kg in the ration with respect to maintenance ($K_m$), milk production ($K_t$), pregnancy ($K_p$) and growth ($K_g$) by using the following equations

$$K_m = 0.23 + (BW - 350 * 0.00054) \quad (1)$$

$$K_t = M(0.051 + (F - 5 * 0.006)) \quad (2)$$

$$K_p = 0.14 \text{ for } \geq 5^{th} \text{ month of pregnancy} \quad (3)$$

$$K_g = 0.293 + (BW-70 \times 0.00131) \quad (4)$$
Energy requirements of the animals were met in terms of TDN, kg with respect to maintenance \( (N_m) \), milk production \( (N_l) \), pregnancy \( (N_p) \) and growth \( (N_g) \) using the following equations.

\[
N_m = 0.27 + (BW - 350 \times 0.0066) \quad (5) \\
N_l = M (0.051 + F - 5 \times 0.048) \quad (6) \\
N_p = 0.7 \text{ for } \geq 5^{th} \text{ month of pregnancy} \quad (7) \\
N_g = 1.242 + (BW - 70 \times 0.00134) \quad (8)
\]

Where,

- \( BW \) - is the body weight
- \( M \) - is the milk yield / day
- \( F \) - is the per cent fat in milk

Equations (1 to 3) and (5 to 8) were adopted from Sen and Ray (1971) standards, except converting the values into algebraic equation form and adjusting the intercept upward assuming 350 kg as minimum adult body weight. Equations 4 and 18 were adopted from Arora et al. (1978).

For the capacity to consume or to satisfy the appetite of the animal, a check for the total amount of dry matter in the ration, which an animal can consume, was observed. The dry matter requirements for cattle generally need about 2.0 to 2.5 kg per 100 kg of live weight, milch stock consume slightly higher than cows (Sen & Ray, 1971). Kumar and Mudgal (1980) emphasized variation in dry matter consumption in different seasons, indicating higher consumption in winter months than in summer months. No specific equation could be obtained directly from the published
data, however, following rate of dry matter (kg) per 100 kg body weight for adult animals in different months was assumed

<table>
<thead>
<tr>
<th>Month</th>
<th>DM (kg) for 100 kg Bw</th>
</tr>
</thead>
<tbody>
<tr>
<td>January</td>
<td>2.6</td>
</tr>
<tr>
<td>February</td>
<td>2.5</td>
</tr>
<tr>
<td>March</td>
<td>2.4</td>
</tr>
<tr>
<td>April</td>
<td>2.3</td>
</tr>
<tr>
<td>May</td>
<td>2.2</td>
</tr>
<tr>
<td>June</td>
<td>2.1</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>Month</td>
<td>DM (kg) for 100 kg Bw</td>
</tr>
<tr>
<td>--------</td>
<td>----------------------</td>
</tr>
<tr>
<td>July</td>
<td>2.2</td>
</tr>
<tr>
<td>August</td>
<td>2.3</td>
</tr>
<tr>
<td>September</td>
<td>2.3</td>
</tr>
<tr>
<td>October</td>
<td>2.4</td>
</tr>
<tr>
<td>November</td>
<td>2.5</td>
</tr>
<tr>
<td>December</td>
<td>2.6</td>
</tr>
</tbody>
</table>

For estimating the capacity for total DM consumption for growth \( D_g \) the prediction equation given by Arora et al. (1978) was used

\[
D_g = 1.974 + (BW_{70} \times 0.0226) \quad (9)
\]

With the help of above equation and table 2 distribution of milking cows with reproductive status, the nutrients requirement DCP, TDN and DM were calculated for each category of cow and for all the month and season the requirement of these nutrients for the milking, pregnant cow and dry cows for their maintenance were calculated separately. Then taking its average for whole herd for respective month and season, the total requirement of DCP, TDN and DM per day per milch cattle was prepared (Table 6). This requirement of nutrients was used for further formulation of linear programming model. To form the constraints
Table 6: Total nutrient requirement (DCP, TDN, and DM) per day per unit in milking crossbred Gir cattle herd of size 100.

<table>
<thead>
<tr>
<th>Month</th>
<th>DCP</th>
<th>TDN</th>
<th>DM</th>
<th>DM to be met from concentrate</th>
<th>DM to be meet from green fodder</th>
<th>DM to be meet from dry fodder</th>
</tr>
</thead>
<tbody>
<tr>
<td>January</td>
<td>0.5191</td>
<td>5.9175</td>
<td>10.4</td>
<td>3.4632</td>
<td>2.3099</td>
<td>4.6268</td>
</tr>
<tr>
<td>February</td>
<td>0.5205</td>
<td>5.9245</td>
<td>10</td>
<td>3.33</td>
<td>2.2211</td>
<td>4.4488</td>
</tr>
<tr>
<td>March</td>
<td>0.5255</td>
<td>5.9875</td>
<td>9.6</td>
<td>3.1968</td>
<td>2.1322</td>
<td>4.2709</td>
</tr>
<tr>
<td>April</td>
<td>0.5272</td>
<td>5.977</td>
<td>9.200</td>
<td>3.0686</td>
<td>2.0434</td>
<td>4.0929</td>
</tr>
<tr>
<td>May</td>
<td>0.5194</td>
<td>5.9</td>
<td>8.800</td>
<td>2.9304</td>
<td>1.9545</td>
<td>3.9150</td>
</tr>
<tr>
<td>June</td>
<td>0.5222</td>
<td>5.914</td>
<td>8.400</td>
<td>2.7972</td>
<td>1.8657</td>
<td>3.7370</td>
</tr>
<tr>
<td>July</td>
<td>0.5172</td>
<td>5.851</td>
<td>8.800</td>
<td>2.9304</td>
<td>1.9545</td>
<td>3.9150</td>
</tr>
<tr>
<td>August</td>
<td>0.5158</td>
<td>5.844</td>
<td>9.200</td>
<td>3.0636</td>
<td>2.0434</td>
<td>4.0929</td>
</tr>
<tr>
<td>September</td>
<td>0.5144</td>
<td>5.837</td>
<td>9.200</td>
<td>3.0636</td>
<td>2.0434</td>
<td>4.0929</td>
</tr>
<tr>
<td>October</td>
<td>0.5169</td>
<td>5.8685</td>
<td>9.600</td>
<td>3.1968</td>
<td>2.1322</td>
<td>4.2709</td>
</tr>
<tr>
<td>November</td>
<td>0.5127</td>
<td>5.8475</td>
<td>10.00</td>
<td>3.33</td>
<td>2.2211</td>
<td>4.4488</td>
</tr>
<tr>
<td>December</td>
<td>0.5166</td>
<td>5.886</td>
<td>10.4</td>
<td>3.4632</td>
<td>2.3099</td>
<td>4.6268</td>
</tr>
<tr>
<td>Rainy</td>
<td>0.5158</td>
<td>5.844</td>
<td>8.900</td>
<td>2.9637</td>
<td>1.9767</td>
<td>3.9595</td>
</tr>
<tr>
<td>Winter</td>
<td>0.5155</td>
<td>5.8615</td>
<td>10.100</td>
<td>3.3633</td>
<td>2.2433</td>
<td>4.4933</td>
</tr>
<tr>
<td>Summer</td>
<td>0.5219</td>
<td>5.9315</td>
<td>9.400</td>
<td>3.1302</td>
<td>2.0878</td>
<td>4.1819</td>
</tr>
<tr>
<td>Overall</td>
<td>0.5169</td>
<td>5.8885</td>
<td>9.4680</td>
<td>3.1528</td>
<td>2.1029</td>
<td>4.2122</td>
</tr>
</tbody>
</table>
of minimum requirement of nutrient viz; DCP, TDN and DM from the feeds and fodders available and their nutrient content capacity has to be matched to get the optimal solution. Therefore, table 6 along with table 5, the feeds and fodders available and there nutrient content with average cost was used to form the objective function and constraints of the formal linear programming model for each month and season, respectively. If we avoid the quantitative restrictions of availability of feeds and fodders then this situation was added in plan II.

4.8 Formal linear programming model

The General Linear Programming problem in defined as follows:

Let \( Z \) be a linear function on \( \mathbb{R}^n \) defined by

\[
Z = C_1X_1 + C_2X_2 + \ldots + C_nX_n \quad \text{(a)}
\]

Where,

\( C_j \)s are constants set \( (a_{ij}) \) be \( m \times n \) real matrix and set \( \{ b_1, b_2, \ldots, b_n \} \) be a set of constraints such that

\[
\begin{align*}
  & a_{11}x_1 + a_{12}x_2 + \ldots + a_{1n}x_n \geq b_1 \\
  & a_{21}x_1 + a_{22}x_2 + \ldots + a_{2n}x_n \geq b_2 \\
  & a_{m1}x_1 + a_{m2}x_2 + \ldots + a_{mn}x_n \geq b_m
\end{align*}
\]

and finally let

\[
x_j \geq 0 \quad j = 1, 2, \ldots, n \quad \text{(c)}
\]
The problem of determining an n-tuple \((x_1, x_2, \ldots, x_n)\) which makes \(z\) minimum (or maximum) and which satisfies (b) and (c) call the General Linear programming problem. Using this general linear programming model we can set our generalized model, applicable to the feed and fodder conditions.

The nutrient requirement so worked out for all the animals in the system was met from among the feeds and fodders available in the month of operation. The optimum combination of feeds with all constraints satisfied was estimated through linear programming (Agarwal and Heady, 1972) to minimize the cost of feeding. The generalized model (Sethi and Nagarcenkar 1987) used to maximize or minimize the objective function was

\[
Z = C_i X_i \quad (10)
\]

Subject to

\[
A_i X_i \geq B_i \\
X_i \geq 0
\]

Where,

\[Z = \text{Value of the objective function, e.g. minimized cost of feeding or maximization of profit per unit time.}\]

\[C_i = \text{Vector of prices or profits associated with one unit of each activity e.g. cost per unit of feed.}\]

\[X_i = \text{Vector of activities whose level in the optimum solution is to be obtained e.g. quantity of each feed in the least cost ration.}\]
\[ B_i = \text{Vector of constraint values which are limits of inputs or outputs of each activity e.g. nutrient requirements.} \]

\[ A_{ij} = \text{Matrix of technical coefficients that indicates amount of inputs and outputs for a unit of each activity e.g. DCP, TDN, DM content in each unit of feeds. Optimum solution is obtained by one or the several iterative algorithms.} \]

For optimizing the system of feeding in variable season, the type of feeds and fodders made available, their average nutrient contents and their average cost (Green and dry roughage's per 100 kg and concentrates per 1 kg) were taken into account.

On the basis of 10 years feeding data of RCDP on cattle, the availability of green and dry fodders and concentrates for feeding of the herd contributing more than 5 per cent of the total of respective feeds and fodder of a particular month were reported by Deokar (2003). The same is used for the availability constraints.

With these constraints, a preliminary analysis through linear programming for the choice of leguminous and non-leguminous fodder was carried out. On the basis of this to make the system more viable in real operating conditions the restrictions were imposed for final analysis (Deokar 2003). The restrictions imposed on various constraints are indicated in Table 7.
<table>
<thead>
<tr>
<th>Constraints</th>
<th>Restriction</th>
</tr>
</thead>
<tbody>
<tr>
<td>DCP</td>
<td>Subject to minimum of requirement</td>
</tr>
<tr>
<td>TDN</td>
<td>Subject to minimum of requirement</td>
</tr>
<tr>
<td>DM</td>
<td>Subject to maximum of requirement</td>
</tr>
<tr>
<td>Green in respect of DM (GDM)</td>
<td>Subject to minimum / maximum of availability</td>
</tr>
<tr>
<td>Dry in respect of DM (DDM)</td>
<td>Subject to maximum of requirement</td>
</tr>
<tr>
<td>Concentrate in respect of DM (CDM)</td>
<td>Subject to maximum / minimum of requirement</td>
</tr>
</tbody>
</table>

The DCP and TDN were restricted to minimum of requirements and DM to the maximum of requirement so that total DM in the feed does not exceed the animals capacity of DM consumption. However, DM and DDM will restricted by incorporating range condition so that their quantity may not fall below 20 % of the animals consumption capacity of DM and bulky roughages, respectively.
Prediction of minimized cost of feeding

The optimum combination of feeds and their minimum cost was estimated for the requirements of all the animals in the herd in terms of DCP, TDN and DM in respect of 12 seasons. The analysis will be repeated for 3 values of constraint requirement, thereby obtaining simulation equations for each season in the form of

\[ C_i = A_iX_1 + A_iX_2 + A_iX_3 \ldots \ldots \ (11) \]

Where,

\[ C_i = \text{is the minimized cost of feeding (} i = 1 \ldots 3 \) \]
\[ A_iX_1 = \text{is the quantity of DCP requirements for all the animals in the system} \]
\[ A_iX_2 = \text{is the quantity of TDN requirements of all the animals in the system} \]
\[ A_iX_3 = \text{is the quantity of total DM requirements of all the animals in the system} \]

Three simultaneous equations were solved to obtain the coefficients for DCP, TDN and DM by the concept of matrix inversion and multiplication (Hohn, 1959) wherein, coefficients were estimated as

\[ X_i = A^{-1}C_i \ldots \ldots \ (12) \]

The cost of feeding for the specific season in the system simulation was predicted by using the following prediction equation.
\[ Y = A_1X_1 + A_2X_2 + A_3X_3 - \ldots \quad (13) \]

Where,

\[ Y = \text{Predicted cost of feeding for all the animals in the system.} \]

\[ A_1, A_2, A_3 = \text{Were the quantities of DCP, TDN and DM requirements for all the animals in the system, respectively.} \]

\[ X_1, X_2, X_3 = \text{Were the estimated coefficients for DCP, TDN \\ & DM, respectively.} \]

### 4.9 Linear programming equations

After evolving the formal linear programming model the detailed model comprising of the different variables input output coefficients etc. is formed to arrive at the mathematical inequalities and equations for the solution of the problem. These in mathematical derivations are obtained with the help of requirement of feeds and fodder and as per the nutritional requirement system for plan I and II. The linear programming equations were set for two models, plan I and plan II.

**Model under plan I**:

In plan I, along with the objective function the following constraints were taken in the study.

a) Constraints for nutrient requirement (DCP, TDN and DM).

b) Constraints for nutrients requirement (CDCP, TDN and DMS) as per feed types viz; green, dry and concentrates.
c) Constraints for requirement of leguminous and cereals type of feeds.

d) Constraints for quantitative restrictions of feeds and fodders available.

Model under Plan II.

In plan II with the same objective function as in plan I the following three main constraints were considered for the model.

a) Constraints for nutrient requirements (DCP, TDN and DM).

b) Constraints for nutrients requirement (DCP, TDN and DM) as per feed types viz; green, dry and concentrates.

c) Constraints for requirements of leguminous and cereals types feeds.

Here the fourth criteria of constraints i.e. quantitative restrictions of feeds and fodders were dropped and a second plan is developed. Sufficient quantity of feeds and fodders was not available then one can not optimize the model and then it becomes also difficult to get the proper solution. Also in plan II as we have dropped the quantity available restrictions naturally the solution obtained will give us a picture, that what types of feeds and fodders in required quantity is needed to met minimum cost and which will satisfy all the nutrient standards. For better management, it is always necessary to think to reduce cost of production with satisfying all types of standards. Also while comparing among the all feeds and fodders it is always desirable
to compare the efficiency of feeds and fodders and to make the selection of appropriate group from the feeds and fodders from what ever available in the situation. Similarly to get solution for plan I may not be possible for some times when the sufficient feeds and fodders are not available as to satisfy all the constraints. But in plan II this difficulty will not arise and it is sure that the optimal solution will be obtained for minimum cost looking to all these views plan II is always preferable than plan I.

4.10 Notations used

a) Feeds and fodders

**Green fodders**

\[\begin{align*}
G_1 &= \text{Lucerne} \\
G_2 &= \text{Berseem} \\
G_3 &= \text{Maize} \\
G_4 &= \text{Jowar} \\
G_5 &= \text{Oat} \\
G_6 &= \text{Bajra} \\
G_7 &= \text{Groundnut} \\
G_8 &= \text{Green grass}
\end{align*}\]

**Dry fodders**

\[\begin{align*}
D_1 &= \text{Jowar Jm -35} \\
D_2 &= \text{Jowar hybrid} \\
C &= \text{Concentrates ( milk ration )}
\end{align*}\]

Distribution of feeds and fodders as leguminous and non leguminous

**Leguminous fodders**: Lucerne (G_1), Berseem (G_2), Groundnut leaves(G_7).

**Non leguminous fodders**: Maize (G_3), Jowar green (G_4), Oat (G_5), Bajra (G_6), Green grass (G_8).
b) Seasons

1) June to September - Rainy - $S_1$
2) October to January - Winter - $S_2$
3) February to May - Summer - $S_3$

4.11 Constraints of the requirement of nutritional standards

In the model four types of major constraints have been used to attain the optimal solution of the model, with satisfying the nutritional standards.

Plan I: In plan I, following constraints were taken into the study

a) Constraints for nutrients requirement

(DCP, TDN and DM)

$C_1 = \text{minimum requirement of DCP}$

$C_2 = \text{minimum requirement of TDN}$

$C_3 = \text{minimum requirement of DM}$

Monthwise minimum requirement of these nutrients was taken from Table 6 and Table 5.

b) Constraints for nutrients requirements

(DCP, TDN and DM) as per feed types

$C_4 = \text{minimum requirement of DM from Green fodders}$

$C_5 = \text{minimum requirement of DM from Dry fodders}$

$C_6 = \text{minimum requirement of DM from concentrate}$

(milk ration)
These constraints were formed as per nutritional standards i.e. requirement of DM and different types of feeds and fodders as per following thumb rule (Banrjee 1978)

- **Total dry matter (DM)**
  - **2/3 (as roughages)**
  - **1/3 (as concentrates)**
    - **2/3** dry roughages or **3/4** if legume is available sufficient
    - **1/3** green roughages (If the green fodder is legume, this proportion may be **1/4** of the total roughages ration.)

**C) Constraints for requirement of leguminous and cereals types feeds and fodders with sufficient quantity as per nutritional standard.**

In the total green fodder, **2/3** green fodder should be leguminous fodder and **1/3** should be from non-leguminous fodder in the optimal solution.

In this constraint requirement of green fodder as per standard of nutrition is considered as **20 kg** per day per milch animal, out of which **2/3** should be leguminous i.e. **12.67 kg** and **1/3** non-leguminous i.e. **6.33 kg**. This constraint was added in all the linear programming model in all the month and season i.e.

\[
C_7 = \text{Total of required legumes fodder} \geq 12.67
\]
\[ C_8 = \text{Total of required non legumes fodder} \geq 6.33 \]

d) Constraints for quantity available of feeds and fodders.

In this constraints, the respective quantity of monthwise availability of feeds and fodders were taken from table 4 to see whether the available quantity of green fodders was sufficient or not to attained optimal solution with minimum cost. This restriction was not imposed on dry fodder or concentrate, as it can be purchased from market and available.

Plan II. In plan II among all the constraints first three i.e. (a), (b) and (c) were taken on it in each month except constraints (d), as to study that what types of feeds and fodders, should be make available to attain the minimum cost and optimum feeding schedule. Also when plan I does not get the required solution, because of sufficient quantity of feeds and fodders, then plan I, I will give solution over plan I and direct us to make the provision accordingly of feeds and fodders to optimize the feeding schedule with the nutritional standards. Therefore, in plan II only constraint (d), i.e. quantity available of feeds and fodders were dropped.

4.12 Monthwise and seasonwise Linear programming model

The monthwise and seasonwise linear programming equations have to be prepared separately because there is a variation in fodder crops because of as the availability of fodders have seasonal fluctuations and the requirement of nutrient content
also changes in each month due to change in physiological status of animal i.e. milching, pregnant, dry etc. Therefore, for each month separate models have to be prepared according to position of feeds and fodder availability and nutritional requirement. The monthwise and seasonwise linear programming equations used were as follows:

**January**

Objective:  
Cost (Minimize)

\[ 1.0 \, G1 + 0.90 \, G2 + 0.60 \, G3 + 0.40 \, G4 + 0.40 \, G5 + 1.10 \]
\[ D1 + 0.55 \, D2 + 5.50 \, C \]

Constraints

a) **Constraints for nutrients requirements**  
(DCP, TDN and DM)

C1  
\[ 0.032 \, G1 + 0.025 \, G2 + 0.012 \, G3 + 0.010 \, G4 + 0.026 \, G5 + \]
\[ 0.011 \, D1 + 0.011 \, D2 + 0.016 \, C \geq 0.519 \]

C2  
\[ 0.120 \, G1 + 0.119 \, G2 + 0.169 \, G3 + 0.162 \, G4 + 0.167 \, G5 + \]
\[ 0.508 \, D1 + 0.508 \, D2 + 0.670 \, C \geq 5.917 \]

C3  
\[ 0.20 \, G1 + 0.20 \, G2 + 0.25 \, G3 + 0.25 \, G4 + 0.25 \, G5 + 0.90 \]
\[ D1 + 0.90 \, D2 + 0.90 \, C \geq 10.4 \]
b) Constraints for nutrients requirements
   (DCP, TDN and DM), as per feed types

   C4 \[ 0.20 \text{G1} + 0.20 \text{G2} + 0.25 \text{G3} + 0.25 \text{G4} + 0.25 \text{G5} \geq 2.309 \]
   C5 \[ 0.90 \text{D1} + 0.90 \text{D2} \geq 4.6268 \]
   C6 \[ 0.90 \text{C} \geq 3.4632 \]

c) Constraint for requirement of leguminous and cereals type feeds and fodder

   C7 \[ \text{G1} + \text{G2} \geq 12.67 \]
   C8 \[ \text{G3} + \text{G4} + \text{G5} \geq 6.33 \]

d) Constraints for availability of feeds and fodder

   C9 \[ \text{G1} \leq 1.108 \]
   C10 \[ \text{G2} \leq 13.426 \]
   C12 \[ \text{G3} \leq 1.784 \]
   C13 \[ \text{G4} \leq 1.372 \]
   C14 \[ \text{G5} \leq 2.525 \]
2. February

Objective:
Cost (Minimize)

\[ 1.0 \, G1 + 0.90 \, G2 + 0.60 \, G3 + 0.40 \, G5 + 1.10 \, D1 + 0.55 \]
\[ D2 + 5.50 \, C \]

Constraints

a) **Constraints for nutrients requirements**
( DCP, TDN and DM)

\[ C1 \quad 0.032 \, G1 + 0.025 \, G2 + 0.012 \, G3 + 0.026 \, G5 + 0.011 \, D1 \]
\[ + 0.011 \, D2 + 0.016 \, C \geq 0.5205 \]

\[ C2 \quad 0.120 \, G1 + 0.119 \, G2 + 0.169 \, G3 + 0.167 \, G5 + 0.508 \, D1 \]
\[ + 0.508 \, D2 + 0.670 \, C \geq 5.924 \]

\[ C3 \quad 0.20 \, G1 + 0.20 \, G2 + 0.25 \, G3 + 0.25 \, G5 + 0.90 \, D1 + \]
\[ 0.90 \, D2 + 0.90 \, C \geq 10 \]

b) **Constraints for nutrients requirements**
(DCP, TDN and DM), as per feed types

\[ C4 \quad 0.20 \, G1 + 0.20 \, G2 + 0.25 \, G3 + 0.25 \, G5 \geq 2.221 \]

\[ C5 \quad 0.90 \, D1 + 0.90 \, D2 \geq 4.449 \]

\[ C6 \quad 0.90 \, C \geq 3.33 \]

c) **Constraint for requirement of leguminous and cereals type feeds**

\[ C7 \quad G1 + G2 \geq 12.67 \]

\[ C8 \quad G3 + G5 \geq 6.33 \]

d) **Constraints for availability of feeds and fodder**

\[ C10 \, G1 \leq 1.623 \quad C11 \, G2 \leq 14.891 \]

\[ C12 \, G3 \leq 1.164 \quad C13 \, G5 \leq 3.775 \]
3. March

Objective:

Cost (Minimize)

\[ 1.0 \ G1 + 0.90 \ G2 + 0.60 \ G3 + 0.40 \ G5 + 1.10 \ D1 + 0.55 \]
\[ D2 + 5.50 \ C \]

Constraints

a) Constraints for nutrients requirements (DCP, TDN and DM)

\[ C1 \ 0.032 \ G1 + 0.025 \ G2 + 0.012 \ G3 + 0.026 \ G5 + 0.011 \]
\[ D1 + 0.011 \ + D2 + 0.016 \ C \geq \ 0.525 \]
\[ C2 \ 0.120 \ G1 + 0.119 \ G2 + 0.169 \ G3 + 0.167 \ G5 + 0.508 \]
\[ D1 + 0.508 \ D2 + 0.670 \ C \geq \ 5.987 \]
\[ C3 \ 0.20 \ G1 + 0.20 \ G2 + 0.25 \ G3 + 0.25 \ G5 + 0.90 \ D1 + \]
\[ 0.90 \ D2 + 0.90 \ C \geq \ 9.600 \]

b) Constraints for nutrients requirements (DCP, TDN and DM), as per feed types

\[ C4 \ 0.20 \ G1 + 0.20 \ G2 + 0.25 \ G3 + 0.25 \ G5 \geq \ 2.132 \]
\[ C5 \ 0.90 \ D1 + 0.90 \ D2 \geq \ 4.270 \]
\[ C6 \ 0.90 \ C \geq \ 3.196 \]

c) Constraint for requirement of leguminous and cereals type feeds

\[ C7 \ G1 + G2 \geq \ 12.67 \]
\[ C8 \ G3 + G5 \geq \ 6.33 \]

d) Constraints for availability of feeds and fodder

\[ C9 \ G1 \leq \ 2.396 \]
\[ C10 \ G2 \leq \ 15.227 \]
\[ C11 \ G3 \leq \ 2.674 \]
\[ C12 \ G5 \leq \ 5.551 \]
4. April

Objective:

Cost (Minimize)

\[ 1.0 \ G1 + 0.90 \ G2 + 0.60 \ G3 + 1.10 \ D1 + 0.55 \ D2 + 5.50 \ C \]

Constraints

a) Constraints for nutrients requirements

\( (DCP, TDN \text{ and } DM) \)

\[ C1 \ 0.032 \ G1 + 0.025 \ G2 + 0.012 \ G3 + 0.011 \ D1 + 0.011 \ D2 \]

\[ + 0.016 \ C \geq 0.527 \]

\[ C2 \ 0.120 \ G1 + 0.119 \ G2 + 0.169 \ G3 + 0.508 \ D1 + 0.508 \ D2 \]

\[ + 0.670 \ C \geq 5.977 \]

\[ C3 \ 0.20 \ G1 + 0.20 \ G2 + 0.25 \ G3 + 0.90 \ D1 + 0.90 \ D2 + 0.90 \]

\[ C \geq 9.2 \]

b) Constraints for nutrients requirements

\( (DCP, TDN \text{ and } DM), \text{ as per feed types} \)

\[ C4 \ 0.20 \ G1 + 0.20 \ G2 + 0.25 \ G3 \geq 2.043 \]

\[ C5 \ 0.90 \ D1 + 0.90 \ D2 \geq 4.092 \]

\[ C6 \ 0.90 \ C \geq 3.068 \]

c) Constraint for requirement of leguminous and cereals type feeds

\[ C7 \ G1 + G2 \geq 12.67 \]

\[ C8 \ G3 \geq 16.33 \]

d) Constraints for availability of feeds and fodder

\[ C9 \ G1 \leq 4.558 \quad C10 \ G2 \leq 6.584 \]

\[ C11 \ G3 \leq 4.079 \]
May

Objective :

Cost ( Minimize)

\[ 1.0 \ G1 + 0.60 \ G3 + 0.40 \ G6 + 1.10 \ D1 + 0.55 \ D2 + 5.50 \ C \]

Constraints

a) Constraints for nutrients requirements ( DCP, TDN and DM)

\[ C1 \quad 0.032 \ G1 + 0.012 \ G3 + 0.011 \ G6 + 0.011 \ D1 + 0.011 \ D2 \\
\quad + 0.016 \ C \geq 0.519 \]

\[ C2 \quad 0.120 \ G1 + 0.169 \ G3 + 0.148 \ G6 + 0.508 \ D1 + 0.508 \ D2 \\
\quad + 0.670 \ C \geq 5.900 \]

\[ C3 \quad 0 \ G1 + 0.25 \ G3 + 0.25 \ G6 + 0.90 \ D1 + 0.90 \ D2 + 0.90 \ C \\
\quad \geq 8.800 \]

b) Constraints for nutrients requirements (DCP, TDN and DM), as per feed types

\[ C4 \quad 0.20 \ G1 + 0.25 \ G3 + 0.25 \ G6 \geq 1.954 \]

\[ C5 \quad 0.90 \ D1 + 0.90 \ D2 \geq 3.915 \]

\[ C6 \quad 0.90 \ C \geq 2.930 \]

c) Constraint for requirement of leguminous and cereals type feeds

\[ C7 \quad G1 \geq 12.67 \]

\[ C8 \quad G3 + G6 \geq 6.33 \]

d) Constraints for availability of feeds and fodder

\[ C9 \quad G1 \leq 3.794 \quad C10 \quad G3 \leq 5.607 \]

\[ C11 \quad G6 \leq 0.778 \]
June
Objective:
Cost (Minimize)

\[ 1.0 \ G1 + 0.60 \ G3 + 0.40 \ G4 + 0.40 \ G6 + 1.35 \ G7 + 1.10 \]
\[ D1 + 0.55 \ D2 + 5.50 \ C \]

Constraints

a) Constraints for nutrients requirements
(DCP, TDN and DM)

C1 \[ 0.032 \ G1 + 0.012 \ G3 + 0.010 \ G4 + 0.011 \ G6 + 0.024 \ G7 + 0.011 \ D1 + 0.011 \ D2 + 0.016 \ C \geq \ 0.522 \]
C2 \[ 0.120 \ G1 + 0.169 \ G3 + 0.162 \ G4 + 0.148 \ G6 + 0.117 \ G7 + 0.508 \ D1 + 0.508 \ D2 + 0.670 \ C \geq \ 5.914 \]
C3 \[ 0.20 \ G1 + 0.25 \ G3 + 0.25 \ G4 + 0.25 \ G6 + 0.25 \ G7 + 0.90 \ D1 + 0.90 \ D2 + 0.90 \ C \geq \ 8.400 \]

b) Constraints for nutrients requirements
(DCP, TDN and DM), as per feed types

C4 \[ 0.20 \ G1 + 0.25 \ G3 + 0.25 \ G4 + 0.25 \ G6 + 0.25 \ G7 \geq \ 1.865 \]
C5 \[ 0.90 \ D1 + 0.90 \ D2 \geq \ 3.737 \]
C6 \[ 0.90 \ C \geq \ 2.797 \]

c) Constraint for requirement of leguminous and cereals
    type feeds

C7 \[ G1 + G2 + G7 \geq \ 12.67 \]
C8 \[ G3 + G4 + G6 \geq \ 6.33 \]

d) Constraints for availability of feeds and fodder

C9 \[ G1 \leq \ 3.427 \]
C10 \[ G3 \leq \ 2.216 \]
C11 \[ G4 \leq \ 1.515 \]
C12 \[ G6 \leq \ 1.232 \]
C13 \[ G7 \leq \ 1.212 \]
July
Objective:
Cost (Minimize)

\[ 1.0 \ G1 + 0.60 \ G3 + 0.40 \ G4 + 1.35 \ G7 + 0.35 \ G8 + 1.10 \]
\[ D1 + 0.55 \ D2 + 5.50 \ C \]

Constraints

a) **Constraints for nutrients requirements**
   (DCP, TDN and DM)

\[ C1 \ 0.032 \ G1 + 0.012 \ G3 + 0.010 \ G4 + 0.024 \ G7 + 0.005 \ G8 \]
\[ + 0.011 \ D1 + 0.011 \ D2 + 0.016 \ C \geq 0.517 \]
\[ C2 \ 0.120 \ G1 + 0.169 \ G3 + 0.162 \ G4 + 0.117 \ G7 + 0.100 \ G8 \]
\[ + 0.508 \ D1 + 0.508 \ D2 + 0.670 \ C \geq 5.851 \]
\[ C3 \ 0.20 \ G1 + 0.25 \ G3 + 0.25 \ G4 + 0.25 \ G7 + 0.25 \ G8 + 0.90 \]
\[ D1 + 0.90 \ D2 + 0.90 \ C \geq 8.800 \]

b) **Constraints for nutrients requirements**
   (DCP, TDN and DM), as per feed types

\[ C4 \ 0.20 \ G1 + 0.25 \ G3 + 0.25 \ G4 + 0.25 \ G7 + 0.25 \ G8 \geq 1.954 \]
\[ C5 \ 0.90 \ D1 + 0.90 \ D2 \geq 3.915 \]
\[ C6 \ 0.90 \ C \geq 2.930 \]

c) **Constraint for requirement of leguminous and cereals**
   **type feeds**

\[ C7 \ G1 + G2 + G7 \geq 12.67 \]
\[ C8 \ G3 + G4 + G8 \geq 6.33 \]

d) **Constraints for availability of feeds and fodder**

\[ C9 \ G1 \leq 3.231 \]
\[ C10 \ G3 \leq 3.565 \]
\[ C11 \ G4 \leq 2.756 \]
\[ C12 \ G7 \leq 3.129 \]
\[ C13 \ G8 \leq 1.417 \]
August
Objective:
Cost (Minimize)

\[ 1.0 \ G_1 + 0.60 \ G_3 + 0.40 \ G_4 + 0.40 \ G_6 + 0.35 \ G_8 + 1.10 \]
\[ D_1 + 0.55 \ D_2 + 5.50 \ C \]

Constraints
a) **Constraints for nutrients requirements**
   (DCP, TDN and DM)

   \[ C_1 \ 0.032 \ G_1 + 0.012 \ G_3 + 0.010 \ G_4 + 0.011 \ G_6 + 0.005 \ G_8 \]
   \[ + 0.011 \ D_1 + 0.011 \ D_2 + 0.016 \ C \geq 0.515 \]

   \[ C_2 \ 0.120 \ G_1 + 0.169 \ G_3 + 0.162 \ G_4 + 0.148 \ G_6 + 0.100 \ G_8 \]
   \[ + 0.508 \ D_1 + 0.508 \ D_2 + 0.670 \ C \geq 5.844 \]

   \[ C_3 \ 0.20 \ G_1 + 0.25 \ G_3 + 0.25 \ G_4 + 0.25 \ G_6 + 0.25 \ G_8 + 0.90 \]
   \[ D_1 + 0.90 \ D_2 + 0.90 \ C \geq 9.200 \]

b) **Constraints for nutrients requirements**
   (DCP, TDN and DM), as per feed types

   \[ C_4 \ 0.20 \ G_1 + 0.25 \ G_3 + 0.25 \ G_4 + 0.25 \ G_6 + 0.25 \ G_8 \geq 2.043 \]

   \[ C_5 \ 0.90 \ D_1 + 0.90 \ D_2 \geq 4.092 \]

   \[ C_6 \ 0.90 \ C \geq 3.063 \]

c) **Constraint for requirement of leguminous and cereals type feeds**

   \[ C_7 \ G_1 \geq 12.67 \]

   \[ C_8 \ G_3 + G_4 + G_6 + G_8 \geq 6.33 \]

d) **Constraints for availability of feeds and fodder**

   \[ C_9 \ G_1 \leq 2.199 \]

   \[ C_10 \ G_3 \leq 9.541 \]

   \[ C_11 \ G_4 \leq 3.075 \]

   \[ C_12 \ G_6 \leq 1.019 \]

   \[ C_13 \ G_8 \leq 1.976 \]
September
Objective:
Cost (Minimize)

\[ 1.0 \text{ G1} + 0.60 \text{ G3} + 0.40 \text{ G4} + 0.40 \text{ G6} + 1.10 \text{ D1} + 0.55 \text{ D2} + 5.50 \text{ C} \]

Constraints
a) Constraints for nutrients requirements
   (DCP, TDN and DM)

   \[ \begin{align*}
   \text{C1} & : 0.032 \text{ G1} + 0.012 \text{ G3} + 0.010 \text{ G4} + 0.011 \text{ G6} + 0.011 \text{ D1} \\
   & + 0.011 \text{ D2} + 0.016 \text{ C} \geq 0.514 \\
   \text{C2} & : 0.120 \text{ G1} + 0.169 \text{ G3} + 0.162 \text{ G4} + 0.148 \text{ G6} + 0.508 \text{ D1} \\
   & + 0.508 \text{ D2} + 0.670 \text{ C} \geq 5.837 \\
   \text{C3} & : 0.20 \text{ G1} + 0.25 \text{ G3} + 0.25 \text{ G4} + 0.25 \text{ G6} + 0.90 \text{ D1} + 0.90 \text{ D2} + 0.90 \text{ C} \geq 9.200
   \end{align*} \]

b) Constraints for nutrients requirements
   (DCP, TDN and DM), as per feed types

   \[ \begin{align*}
   \text{C4} & : 0.20 \text{ G1} + 0.25 \text{ G3} + 0.25 \text{ G4} + 0.25 \text{ G6} \geq 2.043 \\
   \text{C5} & : 0.90 \text{ D1} + 0.90 \text{ D2} \geq 4.092 \\
   \text{C6} & : 0.90 \text{ C} \geq 3.063
   \end{align*} \]

c) Constraint for requirement of leguminous and cereals type feeds

   \[ \begin{align*}
   \text{C7} & : \text{ G1} \geq 12.67 \\
   \text{C8} & : \text{ G3} + \text{ G4} + \text{ G6} \geq 6.33
   \end{align*} \]

d) Constraints for availability of feeds and fodder

   \[ \begin{align*}
   \text{C9} & : \text{ G1} \leq 1.730 \\
   \text{C10} & : \text{ G3} \leq 13.447 \\
   \text{C11} & : \text{ G4} \leq 3.802 \\
   \text{C12} & : \text{ G6} \leq 1.219
   \end{align*} \]
October
Objective:
Cost (Minimize)

\[ 1.0 \ G1 + 0.90 \ G2 + 0.40 \ G4 + 1.10 \ D1 + 0.55 \ D2 + 5.50 \ C \]

Constraints
a) Constraints for nutrients requirements
   (DCP, TDN and DM)
   \[ \begin{align*}
   C1 & : 0.032 \ G1 + 0.012 \ G3 + 0.010 \ G4 + 0.011 \ D1 + 0.011 \ D2 + 0.016 \ C \geq 0.5169 \\
   C2 & : 0.120 \ G1 + 0.169 \ G3 + 0.162 \ G4 + 0.508 \ D1 + 0.508 \ D2 + 0.670 \ C \geq 5.868 \\
   C3 & : 0.20 \ G1 + 0.25 \ G3 + 0.25 \ G4 + 0.90 \ D1 + 0.90 \ D2 + 0.90 \ C \geq 9.600
   \end{align*} \]

b) Constraints for nutrients requirements
   (DCP, TDN and DM), as per feed types
   \[ \begin{align*}
   C4 & : 0.20 \ G1 + 0.25 \ G3 + 0.25 \ G4 \geq 2.132 \\
   C5 & : 0.90 \ D1 + 0.90 \ D2 \geq 4.270 \\
   C6 & : 0.90 \ C \geq 3.196
   \end{align*} \]
c) Constraint for requirement of leguminous and cereals type feeds
   \[ \begin{align*}
   C7 & : G1 \geq 12.67 \\
   C8 & : G3 + G4 \geq 6.33
   \end{align*} \]
d) Constraints for availability of feeds and fodder
   \[ \begin{align*}
   C9 & : G1 \leq 1.182 \\
   C10 & : G3 \leq 14.080 \\
   C11 & : G4 \leq 3.490
   \end{align*} \]
November
Objective:
Cost (Minimize)

\[ 1.0 \, G1 + 0.90 \, G2 + 0.60 \, G3 + 0.40 \, G4 + 0.35 \, G8 + 1.10 \]
\[ D1 + 0.55 \, D2 + 5.50 \, C \]

Constraints

a) Constraints for nutrients requirements (DCP, TDN and DM)

\[ C1 \quad 0.032 \, G1 + 0.025 \, G2 + 0.012 \, G3 + 0.010 \, G4 + 0.005 \, G8 \]
\[ + 0.011 \, D1 + 0.011 \, D2 + 0.016 \, C \geq 0.512 \]
\[ C2 \quad 0.120 \, G1 + 0.119 \, G2 + 0.169 \, G3 + 0.162 \, G4 + 0.100 \, G8 \]
\[ + 0.508 \, D1 + 0.508 \, D2 + 0.670 \, C \geq 5.847 \]
\[ C3 \quad 0.20 \, G1 + 0.20 \, G2 + 0.25 \, G3 + 0.25 \, G4 + 0.25 \, G8 + 0.90 \]
\[ D1 + 0.90 \, D2 + 0.90 \, C \geq 10.000 \]

b) Constraints for nutrients requirements (DCP, TDN and DM), as per feed types

\[ C4 \quad 0.20 \, G1 + 0.20 \, G2 + 0.25 \, G3 + 0.25 \, G4 + 0.25 \, G8 \geq 2.221 \]
\[ C5 \quad 0.90 \, D1 + 0.90 \, D2 \geq 4.448 \]
\[ C6 \quad 0.90 \, C \geq 3.330 \]

c) Constraint for requirement of leguminous and cereals type feeds

\[ C7 \quad G1 + G2 \geq 12.67 \]
\[ C8 \quad G3 + G4 + G8 \geq 6.33 \]

d) Constraints for availability of feeds and fodder

\[ C9 \quad G1 \leq 1.369 \quad C10 \quad G2 \leq 1.271 \]
\[ C11 \quad G3 \leq 7.953 \quad C12 \quad G4 \leq 3.826 \]
\[ C13 \quad G8 \leq 0.720 \]

\[ 335500 \]
December
Objective:
Cost (Minimize)

\[ 1.0 \ G1 + 0.90 \ G2 + 0.60 \ G3 + 0.40 \ G4 + 1.10 \ D1 + 0.55 \]
\[ D2 + 5.50 \ C \]

Constraints
a) **Constraints for nutrients requirements**
   (DCP, TDN and DM)

\[ C1 \quad 0.032 \ G1 + 0.025 \ G2 + 0.012 \ G3 + 0.010 \ G4 + 0.011 \ D1 \]
\[ + 0.011 \ D2 + 0.016 \ C \geq 0.516 \]
\[ C2 \quad 0.120 \ G1 + 0.119 \ G2 + 0.169 \ G3 + 0.162 \ G4 + 0.508 \ D1 \]
\[ + 0.508 \ D2 + 0.670 \ C \geq 5.886 \]
\[ C3 \quad 0.20 \ G1 + 0.20 \ G2 + 0.25 \ G3 + 0.25 \ G4 + 0.90 \ D1 + 0.90 \]
\[ D2 + 0.90 \ C \geq 10.400 \]

b) **Constraints for nutrients requirements**
   (DCP, TDN and DM), as per feed types

\[ C4 \quad 0.20 \ G1 + 0.20 \ G2 + 0.25 \ G3 + 0.25 \ G4 \geq 2.309 \]
\[ C5 \quad 0.90 \ D1 + 0.90 \ D2 \geq 4.626 \]
\[ C6 \quad 0.90 \ C \geq 3.463 \]

c) **Constraint for requirement of leguminous and cereals type feeds**

\[ C7 \quad G1 + G2 \geq 12.67 \]
\[ C8 \quad G3 + G4 \geq 6.33 \]

d) **Constraints for availability of feeds and fodder**

\[ C9 \quad G1 \leq 0.724 \quad C10 \quad G2 \leq 7.486 \]
\[ C11 \quad G3 \leq 3.658 \quad C12 \quad G4 \leq 2.832 \]
Rainy Season:
Objective:
Cost (Minimize)

\[ 1.0 \, G1 + 0.60 \, G3 + 0.40 \, G4 + 0.40 \, G6 + 1.35 \, G7 + 0.35 \, G8 + 1.10 \, D1 + 0.55 \, D2 + 5.50 \, C. \]

Constraints

a) Constraints for nutrients requirements (DCP, TDN and DM)

C1 \[ 0.032 \, G1 + 0.012 \, G3 + 0.010 \, G4 + 0.011 \, G6 + 0.024 \, G7 + 0.005 \, G8 \, 0.011 \, D1 + 0.011 \, D2 + 0.016 \, C \geq 0.515 \]

C2 \[ 0.120 \, G1 + 0.169 \, G3 + 0.162 \, G4 + 0.148 \, G6 + 0.0117 \, G7 + 0.100 \, G8 \, 0.508 \, D1 + 0.508 \, D2 + 0.670 \, C \geq 5.844 \]

C3 \[ 0.20 \, G1 + 0.25 \, G3 + 0.25 \, G4 + 0.25 \, G6 + 0.25 \, G7 + 0.25 \, G8 \, 0.90 \, D1 + 0.90 \, D2 + 0.90 \, C \geq 8.900 \]

b) Constraints for nutrients requirements (DCP, TDN and DM), as per feed types

C4 \[ 0.20 \, G1 + 0.25 \, G3 + 0.25 \, G4 + 0.25 \, G6 + 0.25 \, G7 + 0.25 \, G8 \geq 1.976 \]

C5 \[ 0.90 \, D1 + 0.90 \, D2 \geq 3.959 \]

C6 \[ 0.90 \, C \geq 2.963 \]

c) Constraint for requirement of leguminous and cereals type feeds

C7 \[ G1 + G7 \geq 12.67 \]

C8 \[ G3 + G4 + G6 + G8 \geq 6.33 \]

d) Constraints for availability of feeds and fodder

C9 \[ G1 \leq 3.030 \]

C10 \[ G3 \leq 6.462 \]

C11 \[ G4 \leq 2.846 \]

C12 \[ G6 \leq 0.994 \]

C13 \[ G7 \leq 1.333 \]

C14 \[ G8 \leq 0.819 \]
Winter Season:
Objective:
Cost (Minimize)
\[ 1.0 \ G1 + 0.60 \ G3 + 0.40 \ G4 + 0.40 \ G5 + 0.35 \ G8 + 1.10 \]
\[ D1 + 0.55 \ D2 + 5.50 \ C \]

Constraints
a) Constraints for nutrients requirements
(DCP, TDN and DM)
\[ C1 \ 0.032 \ G1 + 0.025 \ G2 + 0.012 \ G3 + 0.010 \ G4 + 0.026 + \]
\[ 0.005 \ G8 + 0.011 \ D1 + 0.011 \ D2 + 0.016 \ C \geq 0.515 \]
\[ C2 \ 0.120 \ G1 + 0.119 \ G2 + 0.169 \ G3 + 0.162 \ G4 + 0.100 \ G8 \]
\[ 0.508 \ D1 + 0.508 \ D2 + 0.670 \ C \geq 5.861 \]
\[ C3 \ 0.20 \ G1 + 0.20 \ G2 + 0.25 \ G3 + 0.25 \ G4 + 0.25 \ G6 + 0.25 \]
\[ G8 + 0.90 \ D1 + 0.90 \ D2 + 0.90 \ C \geq 10.100 \]
b) Constraints for nutrients requirements
(DCP, TDN and DM), as per feed types
\[ C4 \ 0.20 \ G1 + 0.20 \ G2 + 0.25 \ G3 + 0.25 \ G4 + 0.25 \ G5 + 0.25 \]
\[ G8 \geq 2.243 \]
\[ C5 \ 0.90 \ D1 + 0.90 \ D2 \geq 4.493 \]
\[ C6 \ 0.90 \ C \geq 3.363 \]
c) Constraint for requirement of leguminous and cereals
type feeds
\[ C7 \ G1 + G2 \geq 12.67 \]
\[ C8 \ G3 + G4 + G5 + G8 \geq 6.33 \]
d) Constraints for availability of feeds and fodder
\[ C9 \ G1 \leq 0.579 \]
\[ C10 \ G2 \leq 7.324 \]
\[ C11 \ G3 \leq 6.838 \]
\[ C12 \ G4 \leq 2.979 \]
\[ C13 \ G5 \leq 2.233 \]
\[ C14 \ G8 \leq 0.206 \]
Summer Season :
Objective :
Cost (Minimize)

\[ 1.0 \ G_1 + 0.90 \ G_2 + 0.60 \ G_3 + 0.40 \ G_5 + 0.35 \ G_7 + 1.10 \]
\[ \ D_1 + 0.55 \ D_2 + 5.50 \ C \]

Constraints
a) Constraints for nutrients requirements
   (DCP, TDN and DM)
   \[ C_1 \ 0.032 \ G_1 + 0.025 \ G_2 + 0.012 \ G_3 + 0.026 \ G_5 + 0.011 \ G_6 \]
   \[ + \ D_1 + 0.011 \ D_2 + 0.016 \ C \geq 0.521 \]
   \[ C_2 \ 0.120 \ G_1 + 0.119 \ G_2 + 0.169 \ G_3 + 0.167 \ G_5 + 0.148 \ G_6 + \]
   \[ 0.508 \ D_1 + 0.508 \ D_2 + 0.670 \ C \geq 5.931 \]
   \[ C_3 \ 0.20 \ G_1 + 0.20 \ G_2 + 0.25 \ G_3 + 0.25 \ G_5 + 0.25 \ G_6 + 0.90 \]
   \[ D_1 + 0.90 \ D_2 + 0.90 \ C \geq 9.400 \]

b) Constraints for nutrients requirements
   (DCP, TDN and DM), as per feed types
   \[ C_4 \ 0.20 \ G_1 + 0.20 \ G_2 + 0.25 \ G_3 + 0.25 \ G_5 + 0.25 \ G_6 \geq 2.087 \]
   \[ C_5 \ 0.90 \ D_1 + 0.90 \ D_2 \geq 4.181 \]
   \[ C_6 \ 0.90 \ C \geq 3.130 \]

c) Constraint for requirement of leguminous and cereals
   type feeds
   \[ C_7 \ G_1 + G_2 \geq 12.67 \]
   \[ C_8 \ G_3 + G_5 + G_6 \geq 6.33 \]

d) Constraints for availability of feeds and fodder
   \[ C_9 \ G_1 \leq 3.642 \]
   \[ C_{10} \ G_2 \leq 7.878 \]
   \[ C_{11} \ G_3 \leq 4.205 \]
   \[ C_{12} \ G_5 \leq 1.384 \]
   \[ C_{13} \ G_6 \leq 0.318 \]
B) Plan II

The constraints of (d) quantity available of fodders as mention in all above months and seasons were not considered. Since in this case, what should be feeds and fodders to make available with sufficient quantity, which will minimize cost and satisfy all the nutrients conditions. Therefore, the same linear programming models have been used except the constraints of quantitative availability restriction of feeds and fodders i.e. (d).

4.13 Productivity estimation

Productivity of the system was estimated by considering all the components of input and output variables. The total cost or expenditure (TE) per day per milching animal, total income (TI) per day per milching animal, the productivity ratio (PR) and the net profit per day was estimated as follows:

Total cost : The total cost (TC) per day per milching animal (TC) is calculated by taking various input cost estimates.

Total Expenditure (TE) per day per milch animal

TE : Minimum feeding cost per day per milch animal, as per optimal solution i.e. Table 9.

+ Labour cost per day per milch animal
+ House rent cost per day per unit (depreciation)
+ Interest per day per milch animal unit
+ Insurance cost per day per milch unit
+ Veterinary aids cost per day per animal.
**Income**

For estimating the income milk and manure is considered in calculation.

Total income per day per milch animal

\[ TI = \text{Cost of milk yield per day per milch unit} + \text{cost of manure yield per day per milch animal} \]

**Productivity ratio**

The productivity ratio of the per day per milch unit is calculated as follows:

\[ \text{Productivity Ratio} = \frac{\text{Total income per day per milch unit}}{\text{Total Expenditure per day per milch unit}} \]

**Net Profit**

Per day milch animal net profit as defined as

Net profit per day = Total income per day - Total Expenditure per per milch animal Per milch unit day per milch unit

**Production traits**

To predict the optimum combination of different physiological traits lactation milk yield, lactation length, dry period and service period were considered to observe seasonwise productivity ratio per day per milch animal. These traits were varied at the difference of $\frac{1}{2}$ in all possible combination.
Assumptions

Following assumptions were considered to be operating in the model:

a) Physiological requirement of the individuals: (Mean (μ) + standard deviation (σ))
   i) Lactation milk yield = 3050 ± 30 lit.
   ii) Lactation length = 305 ± 10 days.
   iii) Dry period = 60 ± 10 days.
   iv) Service period = 75 ± 10 days.

b) Genetic potential

Animals with 3 genetic potentials were assumed for the optimization in various physiological traits, which are as follows:

i) Poor genetic potential (PGP): All production, reproduction traits = μ + σ the codes used in the analysis were as follows:

   Codes as 5 = μ + 2σ
   4 = μ + 1.5σ
   3 = μ + σ
   2 = μ + 0.5σ
   1 = μ

ii) Average genetic potential – all traits - μ
the codes used in the analysis were as follows

   Codes as 5 = μ + 1σ
   4 = μ + 0.5σ
3 = μ
2 = μ - 1½ σ
1 = μ - 1 σ

iii) High genetic potential :- all traits = μ - σ

The code used in the analysis were as follows

Codes as
5 = μ
4 = μ - ½ σ
3 = μ - 1 σ
2 = μ - 1½ σ
1 = μ - 2 σ

C) Relation between the productive and reproductive traits

The following relations were taken in to account while calculating optimum traits for productivity ratio.

1) If service period ≥ 75 days then
   Dry period = Dry period in days + No. of days more than 75 in service period.

2) If Service period ≤ 75, then
   Lactation Length = lactation length - No. of days of service period which are less than 75.
   While calculating productivity ratio
   The income and Expenditure is calculated as follows:
I) Income =

(Lactation milk yield in Liter) * (cost of milk per liter) + (Lactation Length + Dry period in days) *
(Cost of manure yield per day). i.e.
= (LMY * 10) + (LL + DP) * 3

II) Expenditure Cost =

(Lactation length ) * (Per day per milch animal expenditure) + (Dry period) * (per day per milch animal expenditure) i.e.

= ( LL * Total cost ) + (DP * Total cost )
= ( LL + DP ) * (Total cost )