# User's Manual for the Program Package ECOWEIGHT (C Programs for Calculating Economic Weights in Livestock), Version 5.1.1. Part 2: Program EWSH1 for Sheep, Version 1.1.6

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25th August 2011

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# Preface

The program package ECOWEIGHT was written within the framework of the research projects MZE-M02-99-02, MZE0002701401 and MZE0002701404 that were supported by the Ministry of Agriculture of the Czech Republic. In the Slovak Republic, financial support was given by the Ministry of Agriculture within the framework of the research project 2006 UO27/0910502/0910517. Travelling was funded by the Ministries of Education of the Czech Republic and Slovak Republic (Program KONTAKT, project number MEB 080802 or SK-CZ-0007-07).

The program for sheep was mainly written by Jochen Wolf on the base of algorithms prepared by Marie Wolfová (both from the Institute of Animal Science in Prague Uhříněves) and Zuzana Krupová (Animal Production Research Centre Nitra). Parts of the programs were written by Emil Krupa from the Animal Production Research Centre Nitra.

Though only four people were engaged directly in writing the program, several colleagues have helped in different ways in preparing the algorithm for the program. M. Margetín, M. Oravcová (both Nitra) and M. Milerski (Prague-Uhříněves) have given advises concerning the management systems and made available information on the breeding value estimation and on selection programs in sheep. Jan Kica and Jozef Daňo from the Animal Production Research Centre Nitra cooperated in the fields of nutrient requirement and economics, respectively. The technical assistance of Petra Mrázková and Renata Prošková (Prague-Uhříněves) is acknowledged.

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# Chapter 1

# Introduction

The program package ECOWEIGHT is intended for the calculation of economic values of economically important traits in livestock. At the given stage, in its fifth version, two programs for cattle and three programs for sheep are available (see Table 1.1). The two programs for cattle (EWBC and EWDC) are described in the first part of the manual. Whereas in the present manual (which forms the second part of the documentation) the stand-alone program EWSH1 for sheep with one lambing per year is presented, the third part of the program package which is documented in two manuals is formed by the program EWSH2 [23] which is a modification of EWSH1 and by the program GFSH [21] which models gene flow in sheep. As the programs EWSH2 and GFSH are run together they are in a joint installation package.

Table 1.1: Survey on the program package ECOWEIGHT, version 5.1.1

| Part[a] | Installation Package[b] | Program(s) | Species, remarks |
|---|---|---|---|
| 01 | ECOWEIGHT01_5_1_1.tgz | EWBC | beef cattle |
| | | EWDC | dairy cattle |
| 02 | ECOWEIGHT02_5_1_1.tgz | EWSH1 | sheep, one lambing per year, stand-alone program |
| 03A | ECOWEIGHT03_5_1_1.tgz for both parts 03A and 03B | EWSH2 | sheep, one lambing per year, used in combination with GFSH |
| 03B | | GFSH | sheep, program for gene flow, used in combination with EWSH2 |

[a]There is one manual for each part; its name is ECOWEIGHT[part].pdf where [part] is to be replaced by the two or three digits given in this column.
[b]Replace 'tgz' by 'zip' for Windows.

The program EWSH1 is the implementation of a bio-economic model on the PC to simulate effects on life-cycle efficiency from genetic change in production and functional traits of sheep under alternative management systems with one lambing per year. The flock structure is described in terms of animal categories and probabilities of transitions among them. The Markov chain approach is used to calculate the stationary state of the ewe flock (see Chapter 3). Up to 47 categories of progeny may be defined whereby pure-bred and cross-bred animals may occur in most categories if cross-breeding is used in the system. The calculation of the

structure of progeny is described in Chapter 4.

The algorithm includes both deterministic and stochastic components. Performance for most traits is simulated as the population mean, but variation in several traits is taken into account. Several performance characteristics for all animal categories (mainly growth and milk production) are calculated in Chapters 5 and 6. Management options include the mating system and culling strategy for ewes, weaning and marketing strategy of progeny, and feeding system. The recent version of the program is for systems with one lambing per year, accelerated lambing cannot be handled at present.

Profit estimated as the difference between the total revenues and total costs per ewe[1] per reproductive cycle is used as criterion of the economic efficiency of the production system in the stationary state. The profit includes also governmental subsidies. Details on the calculation of nutrition costs, non-feed costs and revenues are given in Chapters 9, 10 and 11. The economic importance (economic values) of up to 35 traits (milk production traits, growth traits, carcass traits, functional traits and wool traits) may be estimated. These economic values are intended for developing a breeding objective for sheep. A list of the traits is given in Appendix A and the calculation of the economic weights is described in Chapter 12.

A large number of input parameters (see Chapter 14) can be given by the user allowing a detailed description of the production system and the economic, management and biological conditions. The program will be also useful for some economic analyses in different production systems. The impact of production, management and economic circumstances on the economic efficiency of a given production system can be studied.

The users of the program EWSH1 are recommended to read the papers of Wolfová et al. published 2009 in the Journal of Dairy Science [25, 26] which describe the basic theory underlying the program and show applications.

Version 5.1.1 of the program package ECOWEIGHT contains version 1.1.6 of the EWSH1 program. For installing and running the program read Chapter 13. The program was tested to run under LINUX and Microsoft Windows, but probably it should run also on other platforms if there is a C compiler available.

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[1] present in the flock at lambing time

# Chapter 2

# General principles of modelling production systems

In the current program version, production systems are assumed to be self-reproducing systems which produce female and male replacement for the modelled population (breed). In each system, pure-breeding as well as cross-breeding can be applied. Figure 2.1 shows an example for such a production system. This production system includes farms with breed B which are vertically distinguished in nucleus and commercial farms. Both types of farms are assumed to belong to one and the same production system in our model. Though commercial farms buy male replacement from nucleus farms, purchasing of breeding animals of the same breed is not taken into account. The costs for purchasing animals in some farms are equal to the revenues from selling animals in other farms. This part of costs and revenues is nullified in the profit function for the whole system. Males for crossing, however, are presumed to be bought from outside the modelled population. Therefore, the costs for purchasing rams of breed A for crossing are included into the profit function of the production system for breed B. The proportion of crossing in a self-reproducing system can never be 100%.

Though a self-reproducing system is assumed, purchasing a part of the female and male replacement from outside the system is allowed to account for import of superior breeding animals. The proportions of bought female and male replacements which are input parameters in the program should be always kept low. Female replacement are expected to be purchased as young female lambs which are (to simplify the calculation) included into the category of own replacement female lambs at time of lamb weaning. Therefore, the price of a purchased female lamb is not an input parameter but is set to the costs for rearing a female lamb till weaning increased by a factor which reflects the differences of the rearing costs and the true value of imported animals (this factor is an input parameter too). Male replacement are expected to be purchased at an age and weight suitable for breeding before the start of the breeding (mating) season in the flock. To simplify the calculation, they are included directly to the corresponding category of rams. The price, live weight and age of the purchased male replacement are input parameters.
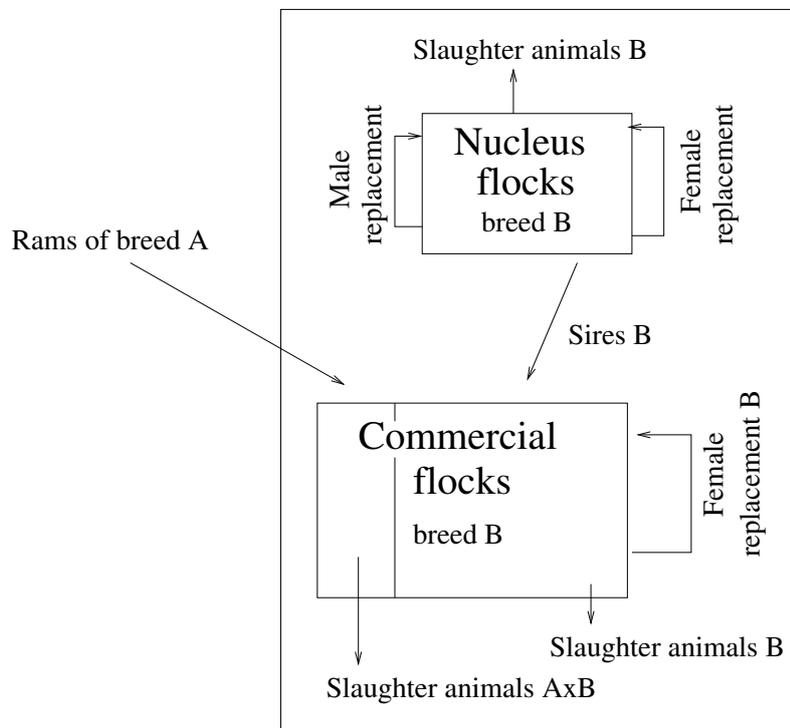
Figure 2.1: Example for a production system with terminal crossing

# Chapter 3

# Structure of the ewe flock and the ram population

## 3.1 Structure of the ewe flock[1]

For calculating the structure of the ewe flock, different categories of animals were defined. The maximal number of the reproductive cycles is an input parameter ($LL$) which is expected to be in the range between 4 to 15. Low numbers of $LL$ may cause problems as the ewe flock might not be able to produce sufficient replacement. Numbers between 10 and 15 should be reasonable values for $LL$.

Categories of ewes distinguished are related to the reproductive cycles of ewes that cover the intervals between two subsequent lambing dates in the flock. A replacement female enters the flock at her first lambing and can stay in the flock until she is replaced or has reached the maximum of reproductive cycles.[2] Each category is characterised by a combination of two variables: *the number of the reproductive cycle r* ($r = 1, ..., LL$) and the defined *stage s* the ewe is in within the given reproductive cycle ($s = 1, ..., nstgE$ for $r < LL$ or $s = 1, ..., nstg1E$ for $r = LL$). The two parameters $nstg1E$ (number of stages for ewes which occur in all reproductive cycles) and $nstg2E$ (number of stages for ewes which do not occur in the last reproductive cycle) are fixed to 3 and 2, respectively, in the given version of the program. The maximal number of stages which can occur in a reproductive cycle ($nstgE$) is then:

$$nstgE = nstg1E + nstg2E = 5 .\tag{3.1}$$

The total number of ewe categories ($TE$) is therefore

$$TE = nstgE(LL - 1) + nstg1E = 5(LL - 1) + 3 .\tag{3.2}$$

### 3.1.1 Definition of reproductive cycles

A maximal number of $LL$ lambings per ewe is assumed ($LL$ is in the interval from 4 to 15). On this basis, the following $LL$ reproductive cycles are defined:

1            Ewes between 1st and 2nd lambing

---

[1]From technical reasons, some calculations concerning the growth of the progeny have to be carried out before the calculation of the structure of the ewe flock and the ram population. The formulae for these calculations are given in Section 5.2 on page 40.

[2]The maximum of allowable reproductive cycles is not always identical to the number of parities for a particular ewe as some ewes can pass the reproductive cycle without lambing, i.e. they can skip a parity. That means, reproductive cycle is defined for the flock and not for individual ewes.

2        Ewes between 2nd and 3rd lambing

3        ...

...        ...

$LL-1$    Ewes between $(LL-1)$th and $LL$th lambing

$LL$      Ewes from $LL$th lambing to culling

### 3.1.2 Definition of categories of animals

#### 3.1.2.1 Developmental stages of ewes within reproductive cycle $r$ ($r = 1, ..., LL-1$)

1        Ewes died within the reproductive cycle

2        Ewes culled within the reproductive cycle due to health problems (in all breed types) or low milk production (in dairy ewes only)

3        Ewes culled because of lack of pregnancy

4        Not pregnant ewes entering the next reproductive cycle

5        Pregnant ewes entering the next reproductive cycle

#### 3.1.2.2 Developmental stages of ewes within reproductive cycle $LL$

1        Ewes died within the reproductive cycle

2        Ewes culled within the reproductive cycle due to health problems or low milk production

3        Ewes culled after lactation for age

### 3.1.3 Calculation of transition matrix $T_E$ and of the stationary state of the ewe flock

The definition of the categories of ewes is the first step on the way to the structure of the ewe flock. In the next step, the so-called transition probabilities must be calculated which are the elements of the transition matrix $\mathbf{T_E}$ (see paragraph 3.1.3.3). To fill the elements of the matrix, the values of several variables will be needed first.

#### 3.1.3.1 Calculation of several variables[3] needed for transition matrix $\mathbf{T_E}$

- Interval between the start of the breeding season and lambing (*intml*, in days)

$$intml = datlamb - datbbs + lengthrc \tag{3.3}$$

- Interval between lambing and mating (*intlm*, in days)

$$intlm = lengthrc - intml \tag{3.4}$$

---

[3] All variables used in equations in this manual are listed in alphabetic order in Appendix B on page 174.

- Fraction of ewes entering reproductive cycle $i$ ($i = 1, \ldots, LL$) that were involuntarily culled for reasons other than infertility ($pcullE[i]$)

$$pcullE[i] = \begin{cases} pcullhE[i] + pcullmE[i] & \text{for dairy ewes} \\ pcullhE[i] & \text{for non-dairy ewes} \end{cases} \qquad (3.5)$$

- Fraction of ewes entering reproductive cycle $i$ ($i = 1, \ldots, LL - 1$) that will be mated in this cycle ($pmatE[i]$)[4]

$$pmatE[i] = 1 - \frac{intlm}{lengthrc}\left(pcullE[i] + pdiedE[i]\right) \qquad (3.6)$$

- Fraction of ewes entering reproductive cycle $i$ ($i = 1, \ldots, LL - 1$) that will become pregnant in this cycle ($pconE[i]$)

$$pconE[i] = pmatE[i] \times conrateE[i] \qquad (3.7)$$

- Fraction of ewes entering reproductive cycle $i$ ($i = 1, \ldots, LL - 1$) that will not become pregnant in this cycle ($pnconE[i]$)

$$pnconE[i] = pmatE[i](1 - conrateE[i]) \qquad (3.8)$$

- Probability that a ewe entering reproductive cycle $i$ ($i = 1, \ldots, LL - 1$) will not become pregnant in this cycle and will be culled ($pnconculE[i]$)

$$pnconculE[i] = pnconE[i](1 - pbarrE[i]) \qquad (3.9)$$

- Probability that a ewe entering reproductive cycle $LL$ will be culled for age in this cycle ($pnconculE[LL]$)

$$pnconculE[LL] = 1 - pcullE[LL] - pdiedE[LL] \qquad (3.10)$$

- Probability that a ewe entering reproductive cycle $i$ ($i = 1, \ldots, LL - 1$) will not become pregnant in this cycle and will stay to the next cycle ($pnconstayE[i]$)

$$pnconstayE[i] = pnconE[i] \times pbarrE[i]\left(1 - \frac{intml}{lengthrc}(pcullE[i] + pdiedE[i])\right) \qquad (3.11)$$

- Probability that a ewe entering reproductive cycle $i$ ($i = 1, \ldots, LL - 1$) will become pregnant in the cycle and stay to the next cycle ($pconstayE[i]$)

$$pconstayE[i] = 1 - pnconstayE[i] - pnconculE[i] - pcullE[i] - pdiedE[i] \qquad (3.12)$$

### 3.1.3.2 Calculation of the elements of the transition matrix

We write $te[i][j]$ for the elements of the transition matrix $\mathbf{T_E}$, $i$ being the index for the row and $j$ being the index for the column. For the first five ($= nstgE$) columns, the non-zero elements are:

$$\begin{aligned} te[i][1] &= pdiedE[1] \\ te[i][2] &= pcullE[1] \\ te[i][3] &= pnconculE[1] \\ te[i][4] &= pnconstayE[1] \\ te[i][5] &= pconstayE[1] \end{aligned} \qquad (3.13)$$

---

[4]It is assumed that culling and dying of ewes are uniformly distributed over the whole reproductive cycle.

where $i = nstgE \times i3 + i1 = 5 \times i3 + i1$ with $i1 = 1, 2, 3$ and $i3 = 0, 1, \ldots LL - 1$.

For the columns greater than $nstgE = 5$ we get for the non-zero elements of the matrix

$$
\begin{aligned}
te[i][i3 \times nstgE + 1] &= pdiedE[i3 + 1] \\
te[i][i3 \times nstgE + 2] &= pcullE[i3 + 1] \\
te[i][i3 \times nstgE + 3] &= pnconculE[i3 + 1] \\
te[i][i3 \times nstgE + 4] &= pnconstayE[i3 + 1] \\
te[i][i3 \times nstgE + 5] &= pconstayE[i3 + 1]
\end{aligned}
\tag{3.14}
$$

where $i = nstgE \times (i3 - 1) + i1 = 5(i3 - 1) + i1$ with $i1 = 4, 5$. Furthermore is

$$
i3 = \left\{
\begin{array}{ll}
1, 2, \ldots, LL - 1 & \text{for the first three equations} \\
1, 2, \ldots, LL - 2 & \text{for the last two equations of (3.14).}
\end{array}
\right.
$$

### 3.1.3.3 Calculation of the stationary state

The structure of the ewe flock in all systems was derived using Markov chains. The flock dynamics was described in terms of categories animals can belong to and probabilities of possible transitions between these categories. The procedure is similar to those described by Jalvingh et al. [11] or Reinsch and Dempfle [15]. Let $\mathbf{T}_E$ be the quadratic transition matrix of dimension $TE$ with elements $te_{ij}$ where $te_{ij}$ is the probability that an animal changes in a given time unit $\Delta t$ from category $i$ to category $j$ ($\Delta t$ is the length of the reproductive cycle). Assume further that $\mathbf{c}^{[t]}$ is the row vector with elements being the probability that an animal belongs to category $i$ at time $t$. Then the same vector at time $t + \Delta t$, $\mathbf{c}^{[t+\Delta t]}$, is calculated as:

$$
\mathbf{c}^{[t+\Delta t]} = \mathbf{c}^{[t]}\mathbf{T_E}
\tag{3.15}
$$

For $t \to \infty$, the Markov chain reaches its stationary state, that means the difference $\mathbf{c}^{[t+\Delta t]} - \mathbf{c}^{[t]}$ converges to zero. In the program, the stationary state is calculated by an iteration procedure. For more details see also Wolfová et al. [27] where the stationary state of a cow herd was calculated.

## 3.1.4 Calculation of some further quantities describing the structure of the ewe flock

In the following text, we will write $l1E[i]$ for the elements of vector $\mathbf{c}^{[t]}$ from equation (3.15) for $t \to \infty$. $l1E[i]$ ($i = 1, \ldots, TE$) is the proportion of ewes of the $i^{\text{th}}$ category and $\sum_{i=1}^{TE} l1E[i] = 1$. The number of ewes entering reproductive cycle $i$ ($i = 1, ..., LL$) expressed as proportion of ewes entering any reproductive cycle ($l4E[i]$) is calculated as follows:

$$
l4E[i] = \left\{
\begin{array}{ll}
\displaystyle\sum_{j=1}^{nstgE} l1E[(i-1) \times nstgE + j] & \text{for } i = 1, \ldots, LL - 1 \\
\displaystyle\sum_{j=1}^{nstg1E} l1E[(i-1) \times nstgE + j] & \text{for } i = LL
\end{array}
\right.
\tag{3.16}
$$

It holds that $\sum_{i=1}^{LL} l4E[i] = 1$.

The number of ewes lambing in reproductive cycle $i$ ($i = 1, ..., LL$) expressed as proportion of the number of ewes entering any reproductive cycle ($l3E[i]$) is

$$
l3E[i] = \left\{
\begin{array}{ll}
l4E[i] & \text{for } i = 1 \\
l1E[(i-1) \times nstgE] & \text{for } i = 2, \ldots, LL
\end{array}
\right.
\tag{3.17}
$$

The number of lambings in the flock per ewe and reproductive cycle ($Nlamb$) is calculated as the sum of the elements of the vector **l3E**:

$$Nlamb = \sum_{i=1}^{LL} l3E[i] \ . \tag{3.18}$$

This sum is smaller than one if barren ewes are kept to the next breeding season. Ewes mated with rams of a different breed as proportion of all mated ewes ($pcrosst$) are calculated as

$$pcrosst = \frac{1}{1 - l4E[LL]} \sum_{i=1}^{LL-1} pcrossE[i] \times l4E[i] \tag{3.19}$$

The fraction of ewes used for pure-breeding ($pctE[1]$), i.e. ewes mated with rams (only natural mating) of the same breed, is

$$pctE[1] = (1 - pinsE[1] \times coninsE) \sum_{i=1}^{LL-1} (l4E[i] \times (1 - pcrossE[i])) \tag{3.20}$$

and the fraction of ewes used for cross-breeding ($pctE[2]$), i.e. for mating to a ram of a different breed, is

$$pctE[2] = (1 - pinsE[2] \times coninsE) \sum_{i=1}^{LL-1} (l4E[i] \times pcrossE[i]) \ . \tag{3.21}$$

In the following text, some quantities will be calculated which are connected with ewe replacement. The dead rate of ewes averaged over all reproductive cycles ($pdiedE0$) is calculated as

$$pdiedE0 = \sum_{i=1}^{LL} l4E[i] \times pdiedE[i] \tag{3.22}$$

and the number of ewes died expressed as percentage of ewes replaced per reproductive cycle ($pdiedEp$) are:

$$pdiedEp = 100 \times \frac{pdiedE0}{l4E[1]} \ . \tag{3.23}$$

The relative frequencies of ewes involuntarily culled for health problems other than failure to conceive ($pcullhE0$), of ewes involuntarily culled for failure to conceive ($pcullfcE0$) and of ewes voluntarily culled for low milk production ($pcullmE0$), all averaged over all reproductive cycles, are

$$
\begin{aligned}
pcullhE0 &= \sum_{i=1}^{LL} l4E[i] \times pcullhE[i] \\
pcullfcE0 &= \sum_{i=1}^{LL-1} l1E[(i-1) \times nstgE + nstg1E] \\
pcullmE0 &= \sum_{i=1}^{LL} l4E[i] \times pcullmE[i] \ .
\end{aligned}
\tag{3.24}
$$

Ewes involuntarily culled for health problems other than failure to conceive ($pcullhEp$), ewes involuntarily culled for failure to conceive ($pcullfcEp$) and ewes voluntarily

culled for low milk production (*pcullmEp*), each expressed as percentage of ewes replaced per reproductive cycle, are calculated as:

$$
\begin{aligned}
pcullhEp &= 100 \times \frac{pcullhE0}{l4E[1]} \\
pcullfcEp &= 100 \times \frac{pcullfcE0}{l4E[1]} \\
pcullmEp &= 100 \times \frac{pcullmE0}{l4E[1]} \; .
\end{aligned}
\tag{3.25}
$$

## 3.2 Structure of the ram population

For calculating the age structure of the ram population, different categories of animals were defined. The number of the breeding cycles a ram is used is an input parameter ($RR$) which is expected to be in the range between 1 to 5. A breeding cycle covers the interval between two subsequent breeding seasons of rams[5]. Categories distinguished are related to the breeding cycles. A replacement male enters the flock at his first breeding cycle and can stay in the flock until he is replaced or has reached the maximum of allowable breeding cycles. Each category is characterised as a combination of two variables: *the number of the breeding cycle r* ($r = 1, ..., RR$) and the defined *stage s* the ram is in within the given breeding cycle ($s = 1, ..., nstgR$ for $r < RR$ and $s = 1, ... nstg1R$ for $r = RR$). The two parameters $nstg1R$ (number of stages for rams which occur in all breeding cycles) and $nstg2R$ (number of stages for rams which do not occur in the last breeding cycle) are fixed to 3 and 1, respectively, in the given version of the program. The maximal number of stages which can occur in a breeding cycle ($nstgR$) is then:

$$
nstgR = nstg1R + nstg2R = 4 \; .
\tag{3.26}
$$

The total number of ram categories ($TR$) is therefore

$$
TR = nstgR(RR - 1) + nstg1R = 4(RR - 1) + 3 \; .
\tag{3.27}
$$

### 3.2.1 Definition of breeding cycles

A maximal number of $RR$ breeding cycles per ram is assumed ($RR$ is in the interval from 1 to 7). On this basis, the following $RR$ breeding cycles are defined:

1          Rams between 1st and 2nd breeding season

2          Rams between 2nd and 3rd breeding season

3          ...

...         ...

$RR - 1$    Rams between $(RR - 1)$th and $RR$th breeding season

$RR$        Rams from $RR$th breeding season to culling or selling

---

[5]The length of the breeding cycle is equal to the length of the corresponding reproductive cycle of ewes.

## 3.2.2  Definition of categories of rams

### 3.2.2.1  Developmental stages of rams within breeding cycle $r$ $(r = 1, ..., RR-1)$

1        Rams died within the breeding cycle

2        Rams sold as breeding animals within the breeding cycle

3        Rams culled within the breeding cycle due to health problems

4        Rams entering the next breeding cycle

### 3.2.2.2  Developmental stages of rams within breeding cycle $RR$

1        Rams died within the breeding cycle

2        Rams sold as breeding animals within the breeding cycle

3        Rams culled within the breeding cycle

## 3.2.3  Calculation of transition matrix $\mathbf{T_R}$ and of the stationary state of the ram population

### 3.2.3.1  Calculation of the elements of the transition matrix

The variables $pdiedR[i]$, $psoldR[i]$ and $pcullR[i]$ are read from the input file IN-PUTS02.TXT for $i = 1, \ldots, RR$. For $i = RR$, it must hold

$$pdiedR[RR] + psoldR[RR] + pcullR[RR] = 1 \ . \tag{3.28}$$

The probability that a ram entering breeding cycle $i$ $(i = 1, \ldots, RR - 1)$ will stay to the next cycle is calculated as

$$pstayR[i] = 1 - pdiedR[i] - psoldR[i] - pcullR[i] \ . \tag{3.29}$$

This value must be always positive. Please note that for the special case of $RR = 1$ this variable does not give sense and is not defined.

We write $tr[i][j]$ for the elements of the transition matrix $\mathbf{T_R}$, $i$ being the index for the row and $j$ being the index for the column. First consider the special case that $RR = 1$. Then matrix $\mathbf{T_R}$ is a $nstg1R \times nstg1R$ matrix ($nstg1R = 3$ in the given version of the program) with all rows equal. The elements of the matrix are $(i = 1, \ldots, nstg1R)$:

$$\begin{aligned}
tr[i][1] &= pdiedR[1] \\
tr[i][2] &= psoldR[1] \\
tr[i][3] &= pcullR[1]
\end{aligned} \tag{3.30}$$

For $RR > 1$, the non-zero elements in the first four $(= nstgR)$ columns of matrix $T_R$ are:

$$\begin{aligned}
tr[i][1] &= pdiedR[1] \\
tr[i][2] &= psoldR[1] \\
tr[i][3] &= pcullR[1] \\
tr[i][4] &= pstayR[1]
\end{aligned} \tag{3.31}$$

where $i = nstgR \times i3 + i1 = 4 \times i3 + i1$ with $i1 = 1, 2, 3$ and $i3 = 0, 1, \ldots RR - 1$.

For the columns greater than $nstgR = 4$ we get for the non-zero elements of the matrix

$$
\begin{aligned}
tr[i][i3 \times nstgR + 1] &= pdiedR[i3 + 1] \\
tr[i][i3 \times nstgR + 2] &= psoldR[i3 + 1] \\
tr[i][i3 \times nstgR + 3] &= pcullR[i3 + 1] \\
tr[i][i3 \times nstgR + 4] &= pstayR[i3 + 1]
\end{aligned}
\tag{3.32}
$$

where $i = nstgR \times (i3 - 1) + i1 = 4(i3 - 1) + i1$ with $i1 = 4$. Furthermore is

$$
i3 = \left\{ \begin{array}{ll} 1, 2, \ldots, RR - 1 & \text{for the first three equations} \\ 1, 2, \ldots, RR - 2 & \text{for the last equation of (3.32).} \end{array} \right.
$$

### 3.2.3.2 Calculation of the stationary state for the ram population

The structure of the ram population in all systems was derived using Markov chains where the stationary state was calculated on the same principles as described in Section 3.1.3.3 on page 17.

## 3.2.4 Calculation of some further quantities describing the structure of the ram population

In the following text, we will write $l1R[i]$ for the elements of vector $\mathbf{c}^{[t]}$ from equation (3.15) for $t \to \infty$ where matrix $\mathbf{T_R}$ (transmission matrix for the ram population) is used instead of matrix $\mathbf{T_E}$. $l1R[i]$ ($i = 1, \ldots, TR$) is the proportion of rams of the $i^{\text{th}}$ category and $\sum_{i=1}^{TR} l1R[i] = 1$.

The number of rams entering breeding cycle $i$ ($i = 1, \ldots, RR$) expressed as proportion of the number of rams entering any breeding cycle ($l4R[i]$) is calculated as follows:

$$
l4R[i] = \left\{ \begin{array}{ll} \displaystyle\sum_{j=1}^{nstgR} l1R[(i-1) \times nstgR + j] & \text{for } i = 1, \ldots, RR - 1 \\ \displaystyle\sum_{j=1}^{nstg1R} l1R[(i-1) \times nstgR + j] & \text{for } i = RR \end{array} \right.
\tag{3.33}
$$

It holds that $\sum_{i=1}^{RR} l4R[i] = 1$. The rams may be from the same breed as the ewes in the flock or from another breed which is used for crossing.

# Chapter 4

# Structure of progeny

## 4.1  General remarks to progeny management

Besides of customary weaning, early weaning of lambs is allowed which is always
followed by an artificial rearing period using milk replacer. After customary weaning
or artificial rearing, all progeny can be divided into three groups whereby not all
groups are necessarily represented in each production system. The first group is
formed by lambs sold for slaughter immediately after weaning or artificial rearing.
The second group is made up by lambs fattened to target slaughter weight or age
(the number of different target weights or ages is limited to 5 each for female progeny,
male progeny and castrates). The third group are lambs reared as breeding animals
intended for own flock replacement or for selling.

Female breeding lambs (i.e. lambs from the third group) may be sold during the
rearing period either without being mated or as pregnant animals. For each female
lamb determined for mating, three options are allowed:

- Female lambs are mated in the first mating period after their weaning (usually
  at an age of 7 to 9 months). Only female lambs reaching the given minimal
  proportion of mature weight at this breeding season can be used for this
  mating.

- Barren female lambs from the first breeding season which were not culled and
  all remaining female lambs alive at the second breeding season are mated in
  this breeding season.

- Barren female lambs from the second breeding season alive at the third breed-
  ing season are mated in this breeding season. After the third breeding season,
  all barren female lambs are culled.[1]

Male breeding lambs reared in the flock may be already sold as young animals before
reaching the minimal weight to be used in breeding, i.e. at an age of about 7 to 9
months before the first breeding season following their weaning, or as older animals.
Male lambs for own replacement can enter the flock at the first or second breeding
season after their weaning. The number of ewes per ram is different for young and
old rams.

Furthermore, the structure of the progeny depends on the survival rates. Losses
of lambs are defined for different periods: (i) losses at birth including stillborn lambs
and lambs died until 24 hours, (ii) losses from 24 hours after birth to weaning and

---

[1] The proportion of mated but barren females kept to the next breeding season can be set to a
value between 0 and 1. The number of breeding seasons can be restricted to two by setting the
proportion of barren female lambs kept to the third breeding season ($pbarrFP[2][i]$) to zero.

(iii) if there is an artificial rearing period after early weaning, losses for this period are defined separately. All losses of lambs are given as average losses jointly for male and female lambs across parities, but separately for each litter size. Litter size can take values from 1 up to 4 in the present program version (level 4 for litter size includes litters with four or more lambs). Within each litter size, the same losses are assumed for pure-bred and cross-bred lambs.

To include the effect of the number of suckled lambs on ewe's milk production, the distribution of the losses over the ewes has to be taken into account. Consider, for example, three ewes with three lambs each and assume that the total losses amount to three lambs. This final number of three lambs may result from a loss of one lamb for each of the ewes or from a loss of three lambs for one of the ewes. This will be of different impact on the milk production of the ewes. The detailed analyses of losses allow to calculate the proportion of ewes at each parity that are without lambs after lambing or are suckled by different numbers of lambs (singles, twins, etc.). Later losses of lambs are of minor importance on ewe's milk production and are therefore not taken into account when calculating the milk production.

The number of suckled lambs has a great impact on the growth of lambs and the final slaughter weight. For the birth weight, the number of lambs born per litter is assumed to be crucial whereas for the subsequent growth rate, the number of lambs alive at 24 hours after lambing is probably more decisive.

The survival rates of progeny after weaning or after artificial rearing are separately defined according to sex, category of progeny and genotype (pure-bred or cross-bred).

## 4.2 Definition of categories of progeny

Categories of progeny are formed according to revenues and costs. The following categories of progeny are differentiated. The time periods the categories are defined for are summarized in Table 4.1. Several categories may be empty.

1. Stillborn lambs and lambs died until 24 hours (both sexes)

2. Lambs died from 24 hours until weaning or until the end of artificial rearing (both sexes)

3. Female lambs died during fattening[2]

4. Female lambs died in the rearing period

5. Female lambs from birth to weaning

6. Female lambs in artificial rearing (This category occurs only when early weaning is used.)

7. Female lambs sold after weaning or after artificial rearing

8. Female lambs fattened[3] to target 1

9. Female lambs fattened to target 2

10. Female lambs fattened to target 3

11. Female lambs fattened to target 4

---

[2]This category will be empty if there is no fattening of females.

[3]Fattening may be to a constant weight or a constant age. The concrete meaning of targets 1 to 5 will be defined by input parameters in input file INPUTS05.TXT (see Subsection 14.2.4 on page 141). Some or all of the categories related to fattening may be empty.

Table 4.1: Time periods for which the individual categories of progeny are defined

| Category | From | To |
|---|---|---|
| 1 | birth | 24 hours |
| 2 | 24 hours | weaning[a] |
| 3,4,28,29,48 | weaning[a] | death |
| 5,30 | birth | weaning[a] |
| 6,31 | weaning | end of artificial rearing |
| 7,32 | weaning[a] | weaning[a] |
| 8-12,33-37,43-47 | weaning[a] | end of fattening of the category |
| 13,38 | weaning[a] | sale |
| 14,39 | weaning[a] | start of 1$^{st}$ breeding season |
| 15 | start of 1$^{st}$ breeding season | sale |
| 16 | start of 1$^{st}$ breeding season | first lambing |
| 17 | start of 1$^{st}$ breeding season | culling |
| 18,41 | start of 1$^{st}$ breeding season | start of 2$^{nd}$ breeding season |
| 19 | start of 2$^{nd}$ breeding season | sale |
| 20 | start of 2$^{nd}$ breeding season | first lambing |
| 21 | start of 2$^{nd}$ breeding season | culling |
| 22 | start of 2$^{nd}$ breeding season | start of 3$^{rd}$ breeding season |
| 23 | start of 3$^{rd}$ breeding season | sale |
| 24 | start of 3$^{rd}$ breeding season | first lambing |
| 25 | start of 3$^{rd}$ breeding season | culling |
| 26,40 | start of 1$^{st}$ breeding season | sale |
| 42 | weaning[a] | culling |

[a]or end of artificial rearing

12. Female lambs fattened to target 5

13. Female lambs sold before the first breeding season

14. Female lambs in the rearing period until the first breeding season

15. Pregnant females sold after the first breeding season

16. Pregnant females used as replacement after the first breeding season

17. Females culled after the first breeding season for failure to conceive

18. Females between the first and the second breeding season

19. Pregnant females sold after the second breeding season

20. Pregnant females used as replacement after the second breeding season

21. Females culled after the second breeding season for failure to conceive

22. Females between the second and the third breeding season

23. Pregnant females sold after the third breeding season

24. Pregnant females used as replacement after the third breeding season

25. Females culled after the third breeding season for failure to conceive

26. Female breeding lambs sold between the first and the second breeding season without being mated (yearlings)

27. Empty category (reserved for further program development)

28. Male lambs died during fattening[4]

29. Male lambs died in the rearing period

30. Male lambs from birth to weaning

31. Male lambs in artificial rearing (This category occurs only when early weaning is used.)

32. Male lambs sold after weaning or after artificial rearing

33. Male lambs fattened[5] to target 1

34. Male lambs fattened to target 2

35. Male lambs fattened to target 3

36. Male lambs fattened to target 4

37. Male lambs fattened to target 5

38. Male lambs sold during the rearing period until the first breeding season

39. Male lambs in the rearing period until the first breeding season

40. Males sold between the first and the second breeding season

41. Males between the first and the second breeding season

42. Male lambs culled in the rearing period

43. Castrates fattened[6] to target 1

44. Castrates fattened to target 2

45. Castrates fattened to target 3

46. Castrates fattened to target 4

47. Castrates fattened to target 5

48. Castrates died during fattening[7]

## 4.3   Structure of progeny from birth to weaning

Most of the following parameters are defined for pure-bred and cross-bred progeny (if cross-breeding is used). Throughout index 1 is used for pure-breds, index 2 for cross-breds and index 0 stands for the sum of pure-breds and cross-breds.

It is assumed that the fraction of stillborn lambs, of lambs died till weaning and of lambs died from early weaning till the end of the artificial rearing period are equal for pure-bred and cross-bred animals ($i = 1, \ldots, clt$):

$$\begin{aligned}
pdiedbL[i][2] &= pdiedbL[i][1] \\
pdiedwL[i][2] &= pdiedwL[i][1] \\
pdiedarL[i][2] &= pdiedarL[i][1] \ .
\end{aligned} \qquad (4.1)$$

---

[4] This category will be empty if there is now fattening of males.

[5] See footnote 3 on page 23

[6] See footnote 3 on page 23

[7] This category will be empty if there is now fattening of castrates.

The number of lambs born per ewe per reproductive cycle ($nbtL[i][j]$) for type $i$ of breeding ($i = 1$ : pure-bred lambs, $i = 2$ : cross-bred lambs, $i = 0$ : sum of pure-bred and cross-bred lambs) and for litter size $j$ ($j = 1, \ldots, clt$; $j = 1$ : singles, $j = 2$ : twins, $j = 3$ : triplets, $j = 4$ : quadruplets) is calculated as

$$
\begin{aligned}
nbtL[1][j] &= j \times \sum_{k=1}^{LL} Pltype[j][k] \times l3E[k] \times (1 - pcrossE[k-1]) \\
nbtL[2][j] &= j \times \sum_{k=1}^{LL} Pltype[j][k] \times l3E[k] \times pcrossE[k-1] \\
nbtL[0][j] &= nbtL[1][j] + nbtL[2][j]
\end{aligned}
\tag{4.2}
$$

The number of lambs born per ewe per reproductive cycle ($NbtL[i]$) summed over litter sizes for the type of breeding ($i = 0, 1, 2$) is then calculated as

$$
NbtL[i] = \sum_{j=1}^{clt} nbtL[i][j] \ .
\tag{4.3}
$$

The number of lambs alive at 24 hours after birth per ewe per reproductive cycle ($na24hL[i][j]$) for type $i$ of breeding ($i = 1$ : pure-bred lambs, $i = 2$ : cross-bred lambs, $i = 0$ : sum of pure-bred and cross-bred lambs) and for each litter size $j$ ($j = 1, \ldots, clt$) is calculated as

$$
\begin{aligned}
na24hL[1][j] &= (1 - pdiedbL[j][1]) \times nbtL[1][j] \\
na24hL[2][j] &= (1 - pdiedbL[j][2]) \times nbtL[2][j] \\
na24hL[0][j] &= na24hL[1][j] + na24hL[2][j]
\end{aligned}
\tag{4.4}
$$

The number of lambs alive at 24 hours after birth per ewe per reproductive cycle ($Na24hL[i]$) summed over litter sizes for the type of breeding $i$ ($i = 0, 1, 2$) is then

$$
Na24hL[i] = \sum_{j=1}^{clt} na24hL[i][j] \ .
\tag{4.5}
$$

The number of lambs weaned per ewe per reproductive cycle ($nwL[i][j]$) for the type of breeding $i$ ($i = 1$ : pure-bred lambs, $i = 2$: cross-bred lambs, $i = 0$: sum of pure-bred and cross-bred lambs) and for each litter size $j$ ($j = 1, \ldots, clt$) is

$$
nwL[i][j] = \begin{cases} (1 - pdiedwL[j][i]) \times na24hL[i][j] & \text{for } i = 1, 2 \\ nwL[1][j] + nwL[2][j] & \text{for } i = 0 \end{cases} \ .
\tag{4.6}
$$

The number of lambs weaned per ewe per reproductive cycle ($NwL[i]$) summed over litter sizes for type $i$ of breeding ($i = 0, 1, 2$) is given by

$$
NwL[i] = \sum_{j=1}^{clt} nwL[i][j] \ .
\tag{4.7}
$$

In the presence of early weaning and artificial rearing of lambs with milk replacer, the number of lambs per ewe and reproductive cycle at the end of artificial rearing ($narL[i][j]$) for type $i$ of breeding ($i = 1$ : pure-bred lambs, $i = 2$ : cross-bred lambs, $i = 0$ : sum of pure-bred and cross-bred lambs) and for each litter size $j$ ($j = 1, \ldots, clt$) is calculated as

$$
narL[i][j] = \begin{cases} (1 - pdiedarL[j][i]) \times nwL[i][j] & \text{for } i = 1, 2 \\ narL[1][j] + narL[2][j] & \text{for } i = 0 \end{cases} \ .
\tag{4.8}
$$

The total number of lambs at the end of artificial rearing summed over the litter sizes is

$$NarL[i] = \sum_{j=1}^{clt} narL[i][j] \ . \tag{4.9}$$

### 4.3.1 Calculation of the array l1L (frequency of progeny in all combinations of individual categories, types of breeding and litter sizes)

The first index of the matrix refers to category $i$ ($i = 1, \ldots, PP$) of progeny as given in Section 4.2 on page 23, the second index refers to type $j$ of breeding ($j = 1$ : pure-bred animals, $j = 2$: cross-bred animals, $j = 0$: sum of pure-bred and cross-bred animals) and the third index refers to the litter size $k$ ($k = 1, \ldots, clt$) where $k = 1$ are singles, $k = 2$ are twins, $k = 3$ are triplets etc. The following numbers of animals are given per ewe and reproductive cycle.

The number of stillborn lambs (category 1 of progeny) of both sexes or lambs died until 24 hours ($l1L[1][j][k]$) is :

$$l1L[1][j][k] = nbtL[j][k] - na24hL[j][k] \quad \text{for } j = 0, 1, 2 \text{ and } k = 1, \ldots, clt. \tag{4.10}$$

The number of lambs died from 24 hours until weaning ($l1L[2][j][k]$, both sexes, category 2) is:

$$l1L[2][j][k] = na24hL[j][k] - nwL[j][k] \quad \text{for } j = 0, 1, 2 \text{ and } k = 1, \ldots, clt. \tag{4.11}$$

If there is artificial rearing, the equation changes to

$$l1L[2][j][k] = na24hL[j][k] - narL[j][k] \quad \text{for } j = 0, 1, 2 \text{ and } k = 1, \ldots, clt. \tag{4.12}$$

The number of female lambs at weaning (category 5) and of male lambs at weaning (category 30) is

$$
\begin{aligned}
l1L[5][j][k] &= sexrbf \times nwL[j][k] \\
l1L[30][j][k] &= sexrbm \times nwL[j][k]
\end{aligned}
\tag{4.13}
$$

The number of female and male lambs at the end of the artificial rearing period ($l1L[6][j][k]$, category 6 and $l1L[31][j][k]$, category 31) are calculated as follows:

$$
\begin{aligned}
l1L[6][j][k] &= sexrbf \times narL[j][k] \\
l1L[31][j][k] &= sexrbm \times narL[j][k]
\end{aligned}
\tag{4.14}
$$

### 4.3.2 Calculation of the array l1skL (frequency of progeny in all combinations of individual categories and types of breeding summarised over litter sizes) - first part

The first index of the matrix refers to the category of progeny as given in Section 4.2 on page 23, the second index refers to type $j$ of breeding ($j = 1$ : pure-bred animals, $j = 2$: cross-bred animals, $j = 0$: sum of pure-bred and cross-bred animals). The elements of the matrix for the categories 1, 2, 5, 6, 30 and 31 are calculated as

$$l1skL[i][j] = \sum_{k=1}^{clt} l1L[i][j][k] \tag{4.15}$$

## 4.4 Structure of progeny after weaning[8]

Variables specific for female progeny only contain "FP" in their name, variables specific for male progeny only are indicated by "MP". In variables which are defined both for female and male progeny and, in some cases, also for castrates, the first index indicates the sex: 1 stands for female progeny, 2 stands for male progeny and 0 is used for castrates.

### 4.4.1 Calculation of the number of pure-bred weaned female lambs needed for own flock replacement

The fraction of pure-bred (second index) weaned female lambs conceived in the first breeding season after their weaning (first index) ($prconFP[1][1]$) is calculated as

$$prconFP[1][1] = surbs[1][1][1] \times pmat[1][1][1] \times conrateFP[1][1] \ . \tag{4.16}$$

The fraction of weaned female lambs conceived in the first breeding season after their weaning and entered the flock ($pherd[1][1]$) is then

$$pherd[1][1] = prconFP[1][1] \times surmlFP[1] \ . \tag{4.17}$$

The fraction of weaned pure-bred female lambs mated in the second breeding season after their weaning ($pmat[1][2][1]$) is

$$
\begin{aligned}
pmat[1][2][1] \quad = \quad & \{surbs[1][1][1] - prconFP[1][1] \\
& -surbs[1][1][1] \times pmat[1][1][1] \times (1 - conrateFP[1][1]) \\
& \times (1 - pbarrFP[1][1])\} \times surbs[1][2][1] \ . \tag{4.18}
\end{aligned}
$$

The fraction of pure-bred weaned female lambs conceived in the second breeding season after their weaning ($prconFP[2][1]$) is

$$prconFP[2][1] = pmat[1][2][1] \times conrateFP[2][1] \ . \tag{4.19}$$

The fraction of pure-bred weaned female lambs conceived in the second breeding season after their weaning and entered the flock ($pherd[1][2]$) is then

$$pherd[1][2] = prconFP[2][1] \times surmlFP[1] \ . \tag{4.20}$$

The fraction of pure-bred weaned female lambs mated in the third breeding season after weaning ($pmat[1][3][1]$) is

$$
\begin{aligned}
pmat[1][3][1] \quad = \quad & (pmat[1][2][1] - prconFP[2][1]) \\
& \times pbarrFP[2][1] \times surbs[1][3][1] \ , \tag{4.21}
\end{aligned}
$$

the fraction of pure-bred weaned female lambs conceived in the third breeding season after their weaning ($prconFP[3][1]$) is calculated as

$$prconFP[3][1] = pmat[1][3][1] \times conrateFP[3][1] \tag{4.22}$$

and the fraction of pure-bred weaned female lambs conceived in the third breeding season after their weaning and entered the flock ($pherd[1][3]$) is then

$$pherd[1][3] = prconFP[3][1] \times surmlFP[1] \ . \tag{4.23}$$

---

[8]Before calculating the structure of the progeny after weaning, several variables connected with the growth of the progeny must be calculated. The appropriate equations are given in Sections 5.3 to 5.7.

The total fraction of pure-bred weaned female lambs that entered the flock as replacement ($Pherd[1]$) is

$$Pherd[1] = \sum_{1=1}^{bs[1]} pherd[1][i] \ .$$ (4.24)

The number[9] of pure-bred weaned female lambs that must be reared for own flock replacement ($nherd[1]$) is

$$nherd[1] = l4E[1]/Pherd[1] \ .$$ (4.25)

The number of pure-bred female lambs for replacement died from weaning to the first breeding season ($nrdied[1][1][1]$) is

$$nrdied[1][1][1] = nherd[1] \times (1 - surbs[1][1][1]) \ .$$ (4.26)

The number of pure-bred female lambs for replacement culled after the first breeding season for failure to conceive ($nrcull[1][1][1]$) is

$$
\begin{aligned}
nrcull[1][1][1] \ = \ & nherd[1] \times (surbs[1][1][1] \times pmat[1][1][1] \\
& - prconFP[1][1]) \times (1 - pbarrFP[1][1]) \ .
\end{aligned}
$$ (4.27)

The number of pure-bred female lambs for replacement mated in the second breeding season after weaning ($nrmatFP[2]$) is

$$nrmatFP[2] = nherd[1] \times pmat[1][2][1] \ .$$ (4.28)

The number of pure-bred female lambs for replacement which died from the first to the second breeding season ($nrdied[1][2][1]$) is

$$
\begin{aligned}
nrdied[1][2][1] \ = \ & \{nherd[1] \times (1 - prconFP[1][1]) - nrdied[1][1][1] \\
& - nrcull[1][1][1]\} \times (1 - surbs[1][2][1])
\end{aligned}
$$ (4.29)

The number of pure-bred female lambs for replacement culled after the second breeding season for failure to conceive ($nrcull[1][2][1]$) is

$$
\begin{aligned}
nrcull[1][2][1] \ = \ & nherd[1] \times (pmat[1][2][1] - prconFP[2][1]) \\
& \times (1 - pbarrFP[2][1])
\end{aligned}
$$ (4.30)

The number of pure-bred female lambs for replacement mated in the third breeding season after weaning ($nrmatFP[3]$) is

$$nrmatFP[3] = nherd[1] \times pmat[1][3][1] \ .$$ (4.31)

The number of pure-bred female lambs died from the second to the third breeding season ($nrdied[1][3][1]$) is

$$
\begin{aligned}
nrdied[1][3][1] \ = \ & (nrmatFP[2] - nherd[1] \times prconFP[2][1] \\
& - nrcull[1][2][1]) \times (1 - surbs[1][3][1])
\end{aligned}
$$ (4.32)

The number of pure-bred female lambs culled after the third breeding season for failure to conceive ($nrcull[1][3][1]$) is

$$nrcull[1][3][1] = nherd[1] \times (pmat[1][3][1] - prconFP[3][1]) \ .$$ (4.33)

The number of pure-bred female lambs for replacement died from mating (conceiving) till lambing ($nrdiedmlFP[1]$) summed over all breeding seasons $i$ is

$$nrdiedmlFP[1] = nherd[1] \times (1 - surmlFP[1]) \sum_{i=1}^{bs[1]} prconFP[i][1] \ .$$ (4.34)

In the present version of the program $bs[1]$ is set to 3.

---

[9]All numbers of animals in this section are per ewe per reproductive cycle.

## 4.4.2 Calculation of the number of surplus weaned female lambs and of the number of purchased females

First assume that all own replacement females are reared. Then, in the case of customary weaning, the number[10] of surplus female progeny for type $i$ of breeding ($nwsp[1][i]$, $i = 1$: pure-bred lambs, $i = 2$: cross-bred lambs) is

$$\begin{aligned} nwsp[1][1] &= l1skL[5][1] - nherd[1] \\ nwsp[1][2] &= l1skL[5][2] \end{aligned} \tag{4.35}$$

If there is artificial rearing of early weaned lambs $nwsp[1][i]$ is calculated as

$$\begin{aligned} nwsp[1][1] &= l1skL[6][1] - nherd[1] \\ nwsp[1][2] &= l1skL[6][2] \end{aligned} \tag{4.36}$$

A negative value of $nwsp[1][1]$ means that there are not enough own replacement females and females must be purchased. The number of purchased females ($npurchFP$) per ewe and reproductive cycle is then simply

$$npurchFP = -nwsp[1][1] \tag{4.37}$$

and $nwsp[1][1]$ is set to zero for the following calculations.

Now consider the case that a part of replacement females ($ppurchFP$) will be purchased. Then the number of surplus weaned pure-bred females is

$$nwsp[1][1] = \begin{cases} l1skL[5][1] - nherd[1] \times (1 - ppurchFP) & \text{for customary weaning} \\ l1skL[6][1] - nherd[1] \times (1 - ppurchFP) & \text{for artificial rearing} \end{cases} \tag{4.38}$$

The number of purchased female replacement is therefore:

$$npurchFP = nherd[1] \times ppurchFP . \tag{4.39}$$

The number of surplus weaned cross-bred females ($nwsp[1][2]$) will not be touched by purchasing female replacement and will be the same as given in equations (4.35) and (4.36) in dependence if there is customary weaning or artificial rearing.

The number of pure-bred ($j = 1$) or cross-bred ($j = 2$) weaned surplus female progeny ($nsp[1][i][j]$) sold in different categories $i$ ($i = 1, \ldots, csp[1]$, $i = 1$: sold at weaning for slaughter, $i = 2$: sold as breeding animals, $i = 3, \ldots 7$: fattened to targets 1 to 5, respectively) is calculated as follows:

$$nsp[1][i][j] = nwsp[1][j] \times psp[1][i][j] . \tag{4.40}$$

If there is fattening of female progeny, the number of pure-bred ($j = 1$) or cross-bred ($j = 2$) female progeny died in fattening to target $i$ ($ndiedfat[1][i][j]$, $i = 1, \ldots, lf[1]$) is

$$ndiedfat[1][i][j] = nsp[1][i+2][j] \times (1 - surfat[1][i][j]) . \tag{4.41}$$

The number of pure-bred ($j = 1$) or cross-bred ($j = 2$) female progeny reaching the appropriate target $i$ ($nfattar[1][i][j]$, $i = 1, \ldots, lf[1]$) in fattening is

$$nfattar[1][i][j] = nsp[1][i+2][j] \times surfat[1][i][j] . \tag{4.42}$$

The number of surplus female progeny for type of breeding $i$ ($i = 1$: pure-bred lambs, $i = 2$: cross-bred lambs) sold as breeding females before mating ($nsold[1][0][i]$) is

$$nsold[1][0][i] = nsp[1][2][i] \times psold[1][0][i] . \tag{4.43}$$

---

[10]All numbers of animals in this section are per ewe per reproductive cycle.

The number of pure-bred ($i = 1$) or cross-bred ($i = 2$) surplus female progeny determined for selling as breeding animals that died from weaning till the first breeding season ($nspdied[1][1][i]$) is

$$nspdied[1][1][i] = (nsp[1][2][i] - nsold[1][0][i] \times ps13[i]) \times (1 - surbs[1][1][i]) \ . \quad (4.44)$$

The following quantities ($nmatFP[1][i]$ till $nspcull[1][3][i]$) will be calculated only if not all surplus female progeny will be sold before mating, i.e. $psold[1][0][i]$ must be less than 1. The number of pure-bred ($i = 1$) or cross-bred ($i = 2$) surplus female progeny determined for selling as breeding animals that were mated in the first breeding season ($nmatFP[1][i]$) is

$$nmatFP[1][i] = (nsp[1][2][i] - nsold[1][0][i]) \times surbs[1][1][i] \times pmat[1][1][i] \ . \quad (4.45)$$

The number of pure-bred ($i = 1$) or cross-bred ($i = 2$) surplus female progeny determined for selling as breeding animals that were culled after the first breeding season because of failure to conceive ($nspcull[1][1][i]$) is

$$nspcull[1][1][i] = nmatFP[1][i] \times (1 - conrateFP[1][i]) \times (1 - pbarrFP[1][i]) \ . \quad (4.46)$$

The number of surplus female progeny (for type of breeding $i$, $i = 1$: pure-bred female lambs, $i = 2$: cross-bred female lambs) sold pregnant after the first breeding season ($nsold[1][1][i]$) is

$$nsold[1][1][i] = nmatFP[1][i] \times conrateFP[1][i] \ . \quad (4.47)$$

The number of pure-bred ($i = 1$) or cross-bred ($i = 2$) surplus female progeny determined for selling as breeding animals that were mated in the second breeding season ($nmatFP[2][i]$) is

$$\begin{aligned} nmatFP[2][i] \ = \ & (nsp[1][2][i] - nsold[1][0][i] - nsold[1][1][i] - nspdied[1][1][i] \\ & -nspcull[1][1][i]) \times surbs[1][2][i] \ . \end{aligned} \quad (4.48)$$

The number of surplus female progeny (for type of breeding $i$, $i = 1$: pure-bred lambs, $i = 2$: cross-bred lambs) sold pregnant after the second breeding season ($nsold[1][2][i]$) is

$$nsold[1][2][i] = nmatFP[2][i] \times conrateFP[2][i] \ . \quad (4.49)$$

The number of pure-bred ($i = 1$) or cross-bred ($i = 2$) surplus female progeny (not pregnant) determined for selling as breeding animals that died from the first to the second breeding season ($nspdied[1][2][i]$) is

$$\begin{aligned} nspdied[1][2][i] \ = \ & (nsp[1][2][i] - nsold[1][0][i] - nsold[1][1][i] - nspdied[1][1][i] \\ & -nspcull[1][1][i]) \times (1 - surbs[1][2][i]) \ . \end{aligned} \quad (4.50)$$

The number of pure-bred ($i = 1$) or cross-bred ($i = 2$) surplus female progeny determined for selling as breeding animals that were culled after the second breeding season because of failure to conceive ($nspcull[1][2][i]$) is

$$nspcull[1][2][i] = (nmatFP[2][i] - nsold[1][2][i]) \times (1 - pbarrFP[2][i]) \ . \quad (4.51)$$

The number of pure-bred ($i = 1$) or cross-bred ($i = 2$) surplus female progeny determined for selling as breeding animals that were mated in the third breeding season ($nmatFP[3][i]$) is

$$\begin{aligned} nmatFP[3][i] \ = \ & (nmatFP[2][i] - nsold[1][2][i] - nspcull[1][2][i]) \\ & \times surbs[1][3][i] \end{aligned} \quad (4.52)$$

The number of surplus female progeny (for type of breeding $i$, $i = 1$: pure-bred lambs, $i = 2$: cross-bred lambs) sold pregnant after the third breeding season ($nsold[1][3][i]$) is

$$nsold[1][3][i] = nmatFP[3][i] \times conrateFP[3][i] \ . \tag{4.53}$$

The number of pure-bred ($i = 1$) or cross-bred ($i = 2$) surplus female progeny (not pregnant) determined for selling as breeding animals that died from the second to the third breeding season ($nspdied[1][3][i]$) is

$$\begin{aligned} nspdied[1][3][i] &= (nmatFP[2][i] - nsold[1][2][i] - nspcull[1][2][i]) \\ &\quad \times (1 - surbs[1][3][i]) \ . \end{aligned} \tag{4.54}$$

The number of pure-bred ($i = 1$) or cross-bred ($i = 2$) female progeny originally determined for selling as breeding animals that were culled after the third breeding season because of failure to conceive ($nspcull[1][3][i]$) is

$$nspcull[1][3][i] = nmatFP[3][i] - nsold[1][3][i] \ . \tag{4.55}$$

### 4.4.3 Calculation of the number of pure-bred weaned male lambs needed for own flock replacement

If there is crossing in the flock the rams in the flock are either from the same breed as the ewes or from another breed which is used for crossing. Therefore it is useful to subdivide the vectors $l1R[i]$ and $l4R[i]$ calculated in subsection 3.2.4 into parts which relate to rams from the breed of the flock ($l1aR[i][1]$ and $l5R[i][1]$) and parts which relate to rams used for crossing in the flock ($l1aR[i][2]$ and $l5R[i][2]$). The values of $l1aR[i][j]$ are calculated as:

$$\begin{aligned} l1aR[i][1] &= l1R[i] \times \frac{pctE[1] + a2 \times (1 - pcrosst)}{pctE[1] + pctE[2] + a2} \\ l1aR[i][2] &= l1R[i] - l1aR[i][1] \end{aligned} \tag{4.56}$$

where $i = 1, \ldots, TR$ and

$$a2 = nherd[1] \sum_{i=1}^{bs[1]} pmat[1][i][1] \ . \tag{4.57}$$

The values of $l5R[i][j]$ are calculated in a similar way:

$$\begin{aligned} l5R[i][1] &= l4R[i] \times \frac{pctE[1] + a2 \times (1 - pcrosst)}{pctE[1] + pctE[2] + a2} \\ l5R[i][2] &= l4R[i] - l5R[i][1] \end{aligned} \tag{4.58}$$

where $i = 1, \ldots, RR$ and $a2$ has the same meaning as above.

The fraction of pure-bred weaned male lambs that entered the flock in the first ($pherd[2][1]$) or the second ($pherd[2][2]$) breeding season after weaning is

$$\begin{aligned} pherd[2][1] &= surbs[2][1][1] \times (1 - cullbsMP[1][1]) \times pmat[2][1][1] \\ pherd[2][2] &= surbs[2][1][1] \times (1 - cullbsMP[1][1]) \times (1 - pmat[2][1][1]) \\ &\quad \times surbs[2][2][1] \times (1 - cullbsMP[2][1]) \ . \end{aligned} \tag{4.59}$$

By summing up these two values we get the total fraction of pure-bred weaned male lambs that entered the flock ($Pherd[2]$):

$$Pherd[2] = \sum_{i=1}^{bs[2]} pherd[2][i] \ . \tag{4.60}$$

Pure-bred young rams (rams used in the first breeding season after their weaning) that entered the flock as proportion of the total number of pure-bred rams that entered the flock ($pherdyMP$) are given by the following relation

$$pherdyMP = pherd[2][1]/Pherd[2] \qquad (4.61)$$

and the fraction of pure-bred rams in the flock that are pure-bred young rams ($pyoungMP[1]$) is

$$pyoungMP[1] = pherdyMP \times l5R[1][1] \ . \qquad (4.62)$$

The average ewes-to-ram ratio in the breeding season ($ratioR$) is

$$ratioR = pyoungMP[1] \times ratioyoungR + (1 - pyoungMP[1]) \times ratiooldR \ . \quad (4.63)$$

The number[11] of pure-bred rams which are of the same breed as the ewes needed per ewe per reproductive cycle ($neweR[1]$) is

$$neweR[1] = \frac{1}{ratioR} \left( pctE[1] + nherd[1] \times (1 - pcrossE[0]) \sum_{i=1}^{bs[1]} pmat[1][i][1] \right) \ . \qquad (4.64)$$

The number of rams of the same breed as the breed of the ewes purchased from outside the flock ($npurchMP[1]$) is

$$npurchMP[1] = ppurchMP[1] \times neweR[1] \ . \qquad (4.65)$$

The number of pure-bred weaned male lambs that must enter the flock per ewe per reproductive cycle ($nramMP[1]$) is

$$nramMP[1] = (neweR[1] - npurchMP[1]) \times l5R[1][1] \qquad (4.66)$$

and the number of pure-bred weaned male lambs per ewe per reproductive cycle that must be reared for own replacement ($nherd[2]$) is given by the following equation:

$$nherd[2] = nramMP[1]/Pherd[2] \ . \qquad (4.67)$$

The number of pure-bred male lambs intended for replacement that died from weaning to the first breeding season ($nrdied[2][1][1]$) is

$$nrdied[2][1][1] = nherd[2] \times (1 - surbs[2][1][1]) \ . \qquad (4.68)$$

The number of pure-bred male lambs that were culled from weaning to the first breeding season ($nrcull[2][1][1]$) is given as

$$nrcull[2][1][1] = nherd[2] \times cullbsMP[1][1] \ . \qquad (4.69)$$

The number of pure-bred male lambs for replacement that died from the first to the second breeding season ($nrdied[2][2][1]$) is

$$\begin{aligned} nrdied[2][2][1] \ = \ & (nherd[2] - nrdied[2][1][1] - nrcull[2][1][1] \\ & -nherd[2] \times pherd[2][1]) \\ & \times (1 - surbs[2][2][1]) \qquad (4.70) \end{aligned}$$

and the number of pure-bred male lambs for replacement that were culled from the first to the second breeding season ($nrcull[2][2][1]$) is

$$\begin{aligned} nrcull[2][2][1] \ = \ & \big(nherd[2] \times (1 - pherd[2][1]) - nrdied[2][1][1] \\ & -nrcull[2][1][1]\big) \times cullbsMP[2][1] \ . \qquad (4.71) \end{aligned}$$

_____

[11] All numbers of animals in this section are per ewe per reproductive cycle.

The number of rams for cross-breeding needed per ewe per reproductive cycle ($neweR[2]$, assumed to be purchased outside the flock) is

$$neweR[2] = \frac{1}{ratioR} \left( pctE[2] + nherd[1] \times pcrossE[0] \sum_{i=1}^{bs[1]} pmat[1][i][1] \right) \ . \quad (4.72)$$

The number of rams of the breed used for crossing which must enter the flock per ewe and reproductive cycle ($nramMP[2]$) is

$$nramMP[2] = neweR[2] \times l5R[1][2] \ . \quad (4.73)$$

The number of rams of the breed used for crossing in the flock which must be purchased ($npurchMP[2]$) is then

$$npurchMP[2] = nramMP[2] \ . \quad (4.74)$$

### 4.4.4 Calculation of the number of pure-bred and cross-bred surplus weaned male lambs (including castrates) used for different purposes

In the case of customary weaning, the number[12] of surplus male progeny for type $j$ of breeding ($nwsp[2][j]$, $j = 1$: pure-bred lambs, $j = 2$: cross-bred lambs) is

$$
\begin{aligned}
nwsp[2][1] &= l1skL[30][1] - nherd[2] \\
nwsp[2][2] &= l1skL[30][2]
\end{aligned}
\quad (4.75)
$$

If there is artificial rearing of early weaned lambs $nwsp[2][j]$ is calculated as

$$
\begin{aligned}
nwsp[2][1] &= l1skL[31][1] - nherd[2] \\
nwsp[2][2] &= l1skL[31][2]
\end{aligned}
\quad (4.76)
$$

The number of pure-bred ($j = 1$) or cross-bred ($j = 2$) weaned surplus male progeny ($nsp[2][i][j]$) sold in different categories $i$ ($i = 1, \ldots, csp[2]$, $i = 1$: sold at weaning for slaughter, $i = 2$: sold as breeding animals, $i = 3$ : castrated, $i = 4, \ldots 8$: fattened to targets 1 to 5, respectively) is calculated as follows:

$$nsp[2][i][j] = nwsp[2][j] \times psp[2][i][j] \ . \quad (4.77)$$

If there is fattening of male progeny, the number of pure-bred ($j = 1$) or cross-bred ($j = 2$) male progeny died in fattening to target $i$ ($ndiedfat[2][i][j]$, $i = 1, \ldots, lf[2]$) is

$$ndiedfat[2][i][j] = nsp[2][i + 3][j] \times (1 - surfat[2][i][j]) \ . \quad (4.78)$$

The number of pure-bred ($j = 1$) or cross-bred ($j = 2$) male progeny reaching the appropriate target $i$ ($nfattar[2][i][j]$, $i = 1, \ldots, lf[2]$) in fattening is

$$nfattar[2][i][j] = nsp[2][i + 3][j] \times surfat[2][i][j] \ . \quad (4.79)$$

The number of surplus male progeny for type of breeding $j$ ($j = 1$: pure-bred lambs, $j = 2$: cross-bred lambs) sold as breeding males between weaning and the first breeding season ($nsold[2][1][j]$) is

$$
\begin{aligned}
nsold[2][1][j] &= nsp[2][2][j] \times surbs[2][1][j] \times (1 - cullbsMP[1][j]) \\
&\quad \times psold[2][1][j] \ .
\end{aligned}
\quad (4.80)
$$

---

[12]All numbers of animals in this section are per ewe per reproductive cycle.

The number of pure-bred ($j = 1$) or cross-bred ($j = 2$) surplus male progeny determined for selling as breeding animals that died from weaning till the first breeding season ($nspdied[2][1][j]$) is

$$nspdied[2][1][j] = nsp[2][2][j] \times (1 - surbs[2][1][j]) . \qquad (4.81)$$

The number of pure-bred ($j = 1$) or cross-bred ($j = 2$) surplus male progeny determined for selling as breeding animals that were culled from weaning till the first breeding season ($nspcull[2][1][j]$) is

$$nspcull[2][1][j] = nsp[2][2][j] \times cullbsMP[1][j] . \qquad (4.82)$$

The number of surplus male progeny for type of breeding $j$ ($j = 1$: pure-bred lambs, $j = 2$: cross-bred lambs) sold as breeding males between the first and the second breeding season after weaning ($nsold[2][2][j]$) is

$$
\begin{aligned}
nsold[2][2][j] \;=\; & (nsp[2][2][j] - nsold[2][1][j] - nspdied[2][1][j] \\
& -nspcull[2][1][j]) \times surbs[2][2][j] \times (1 - cullbsMP[2][j]) .
\end{aligned}
$$
$$(4.83)$$

The number of pure-bred ($j = 1$) or cross-bred ($j = 2$) surplus male progeny determined for selling as breeding animals that died from the first to the second breeding season ($nspdied[2][2][j]$) is

$$
\begin{aligned}
nspdied[2][2][j] \;=\; & (nsp[2][2][j] - nsold[2][1][j] - nspdied[2][1][j] \\
& -nspcull[2][1][j]) \times (1 - surbs[2][2][j]) . \qquad (4.84)
\end{aligned}
$$

The number of pure-bred ($j = 1$) or cross-bred ($j = 2$) surplus male progeny determined for selling as breeding animals that were culled between the first and the second breeding season ($nspcull[2][2][j]$) is

$$
\begin{aligned}
nspcull[2][2][j] \;=\; & (nsp[2][2][j] - nsold[2][1][j] - nspdied[2][1][j] \\
& -nspcull[2][1][j]) \times cullbsMP[2][j] . \qquad (4.85)
\end{aligned}
$$

If there is fattening of castrates, the number of pure-bred ($j = 1$) or cross-bred ($j = 2$) weaned surplus male progeny fattened as castrates to target $i$ ($nsp[0][i][j]$, $i = 1, \ldots, lf[0]$) is calculated as follows[13]:

$$nsp[0][i][j] = nwsp[2][j] \times psp[0][i][j] . \qquad (4.86)$$

The number of pure-bred ($j = 1$) or cross-bred ($j = 2$) castrates died in fattening to target $i$ ($ndiedfat[0][i][j]$, $i = 1, \ldots, lf[0]$) is

$$ndiedfat[0][i][j] = nsp[0][i][j] \times (1 - surfat[0][i][j]) . \qquad (4.87)$$

The number of pure-bred ($j = 1$) or cross-bred ($j = 2$) castrates reaching the appropriate target $i$ ($nfattar[0][i][j]$, $i = 1, \ldots, lf[0]$) in fattening is

$$nfattar[0][i][j] = nsp[0][i][j] \times surfat[0][i][j] . \qquad (4.88)$$

---

[13]Comment: For the input values $psp[0][i][j]$ holds that $\sum_{i=1}^{csp[0]} psp[0][i][j] = 1$ for all $j$. However, immediately after reading the data, the values $psp[0][i][j]$ are converted so that they are expressed as fraction of the weaned surplus male progeny. Therefore is $\sum_{i=1}^{csp[0]} psp[0][i][j] = psp[2][3][j]$ for $j = 1, 2$. These values are used in all calculations.

### 4.4.5 Calculation of the matrix l1skL (frequency of progeny in all combinations of individual categories and types of breeding) - second part

The first index of the matrix refers to the category of progeny as given in Section 4.2 on page 23, the second index refers to the type of breeding ($j = 1$ : pure-bred animals, $j = 2$: cross-bred animals, $j = 0$: sum of pure-bred and cross-bred animals). All numbers of animals are given per ewe per reproductive cycle. The numbers of cross-bred animals are calculated only for the case that there is cross-breeding (parameter *crossing* $= 2$ in the parameter file PARAS.TXT - see Section 14.1 on page 137). The equations for categories 1, 2, 5, 6, 30 and 31 were already given in Section 4.3.2 on page 27. Here the equations for the remaining categories will be presented. In all equations, $j$ takes the values 1 or 2.

- Category 3. This category is calculated only if there is fattening of female progeny.

$$l1skL[3][j] = \sum_{i=1}^{lf[1]} ndiedfat[1][i][j] \tag{4.89}$$

- Category 4

$$
\begin{aligned}
l1skL[4][1] &= nrdiedmlFP[1] + \sum_{i=1}^{bs[1]} (nrdied[1][i][1] + nspdied[1][i][1]) \\
l1skL[4][2] &= \sum_{i=1}^{bs[1]} nspdied[1][i][2]
\end{aligned}
\tag{4.90}
$$

- Category 7

$$l1skL[7][j] = nsp[1][1][j] \tag{4.91}$$

- Categories 8 to 12. These categories are calculated only if there is fattening of female progeny.

$$l1skL[i][j] = nfattar[1][i-7][j] \quad \text{for } i = 8,\dots,12 \tag{4.92}$$

- Category 13

$$l1skL[13][j] = nsold[1][0][j] \times ps13[j] \tag{4.93}$$

- Category 14

$$
\begin{aligned}
l1skL[14][1] &= (nherd[1] + nsp[1][2][1] - nsold[1][0][1] \times ps13[1]) \\
&\quad \times surbs[1][1][1] \\
l1skL[14][2] &= (nsp[1][2][2] - nsold[1][0][2] \times ps13[2]) \\
&\quad \times surbs[1][1][2]
\end{aligned}
\tag{4.94}
$$

- Category 18

$$
\begin{aligned}
l1skL[18][1] &= nrmatFP[2] + nmatFP[2][1] \\
l1skL[18][2] &= nmatFP[2][2]
\end{aligned}
\tag{4.95}
$$

- Category 22

$$
\begin{aligned}
l1skL[22][1] &= nrmatFP[3] + nmatFP[3][1] \\
l1skL[22][2] &= nmatFP[3][2]
\end{aligned}
\tag{4.96}
$$

- Categories 15, 19 and 23

$$lsk1L[i][j] = nsold[1][(i-11)/4][j] \quad \text{for } i = 15, 19, 23 \qquad (4.97)$$

- Categories 16, 20 and 24

$$
\begin{aligned}
l1skL[i][1] &= nherd[1] \times pherd[1][(i-12)/4] \\
l1skL[i][2] &= 0
\end{aligned}
\qquad (4.98)
$$

where $i = 16$, 20 or 24.

- Categories 17, 21 and 25

$$
\begin{aligned}
l1skL[i][1] &= nrcull[1][(i-13)/4][1] + nspcull[1][(i-13)/4][1] \\
l1skL[i][2] &= nspcull[1][(i-13)/4][2]
\end{aligned}
\qquad (4.99)
$$

where $i = 17$, 21 or 25.

- Category 26

$$l1skL[26][j] = nsold[1][0][j] \times (1 - ps13[j]) \times surbs[1][1][j] \qquad (4.100)$$

- Category 28. This category is calculated only if there is fattening of male progeny.

$$l1skL[28][j] = \sum_{i=1}^{lf[1]} ndiedfat[2][i][j] \qquad (4.101)$$

- Category 29

$$
\begin{aligned}
l1skL[29][1] &= \sum_{i=1}^{bs[2]} (nrdied[2][i][1] + nspdied[2][i][1]) \\
l1skL[29][2] &= \sum_{i=1}^{bs[2]} nspdied[2][i][2]
\end{aligned}
\qquad (4.102)
$$

- Category 32

$$l1skL[32][i] = nsp[2][1][i] \qquad (4.103)$$

- Categories 33 to 37. These categories are calculated only if there is fattening of male progeny.

$$l1skL[i][j] = nfattar[2][i-32][j] \quad \text{for } i = 33, \ldots, 37 \qquad (4.104)$$

- Category 38

$$l1skL[38][j] = nsold[2][1][j] \qquad (4.105)$$

- Category 39

$$
\begin{aligned}
l1skL[39][1] &= nherd[2] + nsp[2][2][1] - nrdied[2][1][1] \\
&\quad -nrcull[2][1][1] - nsold[2][1][1] \\
l1skL[39][2] &= nsp[2][2][2] - nsold[2][1][2] - nspdied[2][1][2] \\
&\quad -nspcull[2][1][2]
\end{aligned}
\qquad (4.106)
$$

- Category 40

$$l1skL[40][j] = nsold[2][2][j] \qquad (4.107)$$

- Category 41

$$
\begin{aligned}
l1skL[41][1] &= nherd[2] \times pherd[2][2] \\
l1skL[41][2] &= 0
\end{aligned}
\tag{4.108}
$$

- Category 42

$$
\begin{aligned}
l1skL[42][1] &= \sum_{i=1}^{bs[2]} \left( nrcull[2][i][1] + nspcull[2][i][1] \right) \\
l1skL[42][2] &= \sum_{i=1}^{bs[2]} nspcull[2][i][2]
\end{aligned}
\tag{4.109}
$$

- Categories 43 to 47. These categories are calculated only if there is fattening of castrates.

$$
l1skL[i][j] = nfattar[0][i-42][j] \quad \text{for } i = 43, \dots, 47
\tag{4.110}
$$

- Category 48. This category is calculated only if there is fattening of castrates.

$$
l1skL[48][j] = \sum_{i=1}^{lf[0]} ndiedfat[0][i][j]
\tag{4.111}
$$

For all categories, the sum of frequencies of pure-bred and cross-bred animals ($l1skL[i][0]$) is

$$
l1skL[i][0] = l1skL[i][1] + l1skL[i][2] \; .
\tag{4.112}
$$

# Chapter 5

# Growth of progeny

## 5.1   General assumptions

Growth of progeny is described by average daily gain in different growing periods. As growth rate of animals of the same breed can be very different in different conditions (lowland, highland, intensive, semi-intensive or extensive feeding), a general growth curve is not used in the program. The growth curve is approximated by a multi-phase growth curve assuming linear functions for the individual phases. The following phases of growth are distinguished:

- from birth till weaning

- from weaning to the end of artificial rearing (if early weaning is applied)

- from weaning (or from the end of artificial rearing) to a given target in fattening

- from weaning to the first breeding season for breeding female and male lambs

- from the first to the second breeding season for breeding female and male lambs

- from the second to the third breeding season for breeding female lambs

- from the second breeding season to mature weight for males if the weight at the second breeding season is smaller than mature weight of rams

- from the first lambing to mature weight if the weight at first lambing is smaller than mature weight of ewes

Differences in growth rates between animals according to litter size (singles, twins, triplets, quadruplets) are taken into account till weaning or till the end of artificial rearing. At weaning or at the and of the artificial rearing period, the average weights of male and female lambs are calculated which are used for describing growth in the following periods. That means, after weaning (or after artificial rearing), a sex-specific average growth rate is applied for all litter sizes. Variation in the live weights at first breeding of male and female breeding lambs are described by the phenotypic standard deviations. In fattening, up to 15 targets (animal groups for fattening) can be defined in total (five targets each for female progeny, for male progeny and for castrates). These targets are given as live weight or age at slaughter.

## 5.2 Calculation of several coefficients relating several growth characteristics to each other[1]

First, average daily gain till weaning ($adgbwL[s][i][j]$) for female ($s = 1$) and male ($s = 2$) pure-bred ($j = 1$) and cross-bred ($j = 2$) lambs born in litter size $i$ ($i = 1, \ldots, clt$) is calculated using the input parameters for birth and weaning weight of lambs[2]:

$$adgbwL[s][i][j] = (wwL[s][i][j] - bwL[s][i][j])/agewL .  \quad (5.1)$$

If there is early weaning followed by artificial rearing of lambs, the average daily gains from weaning until the end of artificial rearing for lambs of different sexes, breeding types and from different litter sizes ($adgwarL[s][i][j]$) are calculated in a similar way:

$$adgwarL[s][i][j] = \frac{warL[s][i][j] - wwL[s][i][j]}{agearL - agewL} .  \quad (5.2)$$

Birth weight and average daily gain of female and male progeny born in different litter sizes are related to the birth weight or average daily gain, respectively, of the female progeny born as singles. The coefficients expressing these relations are specific for sex, breeding type and litter size. For birth weight, the following coefficients ($kbw[s][i][j]$) for female ($s = 1$) and male ($s = 2$) progeny are calculated as:

$$kbw[s][i][j] = bwL[s][i][j]/bwL[1][1][j]  \quad (5.3)$$

where $i$ is litter size ($i = 1, \ldots, clt$), $j$ is the breeding type ($j = 1$ : pure-breds, $j = 2$ : cross-breds), $bwL[s][i][j]$ is the birth weight of lambs of sex $s$ of breeding type $j$ born in a litter with size $i$.

The coefficients for average daily gain ($kadgbw[s][i][j]$) of female and male progeny are calculated in the same way:

$$kadgbw[s][i][j] = adgbwL[s][i][j]/adgbwL[1][1][j]  \quad (5.4)$$

where the meaning of the indices is the same as in equation (5.3) and $adgbwL[s][i][j]$ is the average daily gain from birth to weaning for litter size $i$ and breeding type $j$ for female ($s = 1$) or male ($s = 2$) progeny.

If there is artificial rearing, coefficients for the average daily gain of progeny ($kadgwar[s][i][j]$) from weaning until the end of artificial rearing are calculated following the same procedure as for birth weight and average daily gain from birth to weaning:

$$kadgwar[s][i][j] = adgwarL[s][i][j]/adgwarL[1][1][j]  \quad (5.5)$$

where the meaning of the indices is again the same as in equation (5.3) and the variable $adgwarL[s][i][j]$ is average daily gain from weaning until the end of the artificial rearing period for litter size $i$, breeding type $j$ and sex of progeny $s$.

Things become more complicated when calculating the appropriate coefficients for average daily gain in fattening. Up to five targets are allowed for fattening. Two reference growth traits have to be defined when both pure-bred and cross-bred progeny are fattened. If available, average daily gain of pure-bred or cross-bred female progeny of animals fattened to the first target will be used as reference trait for pure-bred or cross-bred animals, respectively. If, for example, only pure-bred female progeny is fattened to targets 1 and 2 and cross-bred female progeny

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[1]These coefficients must be calculated at the very beginning of the program before the structure of the ewe flock. They are needed during the calculation of the economic values for growth traits.

[2]A list of all variables and constants used in the program is given in Appendix B on page 174. See this list for all symbols not explained in the text.

is fattened to target 3, average daily gain of cross-bred female progeny fattened to target 3 will be used as reference trait for cross-bred animals. The coefficients calculated for female progeny ($kadgfat[1][i][j]$) are:

$$kadgfat[1][i][j] = adgP[7+i][j]/adgP[7+l_j][j] \ , \tag{5.6}$$

where $i$ is the number of the target for fattening ($i = 1, \ldots, lf[1]$), $j$ is the breeding type ($j = 1$ : pure-breds, $j = 2$ : cross-breds), $adgP[7+i][j]$ is average daily gain of female progeny of breeding type $j$ in fattening to target $i$ and index $l_j$ ($j = 1$ : pure-breds, $j = 2$ : cross-breds) in $adgP[7+l_j][j]$ refers to the number of the target its average daily gain is used as reference trait.

If male progeny and/or castrates are fattened in addition to female progeny, the appropriate coefficients $kadgfat[2][i][j]$) and ($kadgfat[0][i][j]$) are calculated in the appropriate way:

$$\begin{aligned} kadgfat[2][i][j] &= adgP[32+i][j]/adgP[7+l_j][j] \\ kadgfat[0][i][j] &= adgP[42+i][j]/adgP[7+l_j][j] \ , \end{aligned} \tag{5.7}$$

where $i$ is the number of the target for fattening ($i = 1, \ldots, lf[2]$ for male progeny, $i = 1, \ldots, lf[0]$ for castrates), $j$ is the same as above and $adgP[32+i][j]$ or $adgP[42+i][j]$ are average daily gain of male progeny or castrates of breeding type $j$ in fattening to target $i$.

If there is no fattening of female progeny, the reference traits are defined similarly as above for male progeny or for castrates. If male progeny is available, the following coefficients are calculated:

$$\begin{aligned} kadgfat[2][i][j] &= adgP[32+i][j]/adgP[32+l_j][j] \\ kadgfat[0][i][j] &= adgP[42+i][j]/adgP[32+l_j][j] \ , \end{aligned} \tag{5.8}$$

where $adgP[32+l_j][j]$ ($j = 1, 2$) are the reference traits. If only castrates are fattened, coefficients are calculated only for castrates:

$$kadgfat[0][i][j] = adgP[42+i][j]/adgP[42+l_j][j] \ , \tag{5.9}$$

where $adgP[42+l_j][j]$ ($j = 1, 2$) are the reference traits.

Average daily gain of female or male progeny from weaning to the first breeding season or from breeding season $i-1$ to breeding season $i$ ($i = 2, \ldots, bs[1]$ for female progeny, $i = 2, \ldots, bs[2]$ for male progeny) is related to average daily gain of female progeny from weaning to the first breeding season as reference trait resulting in the coefficients $kadgr[s][i][j]$ for female ($s = 1$) and male ($s = 2$) progeny ($j = 1$ or $2$ for pure-bred or cross-bred progeny, respectively):

$$kadgr[s][i][j] = adgr[s][i][j]/adgr[1][1][j] \ . \tag{5.10}$$

In cross-bred animals it can happen that there are only male animals but no females. Then equation (5.10) cannot be applied for cross-bred animals and must be modified to

$$kadgr[2][i][2] = adgr[2][i][2]/adgr[2][1][2] \ . \tag{5.11}$$

That means average daily gain of cross-bred male progeny from weaning to the first breeding season is used as reference trait for cross-bred animals.

Mature weight of rams of the breed of the flock is related to mature weight of ewes of the same breed:

$$kmwRE[1] = mwR[1]/mwE[1] \ . \tag{5.12}$$

Similarly, mature weight of rams of the breed used for crossing in the flock is related to mature weight of ewes of the same breed:

$$kmwRE[2] = mwR[2]/mwE2 \ . \tag{5.13}$$

Age of lambs at weaning is calculated from the date of weaning and the date of lambing:

$$agewL = datwL - datlamb \tag{5.14}$$

## 5.3 Recalculation of growth parameters

In Section 5.2, coefficients were calculated to relate the value of a growth trait to the value of a reference growth trait. These coefficients are calculated once before starting the calculation of economic weights. In the course of the calculation of economic weights, the reference growth traits are changed. Therefore, all the remaining growth traits must be recalculated from the reference growth traits. The appropriate equations for the recalculation are given in this subsection.

Birth weight, average daily gain from birth to weaning and average daily gain from weaning until the end of the artificial rearing period of lambs for female ($s = 1$) and male ($s = 2$) progeny born in litter size $i$ ($i = 1, \ldots, clt$) and of breeding type $j$ ($j = 1, 2$) will be expressed as functions of birth weight, average daily gain from birth to weaning and average daily gain from weaning until the end of artificial rearing, respectively, for female lambs born as singles (compare equations 5.3 to 5.5):

$$\begin{array}{rcl} bwL[s][i][j] & = & bwL[1][1][j] \times kbw[s][i][j] \\ adgbwL[s][i][j] & = & adgbwL[1][1][j] \times kadgbw[s][i][j] \\ adgwarL[s][i][j] & = & adgwarL[1][1][j] \times kadgwar[s][i][j] \ . \end{array} \tag{5.15}$$

The recalculation of average daily gain in fattening is carried out on the basis of equations (5.6) to (5.9). See also Section 5.2 for further explanations. If female progeny is fattened, average daily gain for female ($s = 1$) and male ($s = 2$) progeny and castrates ($s = 0$) for fattening to target $i$ ($i = 1, \ldots, lf[s]$) for breeding type $j$ ($j = 1$ : pure-breds, $j = 2$ : cross-breds) is calculated as follows:

$$adgP[k_s + i][j] = adgP[7 + l_j][j] \times kadgfat[s][i][j] \tag{5.16}$$

where index $l_j$ in $adgP[7 + l_j][j]$ refers to the number of the target its average daily gain is used as reference trait and

$$k_s = \left\{ \begin{array}{ll} 7 & \text{for } s = 1 \\ 32 & \text{for } s = 2 \\ 42 & \text{for } s = 0 \end{array} \right. \ . \tag{5.17}$$

If there is fattening of male progeny, but no fattening of female progeny, equation (5.16) changes to

$$adgP[k_s + i][j] = adgP[32 + l_j][j] \times kadgfat[s][i][j] \tag{5.18}$$

where $s = 0$ (castrates) or $s = 2$ (male progeny) and $k_s$ is given by equation (5.17). If only castrates are fattened, equation (5.16) reduces to

$$adgP[42 + i][j] = adgP[42 + l_j][j] \times kadgfat[0][i][j] \ . \tag{5.19}$$

Average daily gain of female ($s = 1$) or male ($s = 2$) progeny ($j = 1$ or 2: pure-bred or cross-bred progeny, respectively) from weaning to the first breeding season

or from breeding season $i-1$ to breeding season $i$ ($i = 2, \ldots, bs[s]$) is calculated as (see equation 5.10):

$$adgr[s][i][j] = kadgr[s][i][j] \times adgr[1][1][j] . \tag{5.20}$$

If equation (5.11) was used instead of equation (5.10) then equation (5.20) changes for cross-bred male animals to:

$$adgr[2][i][2] = kadgr[2][i][2] \times adgr[2][1][2] . \tag{5.21}$$

Mature weight of rams from the breed of the flock is calculated as

$$mwR[1] = mwE[1] \times kmwRE[1] \tag{5.22}$$

and mature weight of rams from the breed used for crossing in the flock is

$$mwR[2] = mwE2 \times kmwRE[2] . \tag{5.23}$$

In the cross-breds, a heterotic effect for mature weight *hetmw* (input parameter) is taken into account. Mature weight for cross-bred ewes ($mwE[2]$) and for cross-bred rams ($mwMP[2]$) is then calculated as:

$$\begin{aligned} mwE[2] &= (1 + hetmw/100) \times (mwE[1] + mwE2)/2 \\ mwMP[2] &= (1 + hetmw/100) \times (mwR[1] + mwR[2])/2 . \end{aligned} \tag{5.24}$$

## 5.4 Growth until weaning

Weaning weight ($ww[s][i][j]$) for female ($s = 1$) and male ($s = 2$) lambs born in litter size $i$ ($i = 1, \ldots, clt$) within breeding type $j$ ($j = 1$ : pure-bred progeny, $j = 2$ : cross-bred progeny) is given by

$$ww[s][i][j] = bwL[s][i][j] + adgbwL[s][i][j] \times agewL . \tag{5.25}$$

In the presence of early weaning and artificial rearing of lambs, the weight at the end of artificial rearing ($warL[s][i][j]$) for female ($s = 1$) and male lambs ($s = 2$) born in litter size $i$ within breeding type $j$ is calculated as

$$warL[s][i][j] = ww[s][i][j] + adgwarL[s][i][j] \times (agearL - agewL) . \tag{5.26}$$

According to analyses of Krupová (2006, personal communication) and Milerski (2007, personal communication), the proportions of singles, twins, triplets and quadruplets are approximately the same in weaned and reared lambs. These proportions are assumed to be equal for male and female lambs because only overall losses summed over male and female lambs at birth and till weaning or till the end of artificial rearing are available. To calculate the average weights and daily gains of breeding lambs in the rearing period (till selling or till entering the flock) and in fattening, the average weight of female and male lambs at the start of the rearing period or at the beginning of fattening was taken as start weight for further periods. It was calculated as weighted average of lamb weights over litter sizes.

The proportion of weaned lambs in litter size $i$ ($i = 1, \ldots, clt$) and breeding type $j$ ($pwL[i][j]$) or the proportion of lambs at the end of artificial rearing in litter size $i$ and breeding type $j$ ($parL[i][j]$) are used as weights. They are calculated as follows:

$$\begin{aligned} pwL[i][j] &= nwL[j][i]/NwL[j] \\ parL[i][j] &= narL[j][i]/NarL[j] . \end{aligned} \tag{5.27}$$

The average weaning weight ($avww[s][j]$) for female ($s = 1$) and male ($s = 2$) progeny is then for breeding type $j$ ($j = 1, 2$):

$$avww[s][j] = \sum_{i=1}^{clt} (wwL[s][i][j] \times pwL[i][j]) . \tag{5.28}$$

If there is artificial rearing, the average weight at the end of artificial rearing is calculated for breeding type $j$ by the following equation:

$$avwar[s][j] = \sum_{i=1}^{clt} (warL[s][i][j] \times parL[i][j]) . \tag{5.29}$$

The final weights of categories 7 and 32 (female or male lambs slaughtered after weaning) are therefore:

$$
\begin{aligned}
wP[7][j] &= \left\{ \begin{array}{ll} avww[1][j] & \text{if } typew = 1 \\ avwar[1][j] & \text{if } typew = 2 \end{array} \right. \\
wP[32][j] &= \left\{ \begin{array}{ll} avww[2][j] & \text{if } typew = 1 \\ avwar[2][j] & \text{if } typew = 2 \end{array} \right. .
\end{aligned}
\tag{5.30}
$$

## 5.5 Growth of breeding female progeny after weaning[3]

Age of female lambs at the beginning of breeding season $i$ ($i = 1, \ldots, bs[1]$) after weaning $ager[1][i]$ is assumed not to depend on breeding type $j$:

$$ager[1][i] = datbbs + (i - 1) \times lengthrc - datlamb + 1 \tag{5.31}$$

Average weight of pure-bred ($j = 1$) or cross-bred ($j = 2$) female lambs at the first breeding season after weaning ($wrL[1][1][j]$) is calculated as:

$$wrL[1][1][j] = avww[1][j] + adgr[1][1][j] \times (ager[1][1] - agewL) . \tag{5.32}$$

If there is artificial rearing of lambs, equation (5.32) takes the form

$$wrL[1][1][j] = avwar[1][j] + adgr[1][1][j] \times (ager[1][1] - agearL) . \tag{5.33}$$

The weight at the first breeding season must be lower than mature weight. If this condition is not fulfilled, an error message occurs when running the program.

The minimal weight of pure-bred ($j = 1$) or cross-bred ($j = 2$) female lambs for mating ($minw[1][j]$) is calculated as proportion of the mature weight:

$$minw[1][j] = mwE[j] \times pwrepFP[j] . \tag{5.34}$$

For the further calculations, it is assumed that the weight at the first breeding season both for pure-bred ($j = 1$) or cross-bred ($j = 2$) female lambs is normally distributed with the mean $wrL[1][1][j]$ calculated in equations (5.32) or (5.33) and standard deviation $sigmawr[1][j]$. The standard deviation is calculated from the coefficient of variation and the mean weight:

$$sigmawr[1][j] = vcwr[1][j] \times wrL[1][1][j]/100 . \tag{5.35}$$

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[3]Note please that variables specific for female progeny only contain "FP" in their name. In variables which are defined both for female and male progeny and, in some cases, also for castrates, an index indicates the sex where 1 stands for female progeny. In most variables, the index referring to the sex of progeny is the first index.

On the basis of the normal distribution, the proportion of females that reached the minimal weight for mating ($pmat[1][1][j]$) is calculated. For the two groups of lambs (pure-breds and cross-breds) selected for mating, the mean weight is calculated ($wmat[1][j]$) as median from the part of the normal distribution which belongs to the selected animals. Similarly, the mean weight of lambs not intended for mating ($wnmat[1][j]$) is calculated as median from the part of the normal distribution belonging to the not selected animals. As the animals selected for mating will enter the ewe flock, the mean weight of the animals not selected for mating is the basis for calculating the growth to the next two breeding seasons.

The average weight of pure-bred ($j = 1$) or cross-bred ($j = 2$) female lambs at the second breeding season after weaning ($wrL[1][2][j]$) is given by the following equation:

$$wrL[1][2][j] = wnmat[1][j] + adgr[1][2][j] \times (ager[1][2] - ager[1][1]) . \qquad (5.36)$$

The weight at the second breeding season cannot be higher than mature weight. The weight at the third breeding season is expected to be the mature weight:

$$wrL[1][3][j] = mwE[j] . \qquad (5.37)$$

Average daily gain of female lambs between the second and the third breeding season or between the second breeding season and lambing is no input parameter but is calculated as follows:

$$adgr[1][3][j] = (wrL[1][3][j] - wrL[1][2][j])/(ager[1][3] - ager[1][2]) . \qquad (5.38)$$

The weight after lambing ($wlFP[i]$) of females conceived in breeding season $i$ ($i = 1, \ldots, bs[1]$) is

$$
\begin{aligned}
wlFP[1] &= wmat[1][1] + adgr[1][2][1] \times (datlamb + lengthrc - datbbs) \\
wlFP[2] &= wrL[1][2][1] + adgr[1][3][1] \times (datlamb + lengthrc - datbbs) \\
wlFP[3] &= mwE[1] \qquad (5.39)
\end{aligned}
$$

and the age at lambing of females conceived in breeding season $i$ is calculated as

$$agelFP[i] = i \times lengthrc . \qquad (5.40)$$

For the following calculations the date of conception is needed which is

$$datconFP[i] = datlamb + i \times lengthrc - lpreg \qquad (5.41)$$

where

$$
i = \begin{cases}
1 & \text{for categories 15 and 16} \\
2 & \text{for categories 19 and 20} \\
3 & \text{for categories 23 and 24}
\end{cases} . \qquad (5.42)
$$

For the definition of categories see Section 4.2 on page 23. Next the weight ($wP[i][j]$) of different categories of pure-bred ($j = 1$) or cross-bred ($j = 2$) female progeny is calculated. Index $i$ is the number of category of progeny as given in Section 4.2 on page 23. The weight of breeding female lambs sold before mating (category 13) is calculated in the case of customary weaning as

$$wP[13][j] = avww[1][j] + adgr[1][1][j] \times (agetP[13][j] - agewL) \qquad (5.43)$$

and in the case of artificial weaning as

$$wP[13][j] = avwar[1][j] + adgr[1][1][j] \times (agetP[13][j] - agearL) . \qquad (5.44)$$

The weight of seven further categories of sold or culled females is:

$$
\begin{aligned}
wP[15][j] &= wmat[1][j] + adgr[1][2][j] \times (datconFP[1] + dpregsFP - datbbs) \\
wP[17][j] &= wmat[1][j] + adgr[1][2][j] \times (datebs + dnpregcFP - datbbs) \\
wP[19][j] &= wrL[1][2][j] + adgr[1][3][j] \times (datconFP[2] + dpregsFP - datbbs) \\
wP[21][j] &= wrL[1][2][j] + adgr[1][3][j] \times (datebs + dnpregcFP - datbbs) \\
wP[23][j] &= mwE[j] \qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad (5.45) \\
wP[25][j] &= mwE[j] \\
wP[26][j] &= wnmat[1][j] + adgr[1][2][j] \times (agetP[26][j] - ager[1][1])
\end{aligned}
$$

Average live weight of females died in the rearing period (category 4) is calculated as the weighted average of the weights of the females in the different parts of the rearing period (from weaning to 1st breeding, from 1st to 2nd and from 2nd to 3rd breeding) and from conception to lambing. It is assumed that animals died on average in the middle of the appropriate period. For pure-bred females in a system with customary weaning we get:

$$
\begin{aligned}
wP[4][1] = {} & \frac{1}{2 \times l1skL[4][1]} \Big( (wrL[1][1][1] + avww[1][1]) \times (nrdied[1][1][1] \\
& + nspdied[1][1][1]) + (wrL[1][2][1] + wnmat[1][1]) \\
& \times (nrdied[1][2][1] + nspdied[1][2][1]) + (wrL[1][3][1] \\
& + wrL[1][2][1]) \times (nrdied[1][3][1] + nspdied[1][3][1]) \qquad (5.46) \\
& + nrdiedmlFP[1] \times \big( pherd[1][1] \times (wnmat[1][1] + wlFP[1]) \\
& + pherd[1][2] \times (wrL[1][2][1] + wlFP[2]) \\
& + pherd[1][3] \times (wrL[1][3][1] + wlFP[3]) \big) / Pherd[1] \Big).
\end{aligned}
$$

For cross-bred females in a system with customary weaning this equation changes to:

$$
\begin{aligned}
wP[4][2] = {} & \frac{1}{2 \times l1skL[4][2]} \Big( (wrL[1][1][2] + avww[1][2]) \times (nrdied[1][1][2] \\
& + nspdied[1][1][2]) + (wrL[1][2][2] + wnmat[1][2]) \\
& \times (nrdied[1][2][2] + nspdied[1][2][2]) + (wrL[1][3][2] \qquad (5.47) \\
& + wrL[1][2][2]) \times (nrdied[1][3][2] + nspdied[1][3][2]) \Big).
\end{aligned}
$$

If artificial rearing is used instead of customary weaning, replace $avww[1][j]$ with $avwar[1][j]$ ($j = 1, 2$) in equations (5.46) and (5.47).

## 5.6 Growth of breeding male progeny after weaning[4]

The procedure of calculating growth parameters for male lambs is similar as for female lambs in the preceding subsection. Index $j$ refers generally to the breeding type ($j = 1$ : pure-bred, $j = 2$ : cross-bred animals). Age of male lambs ($ager[2][i]$) at the beginning of breeding season $i$ ($i = 1, \ldots, bs[2]$) is assumed not to depend on breeding type $j$ and is calculated as:

$$
ager[2][i] = datbbs + (i - 1) \times lengthrc - datlamb + 1 \qquad (5.48)
$$

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[4]Note please that variables specific only for male progeny contain "MP" in their name. In variables which are defined both for female and male progeny and, in some cases, also for castrates, the first index indicates the sex where 2 stands for male progeny. In most variables, the index referring to the sex of progeny is the first index.

Average weight of male lambs at the first breeding season after their weaning in the absence of artificial rearing ($wrL[2][1][j]$) is calculated as:

$$wrL[2][1][j] = avww[2][j] + adgr[2][1][j] \times (ager[2][1] - agewL) \ . \tag{5.49}$$

If there is artificial rearing of lambs, equation (5.49) takes the form

$$wrL[2][1][j] = avwar[2][j] + adgr[2][1][j] \times (ager[2][1] - agearL) \ . \tag{5.50}$$

The weight in the first breeding season must be lower than mature weight. If this condition is not fulfilled, an error message occurs when running the program.

The minimal weight of male lambs for mating ($minw[2][j]$) is:

$$minw[2][j] = mwMP[j] \times pwrepMP \ . \tag{5.51}$$

The proportion of males that reached the minimal weight for mating ($pmat[2][1][j]$) is calculated on the basis of assuming the weights to be normally distributed. The standard deviation of this distribution is calculated from the coefficient of variation and the mean weight:

$$sigmawr[2][j] = vcwr[2][j] \times wrL[2][1][j]/100 \ . \tag{5.52}$$

From this normal distribution, the mean weight of animals selected for breeding in the first breeding season ($wmat[2][j]$) and the mean weight of animals not selected for breeding ($wnmat[2][j]$) is calculated. The mean weight of the animals not selected for mating is the basis for calculating the growth to the next breeding season.

The average weight of male lambs at the beginning of the second breeding season after weaning ($wrL[2][2][j]$) is given by the following equation:

$$wrL[2][2][j] = wnmat[2][j] + adgr[2][2][j] \times (ager[2][2] - ager[2][1]) \ . \tag{5.53}$$

The weight at the second breeding season cannot be higher than mature weight.

Finally, the weight ($wP[i][j]$) of different categories of male progeny is calculated. Index $i$ is the number of category of progeny as given in Section 4.2 on page 23. The weight of breeding male lambs sold before mating (category 38) is calculated in the case of customary weaning as

$$wP[38][j] = avww[2][j] + adgr[2][1][j] * (agetP[38][j] - agewL) \tag{5.54}$$

and in the case of artificial weaning as

$$wP[38][j] = avwar[2][j] + adgr[2][1][j] * (agetP[38][j] - agearL) \ . \tag{5.55}$$

The weight of a further category of sold males is:

$$wP[40][j] = wrL[2][1][j] + adgr[2][2][j] \times (agetP[40][j] - ager[2][1]) \ . \tag{5.56}$$

Average live weight of males died in the rearing period (category 29) is calculated as the weighted average of the weights of the males in the different parts of the rearing period (from weaning to 1st breeding, from 1st to 2nd breeding). It is assumed that animals died on average in the middle of the appropriate period. For pure-bred ($j = 1$) or cross-bred ($j = 2$) males in a system with customary weaning we get:

$$
\begin{aligned}
wP[29][j] \quad = \quad & \frac{1}{2 \times l1skL[29][j]} \Big( (wrL[2][1][j] + avww[2][j]) \times (nrdied[2][1][j] \\
& + nspdied[2][1][j]) + (wrL[2][2][j] + wnmat[2][j]) \\
& \times (nrdied[2][2][j] + nspdied[2][2][j]) \Big).
\end{aligned}
\tag{5.57}
$$

If artificial rearing is used instead of customary weaning, replace $avww[2][j]$ with $avwar[2][j]$ in this equation.

The final weights of pure-bred ($j = 1$) or cross-bred ($j = 2$) male lambs in the rearing period until the first breeding season (category 39) and of males between the first and second breeding season (category 41) are:

$$
\begin{aligned}
wP[39][j] &= wrL[2][1][j] \\
wP[41][j] &= wrL[2][2][j] \ .
\end{aligned}
$$

(5.58)

Average live weight of males culled in the rearing period (category 42) is calculated in a similar way as average live weight of males died in the rearing period:

$$
\begin{aligned}
wP[42][j] =\ & \frac{1}{2 \times l1skL[42][j]} \Big( (wrL[2][1][j] + avww[2][j]) \times (nrcull[2][1][j] \\
& + nspcull[2][1][j]) + (wrL[2][2][j] + wnmat[2][j]) \\
& \times (nrcull[2][2][j] + nspcull[2][2][j]) \Big).
\end{aligned}
$$

(5.59)

If artificial rearing is used instead of customary weaning, replace again $avww[2][j]$ with $avwar[2][j]$ in this equation.

## 5.7 Growth in fattening

As already mentioned in Section 5.2, up to 15 targets for fattening to target slaughter weight or slaughter age may be defined in total whereby each 5 targets are reserved for female progeny, male progeny and castrates. Most input parameters for fattening are concentrated in input file INPUTS05.TXT (see subsection 14.2.4 on page 141, where some more explanations of the input parameters are given). The main principles are the same for female and male progeny and castrates. The parameter $ulf[s][i]$ indicates if fattening to target $i$ is to fixed slaughter weight ($ulf[s][i] = 1$) or to fixed slaughter age ($ulf[s][i] = 2$). Index $s$ refers to the sex of progeny ($s = 1$ : female progeny, $s = 2$ : male progeny and $s = 0$ : castrates). The parameter $clf[s][i]$ informs if fattening to target $i$ is only for pure-breds ($clf[s][i] = 1$), only for cross-breds ($clf[s][i] = 2$) or both for pure-breds and cross-breds ($clf[s][i] = 0$).

If there is customary weaning and fattening is to fixed slaughter weight, slaughter age of pure-bred ($j = 1$) or cross-bred ($j = 2$) progeny at target $i$ is calculated as

$$agetP[k_s + i][j] = agewL + (vlf[s][i] - avww[s][j])/adgP[k_s + i][j] \qquad (5.60)$$

where $k_s$ is given by equation (5.17). Equation (5.60) changes to

$$agetP[k_s + i][j] = agearL + (vlf[s][i] - avwar[s][j])/adgP[k_s + i][j] \qquad (5.61)$$

in the case of artificial rearing. If there is fattening to fixed slaughter age, slaughter weight is calculated in the presence of customary weaning as

$$wP[k_s + i][j] = avww[s][j] + (vlf[s][i] - agewL) \times adgP[k_s + i][j] \qquad (5.62)$$

and in the presence of artificial weaning as

$$wP[k_s + i][j] = avwar[s][j] + (vlf[s][i] - agearL) \times adgP[k_s + i][j] \ . \qquad (5.63)$$

Average live weight of females died in fattening (category 3) is calculated as the weighted average of the weights of the females fattened to targets 1 to $lf[1]$. It is assumed that animals died on average in the middle of the appropriate period. For

pure-bred ($j = 1$) or cross-bred ($j = 2$) females in a system with customary weaning we get:

$$
\begin{aligned}
wP[3][j] \quad = \quad & \frac{1}{2 \times l1skL[3][j]} \\
& \times \sum_{i=1}^{lf[1]} (wP[7+i][j] + avww[1][j]) \times ndiedfat[1][i][j]. \quad (5.64)
\end{aligned}
$$

The same approach is used to calculate the average live weight for males died in fattening (category 28)

$$
\begin{aligned}
wP[28][j] \quad = \quad & \frac{1}{2 \times l1skL[28][j]} \\
& \times \sum_{i=1}^{lf[2]} (wP[32+i][j] + avww[2][j]) \times ndiedfat[2][i][j]. \quad (5.65)
\end{aligned}
$$

and for castrates died in fattening (category 48)

$$
\begin{aligned}
wP[48][j] \quad = \quad & \frac{1}{2 \times l1skL[48][j]} \\
& \times \sum_{i=1}^{lf[0]} (wP[42+i][j] + avww[2][j]) \times ndiedfat[0][i][j]. \quad (5.66)
\end{aligned}
$$

If artificial rearing is used instead of customary weaning, replace $avww[s][j]$ with $avwar[s][j]$ in equations (5.64) to (5.66) with the corresponding indices.

## 5.8 Growth of ewes

The average age $ageE[1]$ or weight $wlE[1]$ of females at first lambing are calculated as weighted average of the ages or weights, respectively, of females lambing after the individual breeding seasons $i$ ($i = 1, \ldots, bs[1]$):

$$
\begin{aligned}
ageE[1] \quad = \quad & \sum_{i=1}^{bs[1]} (agelFP[i] \times pherd[1][i])/Pherd[1] \\
wlE[1] \quad = \quad & \sum_{i=1}^{bsFM} (wlFP[i] \times pherd[1][i])/Pherd[1] \, . \quad (5.67)
\end{aligned}
$$

The age of ewes at lambing $i$ ($i = 2, \ldots, LL$) is then

$$
ageE[i] = ageE[1] + (i-1) \times lengthrc \, . \quad (5.68)
$$

It is assumed that the weight of ewes at the second and subsequent lambings is equal to mature weight:

$$
wlE[i] = mwE[1] \quad \text{for } i = 2, \ldots, LL \, . \quad (5.69)
$$

Average daily gain between first and second lambing is then

$$
adgE = (wlE[2] - wlE[1])/lengthrc \, . \quad (5.70)
$$

In case that the ewes reach mature weight at first lambing already, daily gain between first and second lambing will be zero.

## 5.9    Growth of rams

The average age of rams of the breed of the flock when entering the flock ($ageR[1][1]$) is given by the following equation:

$$
\begin{aligned}
ageR[1][1] \quad = \quad & (1 - ppurchMP) \times \left( \sum_{i=1}^{bs[2]} (ager[2][i] \times pherd[2][i]) / Pherd[2] \right) \\
& + agepurMP[1] \times ppurchMP \;.
\end{aligned}
\tag{5.71}
$$

The age of rams of the breed of the flock at the beginning of breeding cycle $i$ ($i = 2, \ldots, RR$) is

$$
ageR[i][1] = ageR[1][1] + (i-1) \times lengthrc \;.
\tag{5.72}
$$

If rams of another breed are used for crossing in the flock, their age at entering the flock ($ageR[1][2]$) or at the beginning of breeding cycle $i$ ($ageR[i][2]$ with $i = 2, \ldots, RR$) is:

$$
\begin{aligned}
ageR[1][2] \quad &= \quad agepurMP[2] \\
ageR[i][2] \quad &= \quad ageR[1][2] + (i-1) \times lengthrc \;.
\end{aligned}
\tag{5.73}
$$

The average weight of rams of the breed of the flock when entering the flock ($wbR[1][1]$) is calculated as:

$$
\begin{aligned}
wbR[1][1] \quad = \quad & (1 - ppurchMP) \times \left( \sum_{i=1}^{bs[2]} (wrL[2][i][1] \times pherd[2][i]) / Pherd[2] \right) \\
& + wpurMP[1] \times ppurchMP \;.
\end{aligned}
\tag{5.74}
$$

The weight at the beginning of the subsequent breeding cycles $i$ ($wbR[i][1]$ with $i = 2, \ldots, RR$) is assumed to be equal to mature weight:

$$
wbR[i][1] = mwR[1] \;.
\tag{5.75}
$$

The average daily gain for rams of the breed of the flock between the time of entering the flock and the beginning of the second breeding cycle is

$$
adgR[1] = (wbR[2][1] - wbR[1][1]) / lengthrc \;.
\tag{5.76}
$$

If rams of another breed are used for crossing in the flock, their weight when entering the flock ($wbR[1][2]$) or at the beginning of breeding cycle $i$ ($wbR[i][2]$ with $i = 2, \ldots, RR$) and their average daily gain between the time of entering the flock and the beginning of the second breeding cycle are:

$$
\begin{aligned}
wbR[1][2] \quad &= \quad wpurMP[2] \\
wbR[i][2] \quad &= \quad mwR[2] \\
adgR[2] \quad &= \quad (wbR[2][2] - wbR[1][2]) / lengthrc \;.
\end{aligned}
\tag{5.77}
$$

# Chapter 6

# Milk production

## 6.1 Lactation curve

### 6.1.1 Lactation curve is known

The time course of milk production is modelled using the Wood function [28] as default. The simplest form of the Wood function can be written as

$$y(t) = at^b e^{-ct} \qquad (6.1)$$

where $y(t)$ is the milk yield at day $t$ of lactation and $a$, $b$ and $c$ are parameters of the lactation curve. Parameter $a$ influences the overall height of the lactation curve, parameter $b$ specifies the increase of milk production and is of importance in the first part of the curve and parameter $c$ is responsible for the decrease of the curve in the second part. In input file INPUTS06.TXT (see subsection 14.2.6 on page 144), the parameters of the lactation function are given for a standard situation (for example for sheep with single lambs in the first lactation). The milk yield in different parities is calculated by multiplying the milk yield in the standard situation with a constant. These constants are input parameters. Similarly the milk yield for ewes with a different number of lambs (including no lambs) is calculated by multiplying the milk yield in the standard situation with appropriate constants which are also input parameters.

### 6.1.2 Lactation curve is unknown

In non-dairy sheep the lactation curve may be unknown. Then it is assumed (because of lack of information) that the daily milk yield is equal for the whole lactation. As it will be convenient to use the same program code for all situations, the Wood function (6.1) will be adapted to this special case by setting the parameters $b$ and $c$ ($bwo$ and $awo$ in the program) to zero. Parameter $a$ ($awo$ in the program) is calculated as average daily milk yield:

$$a = \frac{basemilkw}{agewL} \ . \qquad (6.2)$$

The variable $basemilkw$ is an input parameter if the lactation curve is unknown.

## 6.2 Calculation of the milk yield per ewe in different segments of the lactation

First, the probability $pbtba[i][j]$ that the number of suckled lambs is $j$ for a ewe who has born $i$ ($i \geq j$) lambs will be calculated:

$$pbtba[i][j] = \begin{cases} pdiedbtL[i][i-j]/(i-j) & \text{for } j < i \\ 1 - \displaystyle\sum_{k=1}^{i} pdiedbtL[i][k]/k & \text{for } j = i. \end{cases} \quad (6.3)$$

The number of ewes ($PsuckE[i][j]$) with $i$ suckled lambs ($i = 0, \dots, clt$) in lactation $j$ ($j = 1, \dots, LL$) expressed as proportion of all ewes in the flock is then:

$$PsuckE[i][j] = l3E[j] \sum_{k=i2}^{clt} Pltype[k][j] \times pbtba[k][i] \quad (6.4)$$

where $i2 = 1$ for $i = 0$ or $i = 1$ and $i2 = i$ for $i \geq 2$. For checking the correctness of the results, note that the following two relations must be fulfilled:

$$\sum_{i=0}^{clt} PsuckE[i][j] = l3E[j] \quad \text{for each } j \text{ and}$$

$$\sum_{i=0}^{clt} \sum_{i=1}^{LL} PsuckE[i][j] = Nlamb \, . \quad (6.5)$$

In dairy breeds, it is assumed that ewes without lambs alive at 24 hours after lambing are milked and their milk is collected till weaning lambs and is used for lamb feeding or is sold. The proportion of milk for sale produced by ewes from lambing till weaning is given by the input parameter *pmilkwm* in file INPUTS06.TXT. In non-dairy breeds, ewes without lambs alive at 24 hours after lambing are dried off and this parameter is therefore zero.

### 6.2.1 Calculation of milk yield until weaning

Milk yield until weaning per ewe lambing (*basemilkw*) calculated for the standard situation of the lactation curve (6.1) is calculated as

$$basemilkw = awo \sum_{i=1}^{agewL-1} i^{bwo} e^{-cwo \times i} \quad (6.6)$$

where $i$ is the number of days in lactation, *awo*, *bwo* and *cwo* are the coefficients of the lactation curve. The lactation curve is assumed to be known for dairy ewes. Estimates for the lactation curve are also published for meat sheep breeds [7, 16]. If data are available for different functions than the Wood curve we recommend to recalculate the parameters to allow using the Wood curve. Alternatively, different lactation curves may be implemented in the program in future. If you intend to use such a lactation curve contact please the authors of the program.

If no lactation curve is known (probably in most cases of non-dairy sheep breeds), the milk yield until weaning (*basemilkw*) must be given by the user as input parameter in input file INPUTS07.TXT (see subsection 14.2.7 on page 145). If there are no data available a rough estimate of the milk yield until weaning may be achieved assuming values from 0.6 to 1.0 kg milk per day according to the growth rate of the lambs [17].

Milk yield until weaning ($milkwrel[i][j]$) per ewe lambing with $i$ ($i = 0, \ldots, clt$) suckled lambs in lactation $j$ ($j = 1, \ldots, LL$) is calculated by multiplying the milk yield for the standard situation ($basemilkw$) with the appropriate adjustment factors correcting for the number of suckled lambs ($ktlsl[i]$) and for parity ($ktlp[j]$):

$$milkwrel[i][j] = basemilkw \times ktlsl[i] \times ktlp[j] \ . \tag{6.7}$$

In non-dairy breeds there is no milk available from ewes with no suckling lambs. Therefore, you should put $ktlsl[0] = 0$ in input file INPUTS06.TXT. If you accidentally give a different number, the program will automatically set the value to zero.

The total milk yield until weaning per ewe in the flock per reproductive cycle ($tmilkw$) is:

$$tmilkw = \sum_{i=0}^{clt} \sum_{j=1}^{LL} milkwrel[i][j] \times PsuckE[i][j] \ . \tag{6.8}$$

The amount of milk ($milksw[j]$) milked for sale until weaning in lactation $j$ is[1]:

$$
\begin{aligned}
milksw[j] \quad = \quad & \frac{1}{l3E[j]} \Big( milkwrel[0][j] \times PsuckE[0][j] \\
& + pmilkwm \sum_{i=1}^{clt} milkwrel[i][j] \times PsuckE[i][j] \Big)
\end{aligned}
\tag{6.9}
$$

For non-dairy sheep ($typeb > 1$ in the parameter file), the date of weaning is identical to the date of drying off of ewes:

$$datdry = datwL \ . \tag{6.10}$$

## 6.2.2   Calculation of milk yield from weaning till the end of the milking period

The calculations presented in this subsection are relevant only for dairy sheep. The variables calculated and the calculations themselves are formally very similar to the variables and calculations in the preceding subsection 6.2.1.

The length of the milking period after weaning ($lengthmp$) is

$$lengthmp = datdry - datwL \ . \tag{6.11}$$

Milk yield from weaning to the end of the milking period per lambing ewe ($basemilkm$) calculated for the standard situation of the lactation curve (6.1) is

$$basemilkm = awo \sum_{i=agewL}^{lengthmp+agewL} i^{bwo} e^{-cwo \times i} \ . \tag{6.12}$$

Milk yield from weaning to the end of the milking period ($milkmrel[i][j]$) per lambing ewe with $i$ ($i = 0, \ldots, clt$) suckled lambs in lactation $j$ ($j = 1, \ldots, LL$) is given by the equation:

$$milkmrel[i][j] = basemilkm \times ktlsl[i] \times ktlp[j] \ . \tag{6.13}$$

The total milk yield from weaning to the end of the milking period per ewe in the flock per reproductive cycle ($tmilkm$) is:

$$tmilkm = \sum_{i=0}^{clt} \sum_{j=1}^{LL} milkmrel[i][j] \times PsuckE[i][j] \ . \tag{6.14}$$

---

[1] The variable $milksw[j]$ is calculated only for dairy sheep and if $pmilkwm > 0$.

Milk yield per ewe lambing in parity $j$ ($milkmpar[j]$, $j = 1, \ldots, LL$) averaged over all possible numbers of suckled lambs is calculated as

$$milkmpar[j] = \frac{1}{l3E[j]} \sum_{i=0}^{clt} milkmrel[i][j] \times PsuckE[i][j] \ . \tag{6.15}$$

## 6.3 Cheese production

There are two options for the calculation of the amount of milk needed per kg of cheese. In the first option (parameter $cy = 1$), the amount of milk needed per kg of cheese ($milkch$) is expressed as a linear function of milk fat ($fat$, in %) and milk protein content ($prot$, in %) as follows:

$$milkch = ach + bch \times fat + cch \times protein \ . \tag{6.16}$$

where $ach$ is a constant and $bch$ and $cch$ are the regression coefficients for fat and protein content of milk. These three parameters are input parameters in IN-PUTS06.TXT (see page 144). If the parameters for the regression equation are not known and you did not decide for the second option, insert an average value for the milk needed per kg cheese for the constant $ach$ and zeros for both regression coefficients.

The second option is based on Van Slyke's formula [20]. We used the following modified form of this formula given by Jaeggi et al. [10]:

$$cheesey = \frac{(rfat \times fat + rcas \times casprot \times prot) \times rs}{100 - moich} \tag{6.17}$$

where $cheesey$ is the cheese yield in kg from 1 kg milk, $rfat$ is the fat recovered in cheese (given as fraction), $fat$ is the fat content in milk in %, $rcas$ is the casein recovered in cheese (given as fraction), $casprot$ is the amount of casein given as proportion of milk proteins, $prot$ is the protein content in milk given in %, $rs$ is a coefficient representing other milk solids and added salt recovered in cheese (this coefficient is calculated below) and $moich$ is the moisture of cheese (in %).

The coefficient $rs$ is calculated as follows:

$$rs = \frac{rfat \times fat \times 100}{(rfat \times fat + rcas \times casprot \times prot) \times fdm} \tag{6.18}$$

where $fdm$ is fat in dry matter (in %):

$$fdm = \frac{fatch}{100 - moich} \times 100 \tag{6.19}$$

where $fatch$ is the fat content in cheese given in %. During the calculation of the economic values, $rs$ is held constant.

A by-product of cheese production is cheese whey. The amount of cheese whey (in kg) produced per kg cheese ($cheesewhey$) is given by

$$cheesewhey = milkch - 1 \tag{6.20}$$

assuming that no liquids were lost when processing milk to cheese.

# Chapter 7

# Wool production

## 7.1 Calculation of the wool production of ewes and rams

The wool production per ewe and reproductive cycle ($woolptE$) and the wool production per ram of the breed of the flock ($j = 1$) or of the breed used for crossing in the flock ($j = 2$) and per breeding cycle ($woolptR[j]$) are calculated from the amount of wool gained per shearing and from the number of shearings per animal in the corresponding time periods:

$$
\begin{aligned}
woolptE &= wsheE \times nsheE \\
woolptR[j] &= wsheR[j] \times nsheR[j] \; .
\end{aligned}
\tag{7.1}
$$

## 7.2 Calculation of several ratios relating fleece weight of several categories of animals to fleece weight of rams[1]

In this section, the fleece weight of the individual categories of animals are related to the fleece weight of adult rams. When calculating economic values it is assumed that the following calculated ratios stay constant when changing the fleece weight of rams. That means, fleece weight of all categories of animals is considered to be one trait. The following ratios are calculated:

$$
\begin{aligned}
kwE &= \frac{wsheE}{wsheR[1]} \\
kwarL[i][j] &= \frac{wshearL[i][j]}{wsheR[j]} & \text{if } typew = 2 \\
kwfL[i][j] &= \frac{wshefL[i][j]}{wsheR[j]} & \text{if there is fattening} & \tag{7.2} \\
kwrL[i][j] &= \frac{wsherL[i][j]}{wsheR[j]} \\
kwwL[i][j] &= \frac{wshewL[i][j]}{wsheR[j]} & \text{if } typew = 1
\end{aligned}
$$

---

[1]These ratios must be calculated at the very beginning of the program before the structure of the ewe flock. They are needed during the calculation of the economic value for fleece weight.

## 7.3    Recalculation of parameters for fleece weight

In Section 7.2, ratios were calculated to relate the value of the fleece weight of a category of animals to the value of fleece weight of rams. These ratios are calculated once before starting the calculation of economic weights. In the course of the calculation of economic weights, the fleece weight of rams is changed. Therefore, all the remaining fleece weights must be recalculated from the fleece weight of rams. The appropriate equations for the recalculation are given here:

$$
\begin{aligned}
wsheE &= kwE \times wsheR[1] \\
wshearL[i][j] &= kwarL[i][j] \times wsheR[j] \quad \text{if } typew = 2 \\
wshefL[i][j] &= kwfL[i][j] \times wsheR[j] \quad \text{if there is fattening} \quad (7.3) \\
wsherL[i][j] &= kwrL[i][j] \times wsheR[j] \\
wshewL[i][j] &= kwwL[i][j] \times wsheR[j] \quad \text{if } typew = 1
\end{aligned}
$$

# Chapter 8

# Discounting

Genetic improvement in different traits is expressed in different animal categories at a different age. Consequently, the traits influence revenues and costs in an animal category at a different time. Costs for feeding, e.g., occur daily in the whole period of the animal's life, costs for shearing may be spend at any time and costs for marketing or revenues from slaughtered animals occur only once and that at the end of a particular animal category.

The time at which a trait influences revenues and costs can be accounted for when calculating economic values by discounting all revenues and costs, occurring in the flock for each ewe, ram and progeny category, to the birth date of the animal. For this purpose, discounting coefficients for all revenue and cost items are calculated for each category of ewes, rams and lambs. The discounting coefficient in its general form ($q$) is defined as

$$q = (1 + u)^{-t} \qquad (8.1)$$

where $u$ is the annual discount rate and $t$ is the age of the animal when the revenues and costs occur in a particular category of animals.

If the discount rate $u$ is set to zero in the input parameter file INPUTS01.TXT economic values will be calculated without discounting, i.e. not taking into account the time factor.

## 8.1 Length of the time period for each category

The length of the time period for the occurence of each category is needed for the calculation of the discounting coefficients and for further calculations in the following chapters.

For ewes, we write $dcE[i]$ for the length of the time period for category $i$ from the start of the reproductive cycle to the end of the category. The length of the time period is calculated for stages 1 to 3 (see Section 3.1) for all lactations ($j = 1, \ldots, LL$) :

$$
\begin{aligned}
dcE[(j-1) \times nstgE + 1] &= lengthrc/2 \\
dcE[(j-1) \times nstgE + 2] &= datdry - datlamb + 1 \qquad (8.2) \\
dcE[(j-1) \times nstgE + 3] &= datebs + dnpregcE - datlamb + 1 \ .
\end{aligned}
$$

For stages $k = 4$ or $5$, the following equation holds only for lactations $j = 1, \ldots, LL - 1$ :

$$dcE[(j-1) \times nstgE + k] = lengthrc \ . \qquad (8.3)$$

For rams, we write $dcR[i]$ for the length of the time period for category $i$. The length of the time period is calculated for stages 1 to 2 (see Section 3.2.2) for all

breeding cycles $(j = 1, \ldots, RR)$ in the same way:

$$dcR[(j-1) \times nstgR + 1] = lengthrc/2 \tag{8.4}$$
$$dcR[(j-1) \times nstgR + 2] = datebs + dselR - datbbs + flushbbR + 1 \ .$$

In stage 3, the calculation is different for the last breeding cycle:

$$dcR[(j-1) \times nstgR + 3] = \begin{cases} lengthrc/2 & \text{for } j < RR \\ datebs - datbbs + flushbbR + 1 & \text{for } j = RR \end{cases} \ . \tag{8.5}$$

Stage 4 does not occur in the last breeding cycle so that the following equation holds only for $j = 1, \ldots, RR - 1$:

$$dcR[(j-1) \times nstgR + 4] = lengthrc \ . \tag{8.6}$$

For lambs, we write $dcL[i][j]$ for the length of the time period for category $i$ $(i = 1, \ldots PP)$ and breeding type $j$ $(j = 1 :$ pure-bred animals, $j = 2 :$ cross-bred animals). For female and male lambs till weaning the following equation holds:

$$dcL[5][j] = dcL[30][j] = agewL \ . \tag{8.7}$$

The time period for artificial rearing of lambs is

$$dcL[6][j] = dcL[31][j] = agearL - agewL \ . \tag{8.8}$$

The lambs died till weaning or till the end of the artificial rearing (category 2) are assumed to stay in the flock on average half of the period of the lambs alive:

$$dcL[2][j] = \begin{cases} agewL/2 & \text{for } typew = 1 \\ agearL/2 & \text{for } typew = 2 \end{cases} \ . \tag{8.9}$$

In fattening of pure-bred $(j = 1)$ or cross-bred $(j = 2)$ progeny of category $i$, the time period is

$$dcL[i][j] = agetP[i][j] - a \tag{8.10}$$

where

$$a = \begin{cases} agewL & \text{for } typew = 1 \\ agearL & \text{for } typew = 2 \end{cases} \ . \tag{8.11}$$

The time periods for female (category $i = 3$) and male (category $i = 28$) lambs and castrates (category $i = 48$) that died in fattening are calculated as one half of the weighted averages of the time periods for the appropriate categories $k$ in fattening $(k = 8, \ldots, 12$ for category 3, $k = 33, \ldots, 37$ for category 28 and $k = 43, \ldots, 47$ for category 48):

$$dcL[i][j] = \frac{1}{2 \times l1skL[i][j]} \sum_k (dcL[k][j] \times ndiedfat[s][k-l][j]) \tag{8.12}$$

where

$$\begin{array}{llll} s = 1 & \text{and} & l = 7 & \text{for category } i = 3 \\ s = 2 & \text{and} & l = 32 & \text{for category } i = 28 \\ s = 0 & \text{and} & l = 42 & \text{for category } i = 48 \end{array} \ . \tag{8.13}$$

For breeding female lambs (categories 13 to 26), the following periods are calculated:

$$
\begin{aligned}
dcL[13][j] &= agetP[13][j] - a \\
dcL[14][j] &= ager[1][1] - a \\
dcL[15][j] &= dpregsFP + datconFP[1] - datbbs \\
dcL[16][j] &= lengthrc - ager[1][1] \\
dcL[17][j] &= datebs + dnpregcFP - datlamb - ager[1][1] \\
dcL[18][j] &= ager[1][2] - ager[1][1] \\
dcL[19][j] &= dpregsFP + datconFP[2] - datbbs - 365 \\
dcL[20][j] &= 2 \times lengthrc - ager[1][2] \\
dcL[21][j] &= datebs + dnpregcFP + lengthrc - datlamb - ager[1][2] \\
dcL[22][j] &= ager[1][3] - ager[1][2] \\
dcL[23][j] &= dpregsFP + datconFP[3] - datbbs - 2 \times 365 \\
dcL[24][j] &= 3 \times lengthrc - ager[1][3] \\
dcL[25][j] &= datebs + dnpregcFP + 2 \times lengthrc - datlamb - ager[1][3] \\
dcL[26][j] &= agetP[26][j] - ager[1][1]
\end{aligned}
\tag{8.14}
$$

where $a$ is given by equation (8.11). The time period for female lambs died in the rearing period (category 4) is calculated as one half of the weighted average of the time periods for categories 14, 18, 20 and 22:

$$
\begin{aligned}
dcL[4][j] = \Big( & dcL[14][j] \times (nrdied[1][1][j] + nspdied[1][1][j]) \\
& + dcL[18][[j] \times (nrdied[1][2][j] + nspdied[1][2][j]) \\
& + dcL[22] \times (nrdied[1][3][j] + nspdied[1][3][j]) \\
& + dcL[20][j] \times nrdiedmlFP[j] \Big) \Big/ (2 \times l1skL[4][j]).
\end{aligned}
\tag{8.15}
$$

For breeding male lambs (categories 38 to 41), the periods of time are:

$$
\begin{aligned}
dcL[38][j] &= agetP[38][j] - a \\
dcL[39][j] &= ager[2][1] - a \\
dcL[40][j] &= agetP[40][j] - ager[2][1] \\
dcL[41][j] &= ager[2][2] - ager[2][1] \ .
\end{aligned}
\tag{8.16}
$$

where $a$ is again given by equation (8.11). The time period for male lambs died in the rearing period (category 29) is calculated as one half of the weighted average of the time periods for categories 39 and 41:

$$
\begin{aligned}
dcL[29][j] = \Big( & dcL[39][j] \times (nrdied[2][1][j] + nspdied[2][1][j] \\
& + dcL[41][j] \times (nrdied[2][2][j] + nspdied[2][2][j])\Big) \\
& \Big/ (2 \times l1skL[29][j]) \ .
\end{aligned}
\tag{8.17}
$$

Similarly, the time period for male lambs of category 42 (culled during the rearing period) is also calculated as one half of the weighted average of the time periods for categories 39 and 41:

$$
\begin{aligned}
dcL[42][j] = \Big( & dcL[39][j] \times (nrcull[2][1][j] + nspcull[2][1][j] \\
& + dcL[41][j] \times (nrcull[2][2][j] + nspcull[2][2][j])\Big) \\
& \Big/ (2 \times l1skL[42][j]).
\end{aligned}
\tag{8.18}
$$

## 8.2 Discounting coefficients for ewes

Discounting coefficients for revenues or costs that occur continuously over the whole time period the ewes of category $i$ ($i = 1, ..., TE$) are kept ($qaveE[i]$) are calculated as

$$qaveE[i] = (1 + u)^{-(ageE[j]+dcE[i]/2)/365} \qquad (8.19)$$

where $j$ is the number of the reproductive cycle which belongs to category $i$. It is assumed that costs and revenues are distributed evenly over the whole time period so that the middle of the time period is taken as representative value for the calculation of the discounting coefficient. As all time intervals are primarily given in days and the annual discount rate is applied, the values for these intervals must be divided by 365.

Discounting coefficients for revenues or costs that occur at the end of the keeping period of ewes of category $i$ ($qendE[i]$) are calculated as

$$qendE[i] = (1 + u)^{-(ageE[j]+dcE[i])/365} \;. \qquad (8.20)$$

Discounting coefficients for breeding costs for ewes of category $i$ ($qbreedE[i]$) are given by the equation

$$qbreedE[i] = (1 + u)^{-(ageE[j]+datbbs-datlamb)/365} \qquad (8.21)$$

and discounting coefficients for revenues from milk and/or cheese and for costs connected with milking sheep are

$$qmilkE[i] = (1 + u)^{-(ageE[j]+agew+lengthmp/2)/365} \;. \qquad (8.22)$$

## 8.3 Discounting coefficients for rams

For pure-bred ($j = 1$) or cross-bred ($j = 2$) rams of category $i$ ($i = 1, ..., TR$), discounting coefficients for revenues or costs that occur continuously over the whole time period the rams are kept ($qaveR[i][j]$) are calculated as

$$qaveR[i][j] = (1 + u)^{-(ageR[k][j]+dcR[i][j]/2)/365} \qquad (8.23)$$

where $k$ is the number of the breeding cycle which belongs to category $i$. Discounting coefficients for revenues or costs that occur at the end of the keeping period of rams of category $i$ ($qendR[i][j]$) are calculated as

$$qendR[i][j] = (1 + u)^{-(ageR[k][j]+dcR[i][j])/365} \;. \qquad (8.24)$$

The discounting coefficient for costs for purchasing breeding rams ($qpurchR$) is given by

$$qpurchR = (1 + u)^{-(datbbs-datlamb)/365} \;. \qquad (8.25)$$

## 8.4 Discounting coefficients for lambs

First, the age in the middle of the time period ($taveL[i][j]$) and at the end of the time period ($tendL[i][j]$) is calculated for pure-bred ($j = 1$) and cross-bred ($j = 2$) lambs of all categories $i$ ($i = 1, \ldots, PP$). Both values are zero for catergory 1. The corresponding values for category 2 are:

$$
\begin{aligned}
taveL[2][j] &= dcL[2][j]/2 \\
tendL[2][j] &= dcL[2][j] \;.
\end{aligned}
\qquad (8.26)
$$

For categories $i = 3, 4, 8$ to $14, 28, 29, 33$ to $39$ and $42$ to $48$ we get:

$$
\begin{aligned}
taveL[i][j] &= a + dcL[i][j]/2 \\
tendL[i][j] &= a + dcL[i][j]
\end{aligned}
\tag{8.27}
$$

where $a = agewL$ for customary weaning and $a = agearL$ for artificial rearing. For catetories $i = 5$ and $30$ the corresponding ages are:

$$
\begin{aligned}
taveL[i][j] &= agewL/2 \\
tendL[i][j] &= agewL
\end{aligned}
\tag{8.28}
$$

and in the case of artificial rearing we get for categories $i = 6$ and $31$:

$$
\begin{aligned}
taveL[i][j] &= agewL + dcL[i][j]/2 \\
tendL[i][j] &= agearL \; .
\end{aligned}
\tag{8.29}
$$

Female or male lambs sold after artificial rearing (categories $i = 7$ and $31$) have the following ages in the middle and at the end of their existence:

$$
\begin{aligned}
taveL[i][j] &= a \\
tendL[i][j] &= a
\end{aligned}
\tag{8.30}
$$

where $a$ has the same meaning as in equation (8.27). For female breeding lambs between the first and the second breeding season (categories $i = 15$ to $18$ and $26$) we get:

$$
\begin{aligned}
taveL[i][j] &= ager[1][1] + dcL[i][j]/2 \\
tendL[i][j] &= ager[1][1] + dcL[i][j] \; .
\end{aligned}
\tag{8.31}
$$

Furthermore, the equations for female breeding lambs between the second and the third breeding season (categories $i = 19$ to $22$) are:

$$
\begin{aligned}
taveL[i][j] &= ager[1][2] + dcL[i][j]/2 \\
tendL[i][j] &= ager[1][2] + dcL[i][j]
\end{aligned}
\tag{8.32}
$$

For female breeding lambs after the third breeding season (categories $i = 23$ to $25$), the equations look as follows:

$$
\begin{aligned}
taveL[i][j] &= ager[1][3] + dcL[i][j]/2 \\
tendL[i][j] &= ager[1][3] + dcL[i][j] \; .
\end{aligned}
\tag{8.33}
$$

Finally, the equations for male breeding lambs (categories $40$ and $41$) are

$$
\begin{aligned}
taveL[i][j] &= ager[2][1] + dcL[i][j]/2 \\
tendL[i][j] &= ager[2][1] + dcL[i][j] \; .
\end{aligned}
\tag{8.34}
$$

The discounting coefficients for revenues or costs that occur continuously during the whole time of keeping the given category of lambs ($qaveL[i][j]$) are then:

$$
qaveL[i][j] = (1 + u)^{-taveL[i][j]/365}
\tag{8.35}
$$

and the discounting coefficients for revenues and costs that accrue at the end of the time period of the given category ($qendL[i][j]$) are:

$$
qendL[i][j] = (1 + u)^{-tendL[i][j]/365} \; .
\tag{8.36}
$$

The discounting coefficient for breeding costs ($qbreedL[i]$) is relevant only for categories $i = 14, 18$ and $22$ and is calculated as follows:

$$
qbreedL[i] = (1 + u)^{-ager[1][k]/365}
\tag{8.37}
$$

where $k = (i - 10)/4$.

# Chapter 9

# Nutrition costs

Feed requirements of animals of different categories (ewes, rams, lambs) in different periods of their life are calculated on the base of their daily net energy and protein (PDI, protéines digestibles dans l'intestin) requirements for maintenance, growth of body weight, milk production, wool production, pregnancy and change in body weight during flushing and pregnancy. The daily net energy and protein requirements are summed within periods with the same feeding rations.

Feeding rations should be built from the feed components that are available in a defined production system and for the given seasons during the year. Building the feeding rations, the dry matter intake of the given category of animals in the given production stage (e.g. lactation, pregnancy) and the expected production level (growth rate, body weight, milk production) should be taken into account [5].

For all feeding rations, the average dry matter, net energy, protein (PDI) content and the average price per kg fresh matter of the ration must be known. These values are input parameters for the program. If PDI values for feed components are not available, it is possible to calculate the nutrition costs only on the basis of net energy content in feed. The net energy and protein requirements of animals in all feeding periods within each feeding season are transformed to the amount of fresh feed of the given feeding rations. The calculated feed amount is increased by a given percentage to take into account feed wasting for the given feeding technology (e.g. indoor feeding, different technologies of pasture). Feeding costs are calculated per animal of the given category and per the time period the category exists which is given by the variables $dcE[i]$, $dcR[i][j]$ and $dcL[i][j]$ (see Section 8.1).

## 9.1 Definition of feeding rations and nutrition groups for animals

Feeding rations for the same group of animals can differ between the seasons of the year (e.g. between summer and winter, between wet and dry seasons in the tropics). The number of different feeding seasons during the year is an input parameter ($nfs$) the maximal value of which is set to 4. In case that summer and winter feeding are the only two feeding rations during the year, $nfs$ is 2. For the individual feeding seasons, the codes $1, 2, \ldots, nfs$ must be used in input file INPUTS08.TXT (see Section 14.2.8 on page 146).

The code of the feeding season on January 1st is read to the variable $valfs[0]$. To describe the changes during the year, the date(s) must be given when the feeding ration changes and the new value or code of the feeding ration which is valid from the date of change. It is assumed that the dates of changes and the appropriate codes of the feeding rations remain the same also in the following years.

Table 9.1: Example for modelling the seasonal feeding rations

| Change | Date | Season | Code |
|---|---|---|---|
| Starting value | 1st Jan 00 (fixed) | Winter | 1 |
| Change 1 | 15th Apr 00 | Summer | 2 |
| Change 2 | 1st Oct 00 | Winter | 1 |
| Change 3 | 15th Apr 01 | Summer | 2 |
| Change 4 | 1st Oct 01 | Winter | 1 |
| Change 5 | 15th Apr 02 | Summer | 2 |
| Change 6 | 1st Oct 02 | Winter | 1 |

An example for modelling seasonal feed rations is given in Table 9.1. Winter feeding (code 1) and summer feeding (code 2) are the only seasonal feeding rations. At the beginning of year 0, the code for the feeding ration is set to 1 (winter feeding). On 15th April, this code changes to 2 (summer feeding) and on 1st October again to code 1. These changes are repeated in the next two years. Note please that the code for seasonal feeding after the last change in the year must be the same as at the beginning of the (next) year. If this is not the case, you have to introduce the date 31st December as further date of change.

For each animal group (ewes, rams, lambs), a further differentiation of feeding rations within a seasonal feeding is made (according to the production state of the animals). Within each of the feeding rations different feeding components can be used according to the season of the year (e.g. different components of the feeding ration for lactating ewes will be applied in winter and in summer). In some cases, the feeding ration does not depend on the season of the year (e.g. in artificial rearing of lambs, in intensive fattening). Details on the definition of the individual feeding rations are given in the following subsections.

## 9.1.1 Ewes

The feeding rations of ewes have to cover the energy and protein requirements for maintenance, wool growth and flushing (for all ewes), gain of body weight (only for growing ewes), milk production (only for ewes lambed) and for pregnancy (only for ewes conceived). Therefore, the energy and protein requirements and feed costs will be different for the categories of ewes defined in Section 3.1 on page 14. The following five feeding rations differing in energy and protein content according to the state of the ewe are differentiated:

1. Feeding ration for a lactating ewe with no or one suckled lamb

2. Feeding ration for a lactating ewe with more than one suckled lamb

3. Feeding ration during flushing (several weeks before and after the beginning of the breeding season)

4. Feeding ration during low pregnancy or for dry and barren ewes

5. Feeding ration during high pregnancy

Within each feeding ration, seasonal variants (e.g. feeding ration for winter and feeding ration for summer) can be distinguished. For compiling the feeding ration for high pregnancy, the average expected litter size should be taken into account.

### 9.1.2 Rams

The feeding rations for rams have to cover the energy and protein requirements for maintenance, wool growth and flushing (for all rams) and gain of body weight (only for growing rams). Two feeding rations are differentiated:

1. Feeding ration outside the breeding season

2. Feeding ration during flushing (which starts several weeks before the breeding season) and during the breeding season

Normally, both feeding rations depend on the season of the year and seasonal variants of the feeding rations are defined.

### 9.1.3 Lambs

The feeding rations for lambs cover the periods from birth to death, culling, selling or entering the flock as replacement and to slaughter. During these periods, feeding has to cover the energy and protein requirements for maintenance, body weight gain, wool growth (for all lambs), for flushing (only for female lambs intended to be used for breeding) and for pregnancy (only for pregnant female lambs). Altogether, the following 20 feeding rations are defined:

1. Feeding ration from birth to weaning (includes only supplementary feed, without milk suckled from ewes)

2. Feeding ration in artificial rearing (only if there is artificial rearing)

3. Feeding ration during flushing of female lambs intended for breeding (some days before and after the start of the breeding season)

4. Feeding ration in rearing of breeding female and male lambs (till selling or till entering the flock)

5. Feeding ration during the period of high pregnancy of female progeny

6. to 20. Feeding rations in fattening of female lambs (feeding rations 6 to 10), male lambs (feeding rations 11 to 15) and castrates (feeding rations 16 to 20) to targets 1 to 5 (see Subsection 14.2.4 on page 141 for more information on the targets for fattening)

For each feeding ration, seasonal variants are possible. If only one feeding ration is used over the year (e.g. as expected for lambs in artificial rearing), enter the same values for all seasons in input file INPUTS08.TXT (see Subsection 14.2.8 on page 146). Male lambs intended for flock replacement and rams bought for replacement are expected to enter the flock at the time of starting flushing (some days before starting the breeding season). Therefore, no feeding ration during flushing for male lambs in the rearing period is defined. This ration is included in the rations for rams (see Subsection 9.1.2).

## 9.2 Nutrition costs for ewes

All ewes enter their first reproductive cycle with lambing. After the first lambing, however, it is allowed to keep barren ewes to the next reproductive cycles. Therefore, both lambing and barren ewes will enter reproductive cycle 2. As the culling rate, death rate and conception rate in any reproductive cycle is assumed to be the same for ewes with and without lambs, the proportion of lambed and barren ewes

within each category $i$ ($plambE[i]$ and $pnlambE[i]$ for $i = 1, \ldots, TE$) is given by the proportion of ewes at stages 4 and 5, respectively (see Paragraph 3.1.2.1 on page 15), in the previous reproductive cycle. We express the number of the category $i$ as function of the number of the reproductive cycle $l$ and the stage $k$ within the reproductive cycle. The following equations hold for $l = 2, \ldots, LL$ and $k = 1, \ldots, nstgE$ for $l < LL$ or $k = 1, \ldots, nstg1E$ for $l = LL$ :

$$
\begin{aligned}
plambE[(l-1) \times nstgE + k] &= l1E[(l-2) \times nstgE + 5]/ \\
&\quad (l1E[(l-2) \times nstgE + 5] \\
&\quad +l1E[(l-2) \times nstgE + 4]) \qquad (9.1) \\
pnlambE[(l-1) \times nstgE + k] &= l1E[(l-2) \times nstgE + 4]/ \\
&\quad (l1E[(l-2) \times nstgE + 5] \\
&\quad +l1E[(l-2) \times nstgE + 4])
\end{aligned}
$$

For the first lactation, i.e. for the first $nstgE$ categories, $plambE[i]$ is set to one and $pnlambE[i]$ is set to zero. Both groups of ewes within each ewe category will differ in the dates when they are fed certain feeding rations.

## 9.2.1 Some parameters needed for the calculation of energy and protein requirement

To calculate energy and protein requirements, some further parameters are needed which are calculated first. Daily wool production of ewes is given by the equation

$$dwoolptE = woolptE/lengthrc . \qquad (9.2)$$

Extra daily live weight gain per day during flushing ($adgfE$) is calculated from the total live weight gain during flushing ($wgfE$) and the length of the flushing period ($flushbbE + flushabE$)

$$adgfE = wgfE/(flushbbE + flushabE) . \qquad (9.3)$$

Net energy and protein requirement for pregnancy depends on litter birth weight. Litter weight at birth ($twL[i][l]$) for ewes in reproductive cycle $l$ ($l = 1, \ldots, LL$) with litter size $i$ ($i = 1, \ldots, clt$) is calculated as

$$
\begin{aligned}
twL[i][l] &= i \times ((1 - pcrossE[l-1]) \times (bwL[1][i][1] \times sexrbf \\
&\quad +bwL[2][i][1] \times sexrbm) + pcrossE[l-1] \qquad (9.4) \\
&\quad \times(bwL[1][i][2] \times sexrbf + bwL[2][i][2] \times sexrbm)) .
\end{aligned}
$$

## 9.2.2 Net energy and protein requirement for maintenance, growth of body weight and wool

Net energy and protein requirements for maintenance and growth depend on body weight and growth rate. All calculated values for net energy requirement in this subsection are in MJ per ewe of the given category and per the particular time interval and the calculated values for protein requirement are in grammes per ewe and per appropriate time interval.

The start date and the end date for the individual feeding rations defined in Subsection 9.1.1 are given in Table 9.2 for the ewe categories 3, $nstgE + 3$, $2 \times nstgE+3$, ..., $(LL-1) \times nstgE+3$, in Table 9.3 for the ewe categories 4, $nstgE+4$, $2 \times nstgE + 4$, ..., $(LL-2) \times nstgE + 4$ and in Table 9.4 for the ewe categories 5, $nstgE+5$, $2 \times nstgE+5$, ..., $(LL-2) \times nstgE+5$, where $nstgE = 5$ in the present

Table 9.2: Start and end dates for feeding periods for ewes of categories 3, $nstgE+3$, $2 \times nstgE + 3, \ldots, (LL - 1) \times nstgE + 3$ ($nstgE = 5$ in the given version of the program)

| Start date | Feeding ration for ewes | | | End date |
| --- | --- | --- | --- | --- |
| | with ≤1 lamb | with ≥ 2 lambs | barren | |
| *For all lactations* | | | | |
| $datlamb$ | 1 | 2 | 4 | $datdry - 1$ |
| *For lactations l with $l = 1, \ldots, LL - 1$* | | | | |
| $datdry$[a] | 4 | 4 | 4 | $datbbs - flushbbE - 1$ |
| $datbbs - flushbbE$[b] | 3 | 3 | 3 | $datbbs + flushabE - 1$ |
| $datbbs + flushabE$[c] | 4 | 4 | 4 | $datebs + dnpregcE$ |

[a]This feeding period is only used if $datbbs - flushbbE > datdry$
[b]This feeding period is only used if $datbbs + flushabE > datdry$
[c]If there is no flushing, the start date is $datdry$

Table 9.3: Start and end dates for feeding periods for ewes of categories 4, $nstgE+4$, $2 \times nstgE + 4, \ldots, (LL - 2) \times nstgE + 4$ ($nstgE = 5$ in the given version of the program)

| Start date | Feeding ration for ewes | | | End date |
| --- | --- | --- | --- | --- |
| | with ≤1 lamb | with ≥ 2 lambs | barren | |
| $datlamb$ | 1 | 2 | 4 | $datdry - 1$ |
| $datdry$[a] | 4 | 4 | 4 | $datbbs - flushbbE - 1$ |
| $datbbs - flushbbE$[b] | 3 | 3 | 3 | $datbbs + flushabE - 1$ |
| $datbbs + flushabE$[c] | 4 | 4 | 4 | $datlamb + lengthrc - 1$ |

[a]This feeding period is only used if $datbbs - flushbbE > datdry$
[b]This feeding period is only used if $datbbs + flushabE > datdry$
[c]If there is no flushing, the start date is $datdry$

Table 9.4: Start and end dates for feeding periods for ewes of categories 5, $nstgE+5$, $2 \times nstgE + 5, \ldots, (LL - 2) \times nstgE + 5$ ($nstgE = 5$ in the given version of the program)

| Start date | Feeding ration for ewes | | | End date |
| --- | --- | --- | --- | --- |
| | with ≤1 lamb | with ≥ 2 lambs | barren | |
| $datlamb$ | 1 | 2 | 4 | $datdry - 1$ |
| $datdry$[a] | 4 | 4 | 4 | $datbbs - flushbbE - 1$ |
| $datbbs - flushbbE$[b] | 3 | 3 | 3 | $datbbs + flushabE - 1$ |
| $datbbs + flushabE$[c] | 4 | 4 | 4 | $datlamb + lengthrc - dshpE - 1$ |
| $datlamb + lengthrc - dshpE$ | 5 | 5 | 5 | $datlamb + lengthrc - 1$ |

[a]This feeding period is only used if $datbbs - flushbbE > datdry$
[b]This feeding period is only used if $datbbs + flushabE > datdry$
[c]If there is no flushing, the start date is $datdry$

version of the program. The start and end dates given in Tables 9.2 to 9.4 will be needed for calculating net energy and protein requirements for maintenance, growth, wool production and flushing covered from the given feeding rations. Symbols $k1$ and $k2$ will be used in the following equations for the lower and upper limit of the sums, respectively. They are functions of the start date and end date given in Tables 9.2 to 9.4 and are calculated as:

$$
\begin{aligned}
k1 &= \text{Start date} - datlamb + 1 \\
k2 &= \text{End date} - datlamb + 1
\end{aligned}
$$
(9.5)

This is a simple transformation of the time scale where date of lambing becomes day 1 and all other dates are related to the date of lambing. Please have in mind that both $k1$ and $k2$ depend on the category of ewes and on the feeding ration.

The energy and protein requirement is calculated both for lambed and barren ewes. The equations are the same for both groups of ewes and are therefore given only ones. In the program, all the following variables are calculated both for lambed and barren ewes. For example, $newlE[i][k][l]$ (for lambing ewes) and $newnlE[i][k][l]$ (for barren ewes) is calculated on the basis of the equation for $newE[i][k][l]$. The net energy requirement for wool production of category $i$ of ewes fed with feeding ration $k$ for feeding season $l$ is [2]:

$$
newE[i][k][l] = 23.7 \times dwoolptE \times \sum_{t=k1}^{k2} \delta_l
$$
(9.6)

where $\delta_l$ is a function of $t$ :

$$
\delta_l = \begin{cases} 1 & \text{if } t \text{ is within feeding season } l \\ 0 & \text{if } t \text{ is not within feeding season } l \end{cases} .
$$
(9.7)

The net energy requirement for growth of body weight is calculated only for ewe categories in the first lactation ($i \leq nstgE$) [2]:

$$
negE[i][k][l] = adgE \sum_{t=k1}^{k2} \delta_l \times \left( 2.1 + 0.45 \times (wlE[1] + adgE \times t) \right) .
$$
(9.8)

For $i > nstgE$, $negE[i][k][l] = 0$. The net energy requirement for maintenance is for the categories belonging to the first lactation ($i \leq nstgE$) [1, 2, 4, 13]:

$$
\begin{aligned}
nemE[i][k][l] &= \sum_{t=k1}^{k2} \delta_l \times \Big( 0.277 \times (wlE[1] + adgE \times t)^{0.75} \times (1 + 0.0091 \\
&\quad \times (20 - tp[l])) + ktE \times (wlE[1] + adgE \times t) \Big)
\end{aligned}
$$
(9.9)

where $ktE$ is a function of the sheep husbandry system ($ktechE[l]$, input parameter in file INPUTS08.TXT) used in feeding season $l$. For $i > nstgE$, i.e. for the stages in the second and subsequent lactations, this equation changes to

$$
\begin{aligned}
nemE[i][k][l] &= \Big( 0.277 \times mwE[1]^{0.75} \times (1 + 0.0091 \times (20 - tp[l])) \\
&\quad + ktE \times mwE[1] \Big) \times \sum_{t=k1}^{k2} \delta_l .
\end{aligned}
$$
(9.10)

The appropriate equations for protein requirement were derived on the basis of [2, 4, 5]. The protein requirement for wool production of category $i$ of ewes fed with

Table 9.5: Start and end dates for feeding periods for pregnant ewes (categories 5, $nstgE+5$, $2 \times nstgE+5, \ldots, (LL-2) \times nstgE+5$, $nstgE = 5$ for the given version of the program)

|  | Start date | Feeding ration | End date |
|---|---|---|---|
| Low pregnancy | $datlamb +$ $lengthrc - lpreg$ | 4 | $datlamb +$ $lengthrc - dshpE - 1$ |
| High pregnancy | $datlamb +$ $lengthrc - dshpE$ | 5 | $datlamb +$ $lengthrc - 1$ |

feeding ration $k$ for feeding season $l$ is:

$$pdiwE[i][k][l] = 3088.6 \times dwoolptE \times \sum_{t=k1}^{k2} \delta_l \; . \tag{9.11}$$

The protein requirement for growth of body weight is calculated only for ewe categories in the first lactation ($i \leq nstgE$) :

$$
\begin{aligned}
pdigE[i][k][l] \;=\; & \frac{adgE}{0.59} \sum_{t=k1}^{k2} \delta_l \times \Big( 156.1 - 1.94 \times (wlE[1] + adgE \times t) \\
& + 0.0173 \times (wlE[1] + adgE \times t)^2 \Big) \; .
\end{aligned}
\tag{9.12}
$$

The protein requirement for maintenance is for categories $i$ with $i \leq nstgE$ :

$$pdimE[i][k][l] = 2.1875 \sum_{t=k1}^{k2} \delta_l \times (wlE[1] + adgE \times t)^{0.75} \; . \tag{9.13}$$

For $i > nstgE$ this equation changes to

$$pdimE[i][k][l] = 2.1875 \times mwE[1]^{0.75} \times \sum_{t=k1}^{k2} \delta_l \; . \tag{9.14}$$

### 9.2.3   Net energy and protein requirement for pregnant ewes

The only categories representing pregnant ewes are categories 5, $nstgE + 5$, $2 \times nstgE + 5$, $\ldots$, $(LL - 2) \times nstgE + 5$, where $nstgE = 5$ in the present version of the program. During pregnancy, the ewes are only fed feeding rations 4 and 5 (see Subsection 9.1.1). The start and end dates for the two feeding rations are given in Table 9.5. As before, symbols $k1$ and $k2$ will be used for the lower and upper limit, respectively, of the sums in the equations for net energy and protein requirement. They are calculated as:

$$
\begin{aligned}
k1 \;&=\; \text{Start date} - datlamb - lengthrc + lpreg + 1 \\
k2 \;&=\; \text{End date} - datlamb - lengthrc + lpreg + 1 \; .
\end{aligned}
\tag{9.15}
$$

This is a simple transformation of the time scale where date of conceiving becomes day 1 and all other dates are related to this date. Both $k1$ and $k2$ depend via "Start date" and "End date" on the feeding ration. Net energy requirement will have the unit MJ per ewe and per appropriate time interval and the calculated values for protein requirement are in grammes per ewe and per appropriate time interval.

   The net energy and the protein requirement during low pregnancy for a ewe of category $i = (j - 1) \times nstgE + 5$ ($j = 1, \ldots, LL - 1$, $j$ is the number of the

reproductive cycle) with expected litter size $b$ fed with feeding ration 4 in feeding season $l$ are (derived from equations given in [2]):

$$
\begin{aligned}
nepbE[b][i][4][l] &= 0.083773 \times twL[b][j+1] \sum_{t=k1}^{k2} \delta_l \\
&\times e^{7.6492-0.00643t-11.4646e^{-0.00643t}} ,
\end{aligned}
\tag{9.16}
$$

$$
\begin{aligned}
pdipbE[b][i][4][l] &= 0.043889 \times twL[b][j+1] \sum_{t=k1}^{k2} \delta_l \\
&\times e^{11.3471-0.00601t-11.2205e^{-0.00601t}} .
\end{aligned}
$$

where $\delta_l$ is a function of $t$ as defined in equation (9.7) on page 67, i.e. $\delta_l$ is one if $t$ is within feeding season $l$, otherwise $\delta_l$ is zero. The net energy and protein requirement during high pregnancy (feeding ration 5) is:

$$
\begin{aligned}
nepbE[b][i][5][l] &= 0.083773 \times twL[b][j+1] \\
&\times \sum_{t=k1}^{k2} \delta_l \times e^{7.6492-0.00643t-11.4646e^{-0.00643t}} \\
&-20.034 \times \frac{wgfE}{dshpE} \sum_{t=k1}^{k2} \delta_l , \\
pdipbE[b][i][5][l] &= 0.043889 \times twL[b][j+1] \\
&\times \sum_{t=k1}^{k2} \delta_l \times e^{11.3471-0.00601t-11.2205e^{-0.00601t}} \\
&-119 \times \frac{wgfE}{dshpE} \sum_{t=k1}^{k2} \delta_l .
\end{aligned}
\tag{9.17}
$$

The last terms (which are subtracted) of both equations of (9.17) are the net energy and protein originating from the body reserves built during the flushing period.

The net energy and the protein requirement for pregnancy averaged over the expected litter size for a ewe of category $i = (j-1) \times nstgE + 5$ ($j = 1, \ldots, LL-1$, $j$ is the number of the reproductive cycle) fed with feeding ration $k$ in feeding season $l$ are:

$$
\begin{aligned}
nepE[i][k][l] &= \sum_{b=1}^{clt} nepbE[b][i][k][l] \times Pltype[b][j+1] , \\
pdipE[i][k][l] &= \sum_{b=1}^{clt} pdipbE[b][i][k][l] \times Pltype[b][j+1] .
\end{aligned}
\tag{9.18}
$$

### 9.2.4 Net energy and protein requirement during flushing

In milked sheep, energy and protein requirement for flushing will be calculated only if drying off of ewes is early enough to allow for a flushing period. If the ewes are mated already in the milking period, no flushing period is assumed (see also remarks to Tables 9.2 to 9.4). The ewes are only fed with feeding ration 3 in the flushing period. The start date for the period is $datbbs - flushbbE$ and the end date is $datbbs + flushabE - 1$. Again symbols $k1$ and $k2$ will be used in the following equations as lower and upper limits of the sums. They take the following values:

$$
\begin{aligned}
k1 &= \text{Start date} - datbbs + flushbbE + 1 \\
k2 &= \text{End date} - datbbs + flushbbE + 1 .
\end{aligned}
\tag{9.19}
$$

The net energy and protein requirement for flushing per ewe of category $i$ ($i = (j-1) \times nstgE + k$ where $j$ is the reproductive cycle with $j = 1, \ldots, LL-1$ and $k$ is the stage within the lactation cycle with $k = 3, \ldots, nstgE$, $nstgE = 5$ for the given version of the program) fed with feeding ration 3 in feeding season $l$ ($l = 1, \ldots, nfs$) are [1, 4]:

$$
\begin{aligned}
nefE[i][3][l] &= 23.85 \times adgfE \times \sum_{t=k1}^{k2} \delta_l \\
pdifE[i][3][l] &= 140 \times adgfE \times \sum_{t=k1}^{k2} \delta_l
\end{aligned}
\tag{9.20}
$$

where $\delta_l$ is one if $t$ is within feeding season $l$, otherwise $\delta_l$ is zero.

## 9.2.5 Net energy and protein requirement for lactating ewes

Lactating ewes are fed with feeding rations 1 or 2 in dependence on the number of suckled lambs (see Tables 9.2 to 9.4). The start date for the period is *datlamb* and the end date is $datdry - 1$. Again symbols $k1$ and $k2$ will be used in the following equations as lower and upper limits of the sums. They take the following values:

$$
\begin{aligned}
k1 &= \text{Start date} - datlamb + 1 \\
k2 &= \text{End date} - datlamb + 1 .
\end{aligned}
\tag{9.21}
$$

The net energy and protein requirement for lactation per ewe of category $i$ ($i = (j-1) \times nstgE + i1$ where $i1 = 3, \ldots, nstgE$ for $j = 1, \ldots, LL-1$ and $i1 = 3$ for $j = LL$, $j$ is the number of the reproductive cycle and $i1$ the stage within the reproductive cycle, $nstgE = 5$ for the given version of the program) with $b$ suckled lambs ($b = 0, \ldots, clt$) fed with feeding ration $k$ ($k = 1$ or 2) in feeding season $l$ ($l = 1, \ldots, nfs$) are[1] [5, ?]:

$$
\begin{aligned}
nelbE[b][i][k][l] &= (0.948 + 0.376fat + 0.209prot) \times ktlsl[b] \times ktlp[j] \\
&\quad \times \sum_{t=k1}^{k2} \delta_l \times awo \times t^{bwo} \times e^{-cwo \times t} \\
pdilbE[b][i][k][l] &= 17.2414prot \times ktlsl[b] \times ktlsl[j] \\
&\quad \times \sum_{t=k1}^{k2} \delta_l \times awo \times t^{bwo} \times e^{-cwo \times t}
\end{aligned}
\tag{9.22}
$$

where $\delta_l$ is one if $t$ is within feeding season $l$, otherwise $\delta_l$ is zero.

The net energy and protein requirement during lactation per ewe of category $i$ with 0 or 1 suckled lambs fed with feeding ration 1 in feeding season $l$ ($l =$

---

[1] For non-dairy sheep, energy and protein requirement is zero for $b = 0$. This is solved in the program by setting $ktlsl[0] = 0$.

$1, \ldots, nfs)$ are

$$
nelE[i][1][l] \quad = \quad \frac{\displaystyle\sum_{b=0}^{1} nelbE[b][i][1][l] \times PsuckE[b][j]}{\displaystyle\sum_{b=0}^{1} PsuckE[b][j]} \tag{9.23}
$$

$$
pdilE[i][1][l] \quad = \quad \frac{\displaystyle\sum_{b=0}^{1} pdilbE[b][i][1][l] \times PsuckE[b][j]}{\displaystyle\sum_{b=0}^{1} PsuckE[b][j]}
$$

and net energy and protein requirement during lactation per ewe of category $i$ with 2 or more suckled lambs fed with feeding ration 2 in feeding season $l$ ($l = 1, \ldots, nfs$) are

$$
nelE[i][2][l] \quad = \quad \frac{\displaystyle\sum_{b=2}^{clt} nelbE[b][i][2][l] \times PsuckE[b][j]}{\displaystyle\sum_{b=2}^{clt} PsuckE[b][j]} \tag{9.24}
$$

$$
pdilE[i][2][l] \quad = \quad \frac{\displaystyle\sum_{b=2}^{clt} pdilbE[b][i][2][l] \times PsuckE[b][j]}{\displaystyle\sum_{b=2}^{clt} PsuckE[b][j]} \; .
$$

## 9.2.6 Total net energy and protein requirement for individual categories of ewes

In this subsection, the equations for the total net energy and protein requirement are given. The net energy and protein requirement are specific for the categories of ewes, the feeding ration the ewes are fed with and the seasonal variant of the feeding ration.

The equations for the calculation of the total net energy and protein requirement for a ewe of category $i$ ($i = (j-1) \times nstgE + i1$ where $i1 = 3, \ldots, nstgE$ for $j = 1, \ldots, LL-1$ and $i1 = 3$ for $j = LL$, $j$ is the number of the reproductive cycle and $i1$ the stage within the reproductive cycle, $nstgE = 5$ for the given version of the program) differ between feeding rations. The total net energy and protein requirement for a ewe fed with feeding ration 1 in feeding season $l$ ($l = 1, \ldots, nfs$) are:

$$
\begin{aligned}
neE[i][1][l] \quad = \quad & (neglE[i][1][l] + nemlE[i][1][l] + newlE[i][1][l] + nelE[i][1][l]) \\
& \times plambE[i] \times \frac{1}{l3E[j]} \sum_{b=0}^{1} PsuckE[b][j] \tag{9.25} \\
pdiE[i][1][l] \quad = \quad & (pdiglE[i][1][l] + pdimlE[i][1][l] + pdiwlE[i][1][l] + pdilE[i][1][l]) \\
& \times plambE[i] \times \frac{1}{l3E[j]} \sum_{b=0}^{1} PsuckE[b][j] \; .
\end{aligned}
$$

The appropriate equations for ewes fed with feeding ration 2 are:

$$neE[i][2][l] = (neglE[i][2][l] + nemlE[i][2][l] + newlE[i][2][l] + nelE[i][2][l])$$
$$\times plambE[i] \times \frac{1}{l3E[j]} \sum_{b=2}^{clt} PsuckE[b][j] \qquad (9.26)$$
$$pdiE[i][2][l] = (pdiglE[i][2][l] + pdimlE[i][2][l] + pdiwlE[i][2][l] + pdilE[i][2][l])$$
$$\times plambE[i] \times \frac{1}{l3E[j]} \sum_{b=2}^{clt} PsuckE[b][j] \ .$$

The total net energy and protein requirement for a ewe fed with feeding ration 3 are calculated as:

$$neE[i][3][l] = (neglE[i][3][l] + nemlE[i][3][l] + newlE[i][3][l])$$
$$\times plambE[i] + (negnlE[i][3][l] + nemnlE[i][3][l]$$
$$+ newnlE[i][3][l]) \times (1 - plambE[i]) + nefE[i][3][l] \qquad (9.27)$$
$$pdiE[i][3][l] = (pdiglE[i][3][l] + pdimlE[i][3][l] + pdiwlE[i][3][l])$$
$$\times plambE[i] + (pdignlE[i][3][l] + pdimnlE[i][3][l]$$
$$+ pdiwnlE[i][3][l]) \times (1 - plambE[i]) + pdifE[i][3][l] \ .$$

The equations for feeding ration 4 are:

$$neE[i][4][l] = (neglE[i][4][l] + nemlE[i][4][l] + newlE[i][4][l])$$
$$\times plambE[i] + (negnlE[i][4][l] + nemnlE[i][4][l]$$
$$+ newnlE[i][4][l]) \times (1 - plambE[i]) \qquad (9.28)$$
$$pdiE[i][4][l] = (pdiglE[i][4][l] + pdimlE[i][4][l] + pdiwlE[i][4][l])$$
$$\times plambE[i] + (pdignlE[i][4][l] + pdimnlE[i][4][l]$$
$$+ pdiwnlE[i][4][l]) \times (1 - plambE[i]) \ .$$

Finally, the total net energy and protein requirement for ewes fed with feeding ration 5 are:

$$neE[i][5][l] = (neglE[i][5][l] + nemlE[i][5][l] + newlE[i][5][l])$$
$$\times plambE[i] + (negnlE[i][5][l] + nemnlE[i][5][l]$$
$$+ newnlE[i][5][l]) \times (1 - plambE[i]) + nepE[i][5][l] \qquad (9.29)$$
$$pdiE[i][5][l] = (pdiglE[i][5][l] + pdimlE[i][5][l] + pdiwlE[i][5][l])$$
$$\times plambE[i] + (pdignlE[i][5][l] + pdimnlE[i][5][l]$$
$$+ pdiwnlE[i][5][l]) \times (1 - plambE[i]) + pdipE[i][5][l] \ .$$

### 9.2.7 Total feed costs for individual categories of ewes

Fresh feed requirement is always given in kg per ewe and appropriate time interval in this subsection. Fresh feed requirement ($feE[i][k][l]$) calculated from the net energy content in feed per ewe of category $i$ ($i = (j - 1) \times nstgE + i1$ where $i1 = 3, \ldots, nstgE$ for $j = 1, \ldots, LL - 1$ and $i1 = 3$ for $j = LL$, $j$ is the number of the reproductive cycle and $i1$ the stage within the reproductive cycle, $nstgE = 5$ for the given version of the program) fed with the seasonal variant $l$ of feeding ration $k$ is:

$$feE[i][k][l] = \frac{neE[i][k][l]}{nedE[k][l] \times drymE[k][l]} \ . \qquad (9.30)$$

The appropriate fresh feed requirement calculated from the protein content in the feed ($fpdiE[i][k][l]$) is:

$$fpdiE[i][k][l] = \frac{pdiE[i][k][l]}{pdidE[k][l] \times drymE[k][l]} \ . \tag{9.31}$$

If the final value of the fresh feed requirement ($ffE[i][k][l]$) is calculated both from the net energy content and the protein content of the feed (option $feedcost = 1$ in parameter file PARAS.TXT, see Section 14.1 on page 137) the maximum of the values calculated in equations (9.30) and (9.31) is taken corrected by the losses of feed caused by wasting:

$$ffE[i][k][l] = \frac{\max(feE[i][k][l], fpdiE[i][k][l])}{1 - lossfE[k][l]/100} \tag{9.32}$$

If the final feed requirement is calculated only from the net energy content in the feed (option $feedcost = 2$ in parameter file PARAS.TXT), equation (9.32) changes to:

$$ffE[i][k][l] = \frac{feE[i][k][l]}{1 - lossfE[k][l]/100} \tag{9.33}$$

The total *undiscounted* feeding costs ($costfudE[i]$) per ewe of category $i$ ($i = (j-1) \times nstgE + i1$ where $i1 = 3, \ldots, nstgE$ for $j = 1, \ldots, LL - 1$ and $i1 = 3$ for $j = LL$, $j$ is the number of the reproductive cycle and $i1$ the stage within the reproductive cycle, $nstgE = 5$ for the given version of the program) are then:

$$costfudE[i] = \sum_{k=1}^{fE} \sum_{l=1}^{nfs} ffE[i][k][l] \times prfE[k][l] \ . \tag{9.34}$$

For the remaining categories ($i = (j-1) \times nstgE + i1$ where $i1 = 1, 2$ for $j = 1, \ldots, LL$) it is assumed that the ewes died or were culled on average in the middle of the appropriate time interval. Therefore, the costs for them are half the costs for the corresponding categories the costs were already calculated. For reproductive cycles $j = 1, \ldots, LL - 1$ is

$$costfudE[(j-1) \times nstgE+1] = costfudE[(j-1) \times nstgE+2] = costfudE[j \times nstgE]/2 \tag{9.35}$$

and for $j = LL$

$$costfudE[(j-1) \times nstgE + 1] = costfudE[(j-1) \times nstgE+2] = costfudE[TE]/2 \ . \tag{9.36}$$

The total feeding costs *discounted* to the birth of the animals ($costfE[i]$) are for all categories $i$ of ewes ($i = 1, \ldots, TE$) :

$$costfE[i] = qaveE[i] \times costfudE[i] \ . \tag{9.37}$$

## 9.3   Nutrition costs for rams

### 9.3.1   Net energy and protein requirement for rams

As already mentioned in Subsection 9.1.2, feeding of rams has to cover the energy and protein requirement for maintenance, wool growth, flushing and growth of body weight. Net energy and protein requirements for maintenance and growth depend on body weight and growth rate. All calculated values for net energy requirement in this subsection are in MJ per ram and per appropriate time interval and the calculated values for protein requirement are in grammes per ram and per appropriate

Table 9.6: Start and end dates for feeding rations 1 and 2 for rams of category $i$

| Category of rams | Start date | Feeding ration | End date |
|---|---|---|---|
| $(i-1) \times nstgR + 2$ | $datbbs - flushbbR$ | 2 | $datebs$ |
| $(i = 1, \ldots, RR)$ | $datebs + 1$ | 1 | $datebs + dselR$ |
| $(i-1) \times nstgR + 4$ | $datbbs - flushbbR$ | 2 | $datebs$ |
| $(i = 1, \ldots, RR - 1)$ | $datebs + 1$ | 1 | $datbbs + lengthrc - flushbbR - 1$ |

time interval. Daily wool production of rams of the breed of the flock ($j = 1$) or of the breed used for crossing in the flock ($j = 2$) is given by equation

$$dwoolptR[j] = woolptR[j]/lengthrc \,. \tag{9.38}$$

The start date and the end date for the two feeding rations defined in Subsection 9.1.2 in dependence of the category of rams are given in Table 9.6. Symbols $k1$ and $k2$ will be used in the following equations for the lower and upper limit of the sums, respectively. They are functions of the start date and end date given in Table 9.6 and are calculated as:

$$
\begin{aligned}
k1 &= \text{Start date} - datbbs + flushbbR + 1 \\
k2 &= \text{End date} - datbbs + flushbbR + 1
\end{aligned}
\tag{9.39}
$$

This is a simple transformation of the time scale where the date of starting the flushing period becomes day 1 and all other dates are related to this date. Please have in mind that both $k1$ and $k2$ depend on the category of rams and on the feeding ration.

The net energy requirement for wool production of category $i$ ($i = 2, 4, \ldots, RR - 2$) and breed $j$ ($j = 1$ : breed of the flock, $j = 2$ : breed used for crossing in the flock) of rams fed with feeding ration $k$ in feeding season $l$ is [2]:

$$newR[i][j][k][l] = 23.7 \times dwoolptR[j] \times \sum_{t=k1}^{k2} \delta_l \tag{9.40}$$

where $\delta_l$ is a function of $t$ as defined in equation (9.7) on page 67, i.e. $\delta_l$ is one if $t$ is within feeding season $l$, otherwise $\delta_l$ is zero. The net energy requirement for growth of body weight is calculated only for categories $i = 2$ and $i = 4$, the remaining indices take the same values as above [2]:

$$negR[i][j][k][l] = adgR[j] \sum_{t=k1}^{k2} \delta_l \times \left( 2.5 + 0.35 \times (wbR[1][j] + adgR[j] \times t) \right) \,. \tag{9.41}$$

For $i > 4$, $negR[i][j][k][l] = 0$. The net energy requirement for maintenance is for categories $i = 2$ and $i = 4$ [1, 2, 4, 13]:

$$
\begin{aligned}
nemR[i][j][k][l] &= \sum_{t=k1}^{k2} \delta_l \times \Big( 0.277 \times (wbR[1][j] + adgR[j] \times t)^{0.75} \times a \times (1 \\
&\quad + 0.0091 \times (20 - tp[l])) + 0.0054 \times (wbR[1][j] + adgR[j] \times t) \Big)
\end{aligned}
\tag{9.42}
$$

where $a = 1$ for feeding ration $k = 1$ and $a = 1.8$ for $k = 2$ [Kica 2006, personal communication]. The value of $a$ is higher for feeding ration 2 because the rams

need substantially more energy and protein during flushing and during the breeding season than out of the breeding season. For $i = 6, \ldots, RR - 2$ this equation changes to

$$
\begin{aligned}
nemR[i][j][k][l] \quad = \quad & \Big( 0.277 \times mwR[j]^{0.75} \times a \times (1 + 0.0091 \times (20 - tp[l])) \\
& + 0.0054 \times mwR[j] \Big) \times \sum_{t=k1}^{k2} \delta_l \ . 
\end{aligned}
\tag{9.43}
$$

The total net energy requirement is then:

$$
neR[i][j][k][l] = nemR[i][j][k][l] + negR[i][j][k][l] + newR[i][j][k][l] \ . 
\tag{9.44}
$$

The appropriate equations for protein requirement were derived on the basis of [2, 4, 5]. The protein requirement for wool production of category $i$ ($i = 2, 4, \ldots, RR - 2$) and breed $j$ ($j = 1$ : breed of the flock, $j = 2$ : breed used for crossing in the flock) of rams fed with feeding ration $k$ for feeding season $l$ is:

$$
pdiwR[i][j][k][l] = 3088.6 \times dwoolptR[j] \times \sum_{t=k1}^{k2} \delta_l \ . 
\tag{9.45}
$$

The protein requirement for growth of body weight is calculated only for categories $i = 2$ and $i = 4$:

$$
\begin{aligned}
pdigR[i][j][k][l] \quad = \quad & \frac{adgR[j]}{0.59} \sum_{t=k1}^{k2} \delta_l \times \Big( 160.4 - 1.22 \times (wbR[1][j] + adgR[j] \times t) \\
& + 0.0105 \times (wbR[1][j] + adgR[j] \times t)^2 \Big) \ . 
\end{aligned}
\tag{9.46}
$$

The protein requirement for maintenance is for categories $i = 2$ and $i = 4$:

$$
pdimR[i][j][k][l] = 2.1875 \times a \sum_{t=k1}^{k2} \delta_l \times (wbR[1][j] + adgR[j] \times t)^{0.75}
\tag{9.47}
$$

where $a = 1$ for feeding ration $k = 1$ and $a = 1.8$ for $k = 2$ [Kica 2006, personal communication]. For $i = 6, \ldots, RR - 2$ this equation changes to

$$
pdimR[i][j][k][l] = 2.1875 \times mwR[j]^{0.75} \times a \times \sum_{t=k1}^{k2} \delta_l \ . 
\tag{9.48}
$$

The total protein requirement is then:

$$
pdiR[i][j][k][l] = pdimR[i][j][k][l] + pdigR[i][j][k][l] + pdiwR[i][j][k][l] \ . 
\tag{9.49}
$$

## 9.3.2 Feeding costs per ram of the individual categories

Fresh feed requirement is always given in kg per ram and per appropriate time interval in this subsection. Fresh feed requirement ($feR[i][j][k][l]$) calculated from the net energy content in feed per ram of category $i$ ($i = 2, 4, \ldots, 4 \times RR - 2$) of the breed of the flock ($j = 1$) or of the breed used for crossing in the flock ($j = 2$) fed with the seasonal variant $l$ of feeding ration $k$ is:

$$
feR[i][j][k][l] = \frac{neR[i][j][k][l]}{nedR[k][l] \times drymR[k][l]} \ . 
\tag{9.50}
$$

The appropriate fresh feed requirement ($fpdiR[i][j][k][l]$) calculated from the protein content in the feed is:

$$fpdiR[i][j][k][l] = \frac{pdiR[i][j][k][l]}{pdidR[k][l] \times drymR[k][l]} \ . \tag{9.51}$$

If the final value of the fresh feed requirement ($ffR[i][j][k][l]$) is calculated both from the net energy content and the protein content of the feed (option $feedcost = 1$ in parameter file PARAS.TXT, see subsection 14.1 on page 137) the maximum of the values calculated in equations (9.50) and (9.51) is taken corrected by the losses of feed caused by wasting:

$$ffR[i][j][k][l] = \frac{\max(feR[i][j][k][l], fpdiR[i][j][k][l])}{1 - lossfR[k][l]/100} \tag{9.52}$$

If the final feed requirement is calculated only from the net energy content in the feed (option $feedcost = 2$ in parameter file PARAS.TXT), equation (9.52) changes to:

$$ffR[i][j][k][l] = \frac{feR[i][j][k][l]}{1 - lossfR[k][l]/100} \tag{9.53}$$

The *undiscounted* total feeding costs ($costfudR[i][j]$) per ram of category $i$ ($i = 2, 4, \ldots, 4 \times RR - 2$) of the breed of the flock ($j = 1$) or of the breed used for crossing in the flock ($j = 2$) are then:

$$costfudR[i][j] = \sum_{k=1}^{fR} \sum_{l=1}^{nfs} ffR[i][j][k][l] \times prfR[k][l] \ . \tag{9.54}$$

For the remaining categories ($i = 1, 3, \ldots, 4 \times RR - 1$) it is assumed that the rams died or are culled for health problems on average in the middle of the appropriate time interval. Therefore the costs for them are half the costs for the corresponding categories the costs of which were already calculated. We will now write $l$ for the number of the reproductive cycle. Then we get for $l = 1, \ldots, RR - 1$

$$
\begin{aligned}
costfudR[1 + nstgR(l-1)][j] &= costfudR[nstgR \times l][j]/2 \\
costfudR[3 + nstgR(l-1)][j] &= costfudR[nstgR \times l][j]/2
\end{aligned}
\tag{9.55}
$$

and for $l = RR$

$$costfudR[1 + nstgR(l-1)][j] = costfudR[2 + nstgR(l-1)][j]/2 \ . \tag{9.56}$$

In the last breeding cycle ($l = RR$), the rams are assumed to be sold or culled at the same time resulting in equal costs for both categories:

$$costfudR[3 + nstgR(l-1)][j] = costfudR[2 + nstgR(l-1)][j] \ . \tag{9.57}$$

The total feeding costs *discounted* to the birth of the animals ($costfR[i][j]$) are for all categories $i$ of rams of breed $j$ are:

$$costfR[i][j] = qaveR[i][j] \times costfudR[i][j] \ . \tag{9.58}$$

## 9.4   Nutrition costs for lambs

Altogether, there may be up to 48 categories of progeny (see Section 4.2 on page 23). Nutrition may depend further on the number of litter mates, on the genotype (purebred or cross-bred), on the feeding ration as defined in Subsection 9.1.3 on page 64

Table 9.7: Values of constants $c1$ to $c6$ for female and male progeny; these constants are used in the equations for net energy and protein requirement of progeny

| Constant | Female progeny | Male progeny | Male castrates |
|---|---|---|---|
| $c1$ | 1.00 | 1.15 | 1.15 |
| $c2$ | 2.1 | 2.5 | 4.4 |
| $c3$ | 0.45 | 0.35 | 0.32 |
| $c4$ | 156.1 | 160.4 | 160.4 |
| $c5$ | 1.94 | 1.22 | 1.22 |
| $c6$ | 0.0173 | 0.0105 | 0.0105 |

and on the seasonal variant of the feeding ration. For categories 1 (lambs stillborn or died until 24 hours after birth), 7 and 32 (female or male lambs, respectively, sold at weaning or after artificial rearing) no feeding or other costs are expected.

Here we give the equations for net energy and protein requirement in a general form which is valid for all categories of lambs. Information specific for the individual categories of lambs is then added in the following subsections. All quantities describing net energy and protein requirement have five indices. The first index ($b = 1, \ldots, clt$) refers to litter size, the second index ($i = 1, \ldots, PP$) refers to the category of progeny, the third index ($j$) differentiates between pure-bred ($j = 1$) and cross-bred ($j = 2$) animals, the fourth index ($k = 1, \ldots, fL$) belongs to the feeding ration and the last index ($l = 1, \ldots, nfs$) refers to the seasonal variant of the feeding ration.

The net energy requirement for wool production is calculated as [2]:

$$newbL[b][i][j][k][l] = 23.7 \times dwoolptwL \times \sum_{t=k1}^{k2} \delta_l \qquad (9.59)$$

where $\delta_l$ is a function of $t$ as defined in equation (9.7) on page 67, i.e. $\delta_l$ is one if $t$ is within feeding season $l$, otherwise $\delta_l$ is zero. The net energy requirement for growth is [2]:

$$negbL[b][i][j][k][l] = adgb[s][b][j] \sum_{t=k1}^{k2} \delta_l \times \big( c2[s] + c3[s] \times (swb[s][b][j] + adgb[s][b][j] \times t) \big)$$
$$(9.60)$$

where index $s$ refers to the sex of progeny which is related to the category of progeny in the following way:

$$s = \begin{cases} 1 \text{ (female progeny)} & \text{for } i <= 27 \\ 2 \text{ (male progeny)} & \text{for } i >= 28 \text{ and } i <= 42 \\ 0 \text{ (castrates)} & \text{for } i >= 43 \end{cases} \qquad (9.61)$$

The constants $c2[s]$ and $c3[s]$ depend on the sex of the progeny, the values of the constants are given in Table 9.7. Average daily gain ($adgb[s][b][j]$) and start weight ($swb[s][b][j]$) at the given feeding period similar as $k1$ and $k2$ are specific for the individual categories of lambs and will be specified in the following subsections. The net energy requirement for maintenance is calculated as follows [1, 2, 4, 13]:

$$\begin{aligned} nembL[b][i][j][k][l] & = 0.277 \times c1[s] \sum_{t=k1}^{k2} \delta_l \times \big( (swb[s][b][j] + adgb[s][b][j] \times t)^{0.75} \\ & \times (1 + 0.0091 \times (20 - tp[l])) \\ & + ktL \times (swb[s][b][j] + adgb[s][b][j] \times t) \big) \end{aligned} \qquad (9.62)$$

where $ktL$ is a function of the sheep husbandry system ($ktechbL[l]$, input parameter in file INPUTS08.TXT) used in feeding season $l$ and the values of $c1[s]$ are given in Table 9.7.

The protein requirement for wool production is given by [2]:

$$
\begin{aligned}
pdiwbL[b][i][j][k][l] \quad = \quad & \sum_{t=k1}^{k2} \delta_l \times \Big( 11.54 + adgb[s][b][j] \times 0.3846 \times \big( c4[s] \\
& - c5[s] \times (swb[s][b][j] + adgb[s][b][j] \times t) \\
& + c6[s] \times (swb[s][b][j] + adgb[s][b][j] \times t)^2 \big) \Big)
\end{aligned} \tag{9.63}
$$

where the values of $c4[s]$, $c5[s]$ and $c6[s]$ are given in Table 9.7. The protein requirement for growth is calculated by the equation [2]:

$$
\begin{aligned}
pdigbL[b][i][j][k][l] \quad = \quad & \frac{adgb[s][b][j]}{0.59} \sum_{t=k1}^{k2} \delta_l \times \Big( c4[s] \\
& - c5[s] \times (swb[s][b][j] + adgb[s][b][j] \times t) \\
& + c6[s] \times (swb[s][b][j] + adgb[s][b][j] \times t)^2 \Big) \ .
\end{aligned} \tag{9.64}
$$

Finally, the protein requirement for maintenance is [2, 4, 5]:

$$
pdimbL[b][i][j][k][l] = 2.1875 \times \sum_{t=k1}^{k2} \delta_l \times (swb[s][b][j] + adgb[s][b][j] \times t)^{0.75} \ . \tag{9.65}
$$

### 9.4.1 Lambs till weaning (categories 5, 30 and 2)

The costs are explicitly calculated only for categories 5 (female lambs from birth to weaning) and 30 (male lambs from birth to weaning). Lambs are assumed to be fed only feeding ration 1 (see Subsection 9.1.3 for the definition of feeding rations). As already mentioned, net energy and protein requirement are calculated on the basis of the general equations (9.59) to (9.65). However, if only milk is fed, the equations for protein requirements for wool and growth must be modified because of the high digestibility of milk protein. According to [18], the digestibility of milk protein for calves is nearly 1. As no information on lambs was found, also a digestibility of one for milk proteins was used till weaning. The equation for protein requirements for wool (9.63) changes to

$$
\begin{aligned}
pdiwbL[b][i][j][k][l] \quad = \quad & \sum_{t=k1}^{k2} \delta_l \times \Big( 3.0 + adgb[s][b][j] \times 0.1 \times \big( c4[s] \\
& - c5[s] \times (swb[s][b][j] + adgb[s][b][j] \times t) \\
& + c6[s] \times (swb[s][b][j] + adgb[s][b][j] \times t)^2 \big) \Big)
\end{aligned} \tag{9.66}
$$

and the equation for protein requirement for growth (9.64) takes the form

$$
\begin{aligned}
pdigbL[b][i][j][k][l] \quad = \quad & adgb[s][b][j] \times \sum_{t=k1}^{k2} \delta_l \times \Big( c4[s] \\
& - c5[s] \times (swb[s][b][j] + adgb[s][b][j] \times t) \\
& + c6[s] \times (swb[s][b][j] + adgb[s][b][j] \times t)^2 \Big) \ .
\end{aligned} \tag{9.67}
$$

As there is only one feeding ration, only one start date ($datlamb$) and one end date ($datwL - 1$) is needed. Symbols $k1$ and $k2$ which are used in the equations given above for the lower and upper limit of the sums, respectively, are then

$$
\begin{aligned}
k1 &= \text{Start date} - datlamb + 1 \\
k2 &= \text{End date} - datlamb + 1 \ .
\end{aligned}
\tag{9.68}
$$

This is a simple transformation of the time scale where the lambing date becomes day 1 and all other dates are related to this date. Furthermore, $adgb[s][b][j] = adgbwL[s][b][j]$ and $swb[s][b][j] = bwL[s][b][j]$ for all $s$, $b$ and $j$ in equations (9.59) to (9.65).

For the further calculations it is necessary to subdivide the variables $basemilkw$ and $milkwrel[i][j]$ given in equations (6.6) and (6.7) according to the feeding seasons. Milk yield until weaning per lambing ewe ($basemilkws[l]$) in feeding season $l$ ($l = 1, \ldots, nfs$) calculated for the standard situation of the lactation curve (6.1) is calculated as

$$
basemilkws[l] = awo \sum_{i=k1}^{k2} \delta_l \, i^{bwo} e^{-cwo \times i}
\tag{9.69}
$$

where $i$ is the number of days in lactation, $awo$, $bwo$ and $cwo$ are the coefficients of the lactation curve and

$$
\delta_l = \begin{cases} 1 & \text{if } i \text{ is in feeding season } l \\ 0 & \text{otherwise} \end{cases} \ .
\tag{9.70}
$$

Milk yield until weaning ($milkwsrel[b][j][l]$) per lambing ewe with $b$ ($b = 0, \ldots, clt$) suckled lambs in lactation $j$ ($j = 1, \ldots, LL$) and feeding season $l$ ($l = 1, \ldots, nfs$) is:

$$
milkwsrel[b][j][l] = basemilkws[l] \times ktlsl[b] \times ktlp[j] \ .
\tag{9.71}
$$

Milk yield until weaning ($milkws[b][j][l]$) per ewe in the flock per reproductive cycle for ewes with $b$ ($b = 0, \ldots, clt$) suckled lambs in lactation $j$ ($j = 1, \ldots, LL$) and feeding season $l$ ($l = 1, \ldots, nfs$) is:

$$
milkws[b][j][l] = milkwsrel[b][j][l] \times PsuckE[b][j] \ .
\tag{9.72}
$$

The total milk amount ($milkwL[b][l]$) available from birth till weaning per lamb from a litter with litter size $b$ ($b = 1, \ldots, clt$) in feeding season $l$ ($l = 1, \ldots, nfs$) is

$$
milkwL[b][l] = \frac{1 - pmilkwm}{Nlamb \times i} \sum_{j=1}^{LL} (milkwsrel[b][j][l] \times l3E[j]) \ .
\tag{9.73}
$$

In dairy sheep, the total amount of milk ($tmilkw0[l]$) from ewes without lambs available from birth to weaning for lambs of other ewes or for selling (per ewe in the flock) in feeding season $l$ is calculated as

$$
tmilkw0[l] = \frac{1}{Nlamb} \sum_{j=1}^{LL} milkws[0][j][l] \ .
\tag{9.74}
$$

If this milk is used for additional feeding of lambs from litters with litter size $\geq 2$ the average additional milk amount ($milkw0L[l]$) available per lamb from these litters in feeding season $l$ is[2]

$$
milkw0L[l] = \frac{tmilkw0[l]}{Nlamb} \bigg/ \sum_{b=2}^{clt} na24hL[0][b] \ .
\tag{9.75}
$$

---

[2] The variable $milkw0L[l]$ is calculated only if $pmilkwm = 0$. See remark in Section 6.2. Both $tmilkw0[l]$ and $milkw0L[l]$ are not calculated for non-dairy sheep.

The net energy ($nelwL[b][l]$) and digestible protein (PDI, $pdilwL[b][l]$) available from milk per lamb from a litter of litter size $b$ in feeding season $l$ are:

$$
\begin{aligned}
nelwL[b][l] &= nemilk \times (milkwL[b][l] + \delta_b \times milkw0L[l]) \\
pdilwL[b][l] &= pdimilk \times (milkwL[b][l] + \delta_b \times milkw0L[l])
\end{aligned} \tag{9.76}
$$

where

$$
\delta_b = \left\{ \begin{array}{ll} 0 & \text{for } b < 2 \\ 1 & \text{for } b \geq 2 \end{array} \right. . \tag{9.77}
$$

The net energy ($nebL[b][i][j][1][l]$) and protein ($pdibL[b][i][j][1][l]$) requirement that must be covered from supplementary feeding with the seasonal variant $l$ ($l = 1, \ldots, nfs$) of feeding ration 1 for a pure-bred ($j = 1$) or cross-bred ($j = 2$) lamb of category $i$ ($i = 5$ or $30$) which is from a litter with litter size $b$ ($b = 1, \ldots, clt$) is calculated as:

$$
\begin{aligned}
nebL[b][i][j][1][l] &= negbL[b][i][j][1][l] + nembL[b][i][j][1][l] \\
&\quad + newbL[b][i][j][1][l] - nelwL[b][l] \\
pdibL[b][i][j][1][l] &= pdigbL[b][i][j][1][l] + pdimbL[b][i][j][1][l] \\
&\quad + pdiwbL[b][i][j][1][l] - pdilwL[b][l] .
\end{aligned} \tag{9.78}
$$

Negative values of the energy and protein requirement indicate that there is no supplementary feeding necessary. Therefore, in the weighted average over the different litter sizes only positive values are taken into consideration and negative values are treated as zero:

$$
\begin{aligned}
neL[i][j][1][l] &= \frac{\sum_{b=1}^{clt} l1L[i][j][b] \times \delta_{bn} \times nebL[b][i][j][1][l]}{\sum_{b=1}^{clt} l1L[i][j][b]} \\[2em]
pdiL[i][j][1][l] &= \frac{\sum_{b=1}^{clt} l1L[i][j][b] \times \delta_{bp} \times pdibL[b][i][j][1][l]}{0.65 \times \sum_{b=1}^{clt} l1L[i][j][b]}
\end{aligned} \tag{9.79}
$$

where

$$
\delta_{bn} = \left\{ \begin{array}{ll} 1 & \text{if } nebL[b][i][j][k][l] > 0 \\ 0 & \text{otherwise} \end{array} \right. \tag{9.80}
$$

and

$$
\delta_{bp} = \left\{ \begin{array}{ll} 1 & \text{if } pdibL[b][i][j][k][l] > 0 \\ 0 & \text{otherwise} \end{array} \right. \tag{9.81}
$$

As the utilisation of protein from supplement feeding ration for lambs is lower than that from milk (according to Kica 2007, personal communication, approximately 65%) the protein requirement to be covered by supplementary feeding had be divided by 0.65.

Fresh feed requirement not taking into account wasting of feed and calculated from the net energy requirement ($feL[i][j][k][l]$) for the seasonal variant $l$ ($l = 1, \ldots, nfs$) of feeding ration $k = 1$ for a pure-bred ($j = 1$) or cross-bred ($j = 2$) lamb of category $i$ ($i = 5$ or $30$) is then:

$$
feL[i][j][k][l] = \frac{neL[i][j][k][l]}{nedL[k][l] \times drymL[k][l]} . \tag{9.82}
$$

The fresh feed requirement calculated from the protein requirement ($fpdiL[i][j][k][l]$) is calculated in the same way:

$$fpdiL[i][j][k][l] = \frac{pdiL[i][j][k][l]}{pdidL[k][l] \times drymL[k][l]} \ .$$
(9.83)

If the final value of the fresh feed requirement ($ffL[i][j][k][l]$) is calculated both from the net energy content and the protein content of the feed (option $feedcost = 1$ in parameter file PARAS.TXT, see Section 14.1 on page 137) the maximum of the values calculated in equations (9.82) and (9.83) is taken corrected by the losses of feed caused by wasting:

$$ffL[i][j][k][l] = \frac{\max(feL[i][j][k][l], fpdiL[i][j][k][l])}{1 - lossfL[k][l]/100}$$
(9.84)

If the final feed requirement is calculated only from the net energy content in the feed (option $feedcost = 2$ in parameter file PARAS.TXT), equation (9.84) changes to:

$$ffL[i][j][k][l] = \frac{feL[i][j][k][l]}{1 - lossfL[k][l]/100}$$
(9.85)

The total *undiscounted* costs for feeding pure-bred ($j = 1$) or cross-bred ($j = 2$) lambs of category $i$ ($i = 5$ or $30$) from birth until weaning are calculated as follows:

$$costfudL[i][j] = \sum_{k=1}^{fL} \sum_{l=1}^{nfs} ffL[i][j][k][l] \times prfL[k][l] \ .$$
(9.86)

The costs are expressed per lamb. The costs for category 2 (lambs died from 24 hours until weaning) are estimated assuming that the lambs died on average in the middle of the period:

$$costfudL[2][j] = (sexrbf \times costfudL[5][j] + sexrbm \times costfudL[30][j])/2 \ .$$
(9.87)

## 9.4.2 Lambs from early weaning till the end of artificial rearing (categories 6, 31 and 2)

The calculations in this subsection are carried out only if there is artificial rearing in the system (parameter $typew = 2$ in the parameter file PARAS.TXT, see Section 14.1 on page 137). Lambs are assumed to be fed only feeding ration 2 (see Subsection 9.1.3 for the definition of feeding rations). Net energy and protein requirement are calculated on the basis of the general equations (9.59) to (9.65). However, the equations for protein requirements for wool and growth must be modified. The main feed in artificial lamb rearing is milk replacer so that a higher utilisation of protein is expected than given for older lambs in [2]. A coefficient of utilisation of 80% was used (Kica 2007, personal communication). The equation for protein requirements for wool (9.63) changes to

$$\begin{aligned}
pdiwbL[b][i][j][k][l] &= \sum_{t=k1}^{k2} \delta_l \times \Big( 3.75 + adgb[s][b][j] \times 0.125 \times \big( c4[s] \\
&\quad -c5[s] \times (swb[s][b][j] + adgb[s][b][j] \times t) \\
&\quad +c6[s] \times (swb[s][b][j] + adgb[s][b][j] \times t)^2 \big) \Big)
\end{aligned}$$
(9.88)

and the equation for protein requirement for growth (9.64) takes the form

$$
\begin{aligned}
pdigbL[b][i][j][k][l] \quad = \quad & \frac{adgb[s][b][j]}{0.8} \sum_{t=k1}^{k2} \delta_l \times \Big( c4[s] \\
& -c5[s] \times (swb[s][b][j] + adgb[s][b][j] \times t) \qquad (9.89) \\
& +c6[s] \times (swb[s][b][j] + adgb[s][b][j] \times t)^2 \Big) \ .
\end{aligned}
$$

As there is only one feeding ration, only one start date ($datwL$) and one end date ($datlamb + agearL - 1$) is needed. Symbols $k1$ and $k2$ which are used in the equations given above for the lower and upper limit of the sums, respectively, are then

$$
\begin{aligned}
k1 \quad &= \quad \text{Start date} - datlamb - agewL + 1 \\
k2 \quad &= \quad \text{End date} - datlamb - agewL + 1 \qquad (9.90)
\end{aligned}
$$

This is a simple transformation of the time scale where the date of early weaning becomes day 1 and all other dates are related to this date. Furthermore, $adg[s][b][j] = adgwarL[s][b][j]$ and $sw[s][b][j] = wwL[s][b][j]$ for all $s$, $b$ and $j$ in equations (9.59) to (9.65).

The net energy ($nebL[b][i][j][2][l]$) and protein ($pdibL[b][i][j][2][l]$) requirement for feed of seasonal variant $l$ ($l = 1, \ldots, nfs$) of feeding ration 2 for a pure-bred ($j = 1$) or cross-bred ($j = 2$) lamb of category $i$ ($i = 6$ or 31) which is from a litter with litter size $b$ ($b = 1, \ldots, clt$) is calculated as:

$$
\begin{aligned}
nebL[b][i][j][2][l] \quad &= \quad negbL[b][i][j][2][l] + nembL[b][i][j][2][l] \\
& \qquad +newbL[b][i][j][2][l] \\
pdibL[b][i][j][2][l] \quad &= \quad pdigbL[b][i][j][2][l] + pdimbL[b][i][j][2][l] \qquad (9.91) \\
& \qquad +pdiwbL[b][i][j][2][l] \ .
\end{aligned}
$$

The weighted average over the different litter sizes is:

$$
\begin{aligned}
neL[i][j][2][l] \quad &= \quad \frac{\displaystyle\sum_{b=1}^{clt} l1L[i][j][b] \times nebL[b][i][j][2][l]}{\displaystyle\sum_{b=1}^{clt} l1L[i][j][b]} \\[2em]
pdiL[i][j][2][l] \quad &= \quad \frac{\displaystyle\sum_{b=1}^{clt} l1L[i][j][b] \times pdibL[b][i][j][2][l]}{\displaystyle\sum_{b=1}^{clt} l1L[i][j][b]} \qquad (9.92)
\end{aligned}
$$

The fresh feed requirement calculated on the basis of the net energy ($feL[i][j][k][l]$) or protein ($fpdiL[i][j][k][l]$) requirement not taking into account wasting of feed is calculated using equations (9.82) and (9.83) where $i = 6$ or 31, $k = 2$ and the remaining indices take the same values as given in Subsection 9.4.1. The fresh feed requirement ($ffL[i][j][k][l]$) taking into account wasting of feed is calculated from equation (9.84) or (9.85), dependent on the value of the parameter *feedcost* in parameter file PARAS.TXT (see Section 14.1 on page 137), where $i = 6$ or 31 and $k = 2$. The *undiscounted* total cost for feeding lambs from weaning until the end of artificial rearing (categories 6 and 31) using feeding ration 2 are given by equation

(9.86). In the case of artificial rearing equation (9.87) changes to

$$
\begin{aligned}
costfudL[2][j] \;=\; & \big(sexrbf \times (costfudL[5][j] + costfudL[6][j]) \\
& + sexrbm \times (costfudL[30][j] + costfudL[31][j])\big)\big/2 \; .
\end{aligned}
\tag{9.93}
$$

### 9.4.3 Lambs sold for slaughter after weaning or artificial rearing (categories 7 and 32)

For categories 7 and 32 (female and male lambs sold after weaning or artificial rearing) no feeding costs are expected as the lambs are assumed to be sold immediately at weaning or at the end of artificial rearing.

### 9.4.4 Breeding lambs in the rearing period (categories 4, 13 to 26, 29 and 38 to 42)

This period covers the time from weaning till selling, entering the flock, death or culling. Feeding rations 3, 4 and 5 (see Subsection 9.1.3 on page 64) are used for breeding lambs. Within each feeding ration, seasonal variants are allowed.

#### 9.4.4.1 Net energy and protein requirement for maintenance, growth and wool

The calculation of net energy and protein requirement for maintenance, growth and wool production is based on equations (9.59) to (9.65). These equations are modified as the calculated quantities are not dependent from the size of the litter the lamb is born in for the considered categories of progeny. The modified equations will be given here.

Other than in equations (9.59) to (9.65), all quantities describing net energy and protein requirement have four indices. The first index $(i = 1, \ldots, PP)$ refers to the category of progeny, the second index $(j)$ differentiates between pure-bred $(j = 1)$ and cross-bred $(j = 2)$ animals, the third index $(k = 1, \ldots, fL)$ belongs to the feeding ration and the last index $(l = 1, \ldots, nfs)$ refers to the seasonal variant of the feeding ration. The start and end dates for the individual feeding rations for all categories considered are given in Tables 9.8 and 9.9[3].

The net energy requirement for wool production is then calculated as [2]:

$$
newL[i][j][k][l] = 23.7 \times dwoolptrL[s][j] \times \sum_{t=k1}^{k2} \delta_l
\tag{9.94}
$$

where $\delta_l$ is a function of $t$ as defined in equation (9.7) on page 67, i.e. $\delta_l$ is one if $t$ is within feeding season $l$, otherwise $\delta_l$ is zero. A value different from that in equation (9.59) is inserted for daily wool production $(dwoolptrL[s][j])$ where index $s$ refers to the sex of progeny. The values to be inserted in this and the following equations for $k1$ and $k2$ are given in Table 9.10 where the start and end dates cited in this table are to be taken from Tables 9.8 and 9.9.

---

[3]In several categories, the same feeding ration occurs twice. In these cases the sums in equations (9.94) to (9.99) are calculated over all days the feeding ration is fed.

Table 9.8: Start and end dates for individual feeding rations for categories of female and male breeding lambs. Part I: Categories 13 to 19

| Category | Start date | Feeding ration | End date |
|---|---|---|---|
| | *Female progeny* | | |
| 13 | $datwL$ for customary weaning<br>$datlamb + agearL$ for artificial rearing | 4 | $datlamb + agetP[13][j] - 1$ |
| 14[a] | $datwL$ for customary weaning<br>$datlamb + agearL$ for artificial rearing | 4 | $datbbs - flushbbL - 1$ |
| | $datbbs - flushbbL$ | 3 | $datlamb + ager[1][1] - 1$ |
| 14[b] | $datwL$ for customary weaning<br>$datlamb + agearL$ for artificial rearing | 4 | $datlamb + ager[1][1] - 1$ |
| 15 | $datlamb + ager[1][1]$ | 3 | $datlamb + ager[1][1] + flushabL - 1$ |
| | $datlamb + ager[1][1] + flushabL$ | 4 | $\begin{cases} datlamb + lengthrc - lpreg + dpregsFP - 1^c \\ datlamb + lengthrc - dshpE - 1^d \end{cases}$ |
| | $datlamb + lengthrc - dshpE$ | 5[d] | $datlamb + lengthrc - lpreg + dpregsFP - 1$ |
| 16 | $datlamb + ager[1][1]$ | 3 | $datlamb + ager[1][1] + flushabL - 1$ |
| | $datlamb + ager[1][1] + flushabL$ | 4 | $datlamb + lengthrc - dshpE - 1$ |
| | $datlamb + lengthrc - dshpE$ | 5 | $datlamb + lengthrc - 1$ |
| 17 | $datlamb + ager[1][1]$ | 3 | $datlamb + ager[1][1] + flushabL - 1$ |
| | $datlamb + ager[1][1] + flushabL$ | 4 | $datebs + dnpregcFP - 1$ |
| 18 | $datlamb + ager[1][1]$ | 3 | $datlamb + ager[1][1] + flushabL - 1$ |
| | $datlamb + ager[1][1] + flushabL$ | 4 | $datbbs + lengthrc - flushbbL - 1$ |
| | $datbbs + lengthrc - flushbbL$ | 3 | $datbbs + lengthrc - 1$ |
| 19 | $datlamb + ager[1][2]$ | 3 | $datlamb + ager[1][2] + flushabL - 1$ |
| | $datlamb + ager[1][2] + flushabL$ | 4 | $\begin{cases} datlamb + 2 \times lengthrc - lpreg + dpregsFP - 1^c \\ datlamb + 2 \times lengthrc - dshpE - 1^d \end{cases}$ |
| | $datlamb + 2 \times lengthrc - dshpE$ | 5[d] | $datlamb + 2 \times lengthrc - lpreg + dpregsFP - 1$ |

[a] to be mated, [b] not to be mated, [c] if $dpregsFP < lpreg - dshpE$, [d] if $dpregsFP \geq lpreg - dshpE$

Table 9.9: Start and end dates for individual feeding rations for categories of female and male breeding lambs. Part II: Categories 20 to 25 and 38 to 41

| Category | Start date | Feeding ration | End date |
| --- | --- | --- | --- |
| | *Female progeny (continued)* | | |
| 20 | $datlamb + ager[1][2]$ | 3 | $datlamb + ager[1][2] + flushabL - 1$ |
| | $datlamb + ager[1][2] + flushabL$ | 4 | $datlamb + 2 \times lengthrc - dshpE - 1$ |
| | $datlamb + 2 \times {+}lengthrc - dshpE$ | 5 | $datlamb + 2 \times lengthrc - 1$ |
| 21 | $datlamb + ager[1][2]$ | 3 | $datlamb + ager[1][2] + flushabL - 1$ |
| | $datlamb + ager[1][2] + flushabL$ | 4 | $datebs + lengthrc + dnpregcFP - 1$ |
| 22 | $datlamb + ager[1][2]$ | 3 | $datlamb + ager[1][2] + flushabL - 1$ |
| | $datlamb + ager[1][2] + flushabL$ | 4 | $datbbs + 2 \times lengthrc - flushbbL - 1$ |
| | $datbbs + 2 \times lengthrc - flushbbL$ | 3 | $datbbs + 2 \times lengthrc - 1$ |
| 23 | $datlamb + ager[1][3]$ | 3 | $datlamb + ager[1][3] + flushabL - 1$ |
| | $datlamb + ager[1][3] + flushabL$ | 4 | $\begin{cases} datlamb + 3 \times lengthrc - lpreg + dpregsFP - 1^a \\ datlamb + 3 \times lengthrc - dshpE - 1^b \end{cases}$ |
| | $datlamb + 3 \times lengthrc - dshpE$ | $5^b$ | $datlamb + 3 \times lengthrc - lpreg + dpregsFP - 1$ |
| 24 | $datlamb + ager[1][3]$ | 3 | $datlamb + ager[1][3] + flushabL - 1$ |
| | $datlamb + ager[1][3] + flushabL$ | 4 | $datlamb + 3 \times lengthrc - dshpE - 1$ |
| | $datlamb + 3 \times lengthrc - dshpE$ | 5 | $datlamb + 3 \times lengthrc - 1$ |
| 25 | $datlamb + ager[1][3]$ | 3 | $datlamb + ager[1][3] + flushabL - 1$ |
| | $datlamb + ager[1][3] + flushabL$ | 4 | $datebs + 2 \times lengthrc + dnpregcFP - 1$ |
| 26 | $datlamb + ager[1][1]$ | 4 | $datlamb + agetP[26][j] - 1$ |
| | *Male progeny* | | |
| 38 | $datwL$ for customary weaning $datlamb + agearL$ for artificial rearing | 4 | $datlamb + agetP[38][j] - 1$ |
| 39 | $datwL$ for customary weaning $datlamb + agearL$ for artificial rearing | 4 | $datbbs - 1$ |
| 40 | $datbbs$ | 4 | $datlamb + agetP[40][j] - 1$ |
| 41 | $datbbs$ | 4 | $datbbs + lengthrc - 1$ |

$^a$ if $dpregsFP < lpreg - dshpE$, $^b$ if $dpregsFP \geq lpreg - dshpE$

Table 9.10: Values for $k1$ and $k2$ for the categories of breeding lambs

| Category | Value to be subtracted from the start date or the end date to get $k1$ or $k2$, respectively |
|---|---|
| *Female progeny* | |
| 13, 14 | $\begin{cases} datwL - 1 & \text{for customary weaning} \\ datlamb + agearL - 1 & \text{for artificial rearing} \end{cases}$ |
| 15 to 18 | $datlamb + ager[1][1] - 1$ |
| 19 to 22 | $datlamb + ager[1][2] - 1$ |
| 23 to 25 | $datlamb + ager[1][3] - 1$ |
| *Male progeny* | |
| 38, 39 | $\begin{cases} datwL - 1 & \text{for customary weaning} \\ datlamb + agearL - 1 & \text{for artificial rearing} \end{cases}$ |
| 40, 41 | $datbbs - 1$ |

The net energy requirement for growth is [2]:

$$negL[i][j][k][l] = adg[s][j] \sum_{t=k1}^{k2} \delta_l \times \big(c2[s] + c3[s] \times (sw[s][j] + adg[s][j] \times t)\big) \quad (9.95)$$

The values of the constants $c2[s]$ and $c3[s]$ are given in Table 9.7. Average daily gain ($adg[s][j]$) and start weight ($sw[s][j]$) at the given feeding period are specific for the individual categories of lambs (see Table 9.11). The net energy requirement for maintenance is calculated as follows [1, 2, 4, 13]:

$$
\begin{aligned}
nemL[i][j][k][l] \;=\;& 0.277 \times c1[s] \sum_{t=k1}^{k2} \delta_l \times \big((sw[s][j] + adg[s][j] \times t)^{0.75} \\
& \times (1 + 0.0091 \times (20 - tp[l])) \\
& + ktL \times (sw[s][j] + adg[s][j] \times t)\big)
\end{aligned}
\quad (9.96)
$$

where $c1[s]$ is given in Table 9.7.

The protein requirement for wool production is now calculated according to [2]:

$$
\begin{aligned}
pdiwL[i][j][k][l] \;=\;& \sum_{t=k1}^{k2} \delta_l \times \Big(11.54 + adg[s][j] \times 0.3846 \times \big(c4[s] \\
& - c5[s] \times (sw[s][j] + adg[s][j] \times t) \\
& + c6[s] \times (sw[s][j] + adg[s][j] \times t)^2\big)\Big)
\end{aligned}
\quad (9.97)
$$

where the values of $c4[s]$, $c5[s]$ and $c6[s]$ are given in Table 9.7. The protein requirement for growth is calculated by the equation [2]:

$$
\begin{aligned}
pdigL[i][j][k][l] \;=\;& \frac{adg[s][j]}{0.59} \sum_{t=k1}^{k2} \delta_l \times \Big(c4[s] \\
& - c5[s] \times (sw[s][j] + adg[s][j] \times t) \\
& + c6[s] \times (sw[s][j] + adg[s][j] \times t)^2\Big) \, .
\end{aligned}
\quad (9.98)
$$

Finally, the protein requirement for maintenance is [2, 4, 5]:

$$pdimL[i][j][k][l] = 2.1875 \times \sum_{t=k1}^{k2} \delta_l \times (swb[s][j] + adgb[s][j] \times t)^{0.75} \, . \quad (9.99)$$

Table 9.11: Start weight and daily gain used in the equations for net energy and protein requirements for categories of pure-bred ($j = 1$) and cross-bred ($j = 2$) female and male breeding progeny

| Category | Start weight | Daily gain | Remark |
|---|---|---|---|
| *Female progeny* | | | |
| 13, 14 | $avww[1][j]$ $avwar[1][j]$ | $adgr[1][1][j]$ | Customary weaning Artificial rearing |
| 15 to 17 | $wmat[1][j]$ | $adgr[1][2][j]$ | |
| 18, 26 | $wnmat[1][j]$ | $adgr[1][2][j]$ | |
| 19 to 22 | $wrL[1][2][j]$ | $adgr[1][3][j]$ | |
| 23 to 25 | $wrL[1][3][j]$ | 0 | No further growth, animals have already reached mature weight |
| *Male progeny* | | | |
| 38, 39 | $avww[2][j]$ $avwar[2][j]$ | $adgr[2][1][j]$ | Customary weaning Artificial rearing |
| 40, 41 | $wnmat[2][1]$ | $adgr[2][2][j]$ | |

In category 14, the net energy and protein requirement for feeding ration 4 is not calculated directly as shown above. In this category, two subcategories are formed: one subcategory of animals intended for mating and a second subcategory of animals not intended for mating. The net energy and protein requirement is first calculated for both subcategories according to equations (9.94) to (9.99). Let us write $negL14m[j][i2]$ and $negL14nm[j][i2]$ for the net energy for growth for the subcategory of animals intended to be mated and for the subcategory of animals not intended to be mated, respectively. Then the total net energy from feeding ration 4 needed for growth of category 14 is:

$$
\begin{aligned}
negL[14][j][4][i2] &= negL14m[j][i2] \times pmat[1][1][j] \\
&\quad + negL14nm[j][i2] \times (1 - pmat[1][1][j]) \, . \quad (9.100)
\end{aligned}
$$

The procedure for the calculation of the net energy requirement for maintenance and wool and for the protein requirement for growth, maintenance and wool is the same.

### 9.4.4.2  Net energy and protein requirement for pregnancy

Net energy and protein requirement for pregnancy are calculated for categories 15, 16, 19, 20, 23 and 24. During pregnancy, the females are only fed feeding rations 4 and 5. The start date for feeding ration 4 is the date of conception which is calculated in equation (5.41) on page 45. The start dates for feeding ration 5 and the end dates for both feeding rations are given in Tables 9.8 and 9.9. As before, symbols $k1$ and $k2$ will be used for the lower and upper limit, respectively, of the sums in the equations for net energy and protein requirement. Their values are

$$
\begin{aligned}
k1 &= \text{Start date} - datconFP[i] + 1 \\
k2 &= \text{End date} - datconFP[i] + 1 \quad\quad (9.101)
\end{aligned}
$$

where index $i$ is related to the categories as follows

$$
i = \begin{cases} 1 & \text{for categories 15 and 16} \\ 2 & \text{for categories 19 and 20} \\ 3 & \text{for categories 23 and 24} \end{cases} \quad . \quad\quad (9.102)
$$

The net energy and the protein requirement for low pregnancy for a pure-bred ($j = 1$) or cross-bred ($j = 2$) female of category $i$ with expected litter size $b$ fed

with feeding ration 4 in feeding season $l$ are calculated essentially in the same way as in equations (9.16):

$$
\begin{aligned}
nepbL[b][i][j][4][l] &= 0.083773 \times twL[b][1] \sum_{t=k1}^{k2} \delta_l \\
&\quad \times e^{7.6492-0.00643t-11.4646e^{-0.00643t}} \,, \qquad (9.103) \\
pdipbL[b][i][j][4][l] &= 0.043889 \times twL[b][1] \sum_{t=k1}^{k2} \delta_l \\
&\quad \times e^{11.3471-0.00601t-11.2205e^{-0.00601t}} \,.
\end{aligned}
$$

where $\delta_l$ is a function of $t$ as defined in equation (9.7) on page 67, i.e. $\delta_l$ is one if $t$ is within feeding season $l$, otherwise $\delta_l$ is zero. The net energy and protein requirement for high pregnancy (feeding ration 5) is:

$$
\begin{aligned}
nepbL[b][i][j][5][l] &= 0.083773 \times twL[b][1] \\
&\quad \times \sum_{t=k1}^{k2} \delta_l \times e^{7.6492-0.00643t-11.4646e^{-0.00643t}} \\
&\quad -20.034 \times \frac{wgfL}{dshpE} \sum_{t=k1}^{k2} \delta_l \,, \qquad (9.104) \\
pdipbL[b][i][j][5][l] &= 0.043889 \times twL[b][1] \\
&\quad \times \sum_{t=k1}^{k2} \delta_l \times e^{11.3471-0.00601t-11.2205e^{-0.00601t}} \\
&\quad -119 \times \frac{wgfL}{dshpE} \sum_{t=k1}^{k2} \delta_l \,.
\end{aligned}
$$

The last terms (which are subtracted) of both equations of (9.104) are the net energy and protein originating from the body reserves built during the flushing period.

The net energy and the protein requirement for pregnancy averaged over the expected litter size for a pure-bred ($j = 1$) or cross-bred ($j = 2$) female of category $i$ fed with feeding ration $k$ in feeding season $l$ are:

$$
\begin{aligned}
nepL[i][j][k][l] &= \sum_{b=1}^{clt} nepbL[b][i][j][k][l] \times Pltype[b][1] \,, \\
pdipL[i][j][k][l] &= \sum_{b=1}^{clt} pdipbL[b][i][j][k][l] \times Pltype[b][1] \,. \qquad (9.105)
\end{aligned}
$$

### 9.4.4.3 Net energy and protein requirement for flushing

Extra daily live weight gain per day during flushing ($adgfL$) is calculated from the total live weight gain during flushing ($wgfL$) and the length of the flushing period ($flushbbL + flushabL$)

$$
adgfL = wgfL/(flushbbL + flushabL) \,. \qquad (9.106)
$$

Net energy and protein requirement for flushing will be calculated for categories 14 to 25. Lambs of these categories are fed with feeding ration 3 in the flushing period. The start dates and end dates are the start and end dates for feeding ration 3 for the corresponding categories as given in Table 9.8 to 9.9. Again symbols $k1$

and $k2$ will be used in the following equations as lower and upper limits of the sums. They take the following values:

$$
\begin{aligned}
k1 &= \text{Start date} - datlamb - ager[i][1] + 1 \\
k2 &= \text{End date} - datlamb - ager[i][1] + 1
\end{aligned}
\tag{9.107}
$$

where

$$
i = \begin{cases}
1 & \text{for categories 15 to 18} \\
2 & \text{for categories 19 to 22} \\
3 & \text{for categories 23 to 25}
\end{cases} .
\tag{9.108}
$$

For category 14 we get

$$
\begin{aligned}
k1 &= \text{Start date} - datbbs + flushbbL + 1 \\
k2 &= \text{End date} - datbbs + flushbbL + 1 .
\end{aligned}
\tag{9.109}
$$

The net energy and protein requirement for flushing per pure-bred ($j = 1$) or cross-bred ($j = 2$) female of category 14 fed with feeding ration 3 in feeding season $l$ ($l = 1, \ldots, nfs$) are [1, 4]:

$$
\begin{aligned}
nefL[14][j][3][l] &= 23.85 \times adgfL \times pmat[1][1][j] \times \sum_{t=k1}^{k2} \delta_l \\
pdifL[14][j][3][l] &= 140 \times adgfL \times pmat[1][1][j] \times \sum_{t=k1}^{k2} \delta_l
\end{aligned}
\tag{9.110}
$$

where $\delta_l$ is one if $t$ is within feeding season $l$, otherwise $\delta_l$ is zero. The multiplication by $pmat[1][1][j]$ is necessary because only a part of the females in this category are intended for mating. The equations for the remaining categories ($i = 15$ to $25$) is without this term as all females of these categories are prepared for mating[4]:

$$
\begin{aligned}
nefL[i][j][3][l] &= 23.85 \times adgfL \times \sum_{t=k1}^{k2} \delta_l \\
pdifL[i][j][3][l] &= 140 \times adgfL \times \sum_{t=k1}^{k2} \delta_l .
\end{aligned}
\tag{9.111}
$$

### 9.4.4.4 Total net energy and protein requirement

The total net energy requirement ($neL[i][j][k][l]$) for pure-bred ($j = 1$) or cross-bred ($j = 2$) animals of categories $i =$ 13 to 26 and 38 to 41 fed with feeding ration $k$ in feeding season $l$ is calculated as the sum of the net energy requirement for maintenance, growth, wool production, pregnancy and flushing whereby the values of net energy for pregnancy and flushing are different from zero only in several categories of female progeny:

$$
\begin{aligned}
neL[i][j][k][l] &= nemL[i][j][k][l] + negL[i][j][k][l] + newL[i][j][k][l] \\
&\quad + nepL[i][j][k][l] + nefL[i][j][k][l] .
\end{aligned}
\tag{9.112}
$$

The total protein requirement ($pdiL[i][j][k][l]$) is calculated in the same way:

$$
\begin{aligned}
pdiL[i][j][k][l] &= pdimL[i][j][k][l] + pdigL[i][j][k][l] + pdiwL[i][j][k][l] \\
&\quad + pdipL[i][j][k][l] + pdifL[i][j][k][l] .
\end{aligned}
\tag{9.113}
$$

---

[4]If two flushing periods occur for a category (categories 18 and 22) the summation is over both periods.

#### 9.4.4.5   Fresh feed requirement and feeding costs

For breeding lambs of categories 13 to 26 and 38 to 41, the fresh feed requirement calculated on the basis of the net energy ($feL[i][j][k][l]$) or protein ($fpdiL[i][j][k][l]$) requirement not taking into account wasting of feed and the fresh feed requirement ($ffL[i][j][k][l]$) taking into account wasting of feed are calculated from equations (9.82) to (9.85). The *undiscounted* total cost for feeding breeding lambs are given by equation (9.86).

The feeding costs per female lamb died in the rearing period (category 4) is calculated as one half of the weighted sum of the feeding costs for categories 14, 18, 22 and 16, 20 and 24:

$$
\begin{aligned}
costfudL[4][j] \quad = \quad & \frac{1}{2 \times l1skL[4][j]} \Bigg( \sum_{i=1}^{3} costfudL[14 + 4(i-1)][j] \times \\
& (nrdied[1][i][j] + nspdied[1][i][j]) \\
& + \frac{nrdiedmlFP[j]}{Pherd[1]} \sum_{i=1}^{3} costfudL[16 + 4(i-1)][j] \times pherd[1][i] \Bigg)
\end{aligned}
\tag{9.114}
$$

The feeding costs per male breeding lamb of category 29 (died during rearing) are calculated as one half of the weighted average of the feeding costs for categories 39 and 41:

$$
costfudL[29][j] = \frac{\sum_{i=1}^{2} costfudL[39 + 2(i-1)][j] \times nrdied[2][i][j] \times nspdied[2][i][j]}{2 \times l1skL[29][j]}
\tag{9.115}
$$

The feeding costs per male breeding lamb of category 42 (culled during rearing) are also calculated as one half of the corresponding weighted average of the feeding costs for categories 39 and 41:

$$
costfudL[42][j] = \frac{\sum_{i=1}^{2} costfudL[39 + 2(i-1)][j] \times nrcull[2][i][j] \times nspcull[2][i][j]}{2 \times l1skL[42][j]}
\tag{9.116}
$$

### 9.4.5   Fattened lambs (categories 3, 8 to 12, 28, 33 to 37, 43 to 47 and 48)

If there is fattening of all categories, the net energy requirement for wool, growth and maintenance for fattened female (categories 8 to 12) and male (categories 33 to 37) progeny and castrates (categories 43 to 47) is calculated using equations (9.94) to (9.96). In most cases, probably only some of the categories will be calculated. More exactly, categories 8 to $7 + lf[1]$ will be calculated if there is fattening of female progeny, categories 33 to $32 + lf[2]$ will be calculated if there is fattening of male progeny and categories 43 to $42 + lf[0]$ will be calculated if there is fattening of castrates.

For fattened lambs the same daily wool production as for breeding lambs is assumed ($dwoolptrL[s][j]$) whereas the value for male lambs is inserted also for castrates. The protein requirement for wool, growth and maintenance for fattened progeny is given by equations (9.97) to (9.99). Each category is fed only with one

feeding ration. Writing $i$ for the category, the number of the feeding ration $k$ is:

$$k = \begin{cases} i-2 & \text{for categories 8 to 12} \\ i-22 & \text{for categories 33 to 37} \\ i-27 & \text{for categories 43 to 47} \end{cases} . \tag{9.117}$$

The start date for all categories is $datwL$ if there is customary weaning or $datlamb + agearL$ if there is artificial rearing. The end date for all categories is $datlamb + agetP[k_s + i][j]$ where $k_s$ is given in equation (5.17). In the case of customary weaning, $k1$ and $k2$ used in the equations given above for the lower and upper limit of the sums, respectively, are

$$\begin{aligned} k1 &= \text{Start date} - datlamb - agewL + 1 \\ k2 &= \text{End date} - datlamb - agewL + 1 \end{aligned} \tag{9.118}$$

This equation changes to

$$\begin{aligned} k1 &= \text{Start date} - datlamb - agearL + 1 \\ k2 &= \text{End date} - datlamb - agearL + 1 \end{aligned} \tag{9.119}$$

for artificial rearing.

For average daily gain of pure-bred ($j = 1$) or cross-bred ($j = 2$) progeny of category $i$ the following values are inserted into equations (9.94) to (9.99):

$$adg[s][j] = adgP[k_s + i][j] \tag{9.120}$$

where $k_s$ is given by equation (5.17). The start weight for female progeny (categories 8 to 12) is

$$sw[1][j] = \begin{cases} avww[1][j] & \text{if there is customary weaning} \\ avwar[1][j] & \text{if there is artificial weaning} \end{cases} \tag{9.121}$$

and the start weight for male progeny (categories 33 to 37) and castrates (categories 43 to 47) is:

$$sw[s][j] = \begin{cases} avww[2][j] & \text{if there is customary weaning} \\ avwar[2][j] & \text{if there is artificial weaning} \end{cases} \tag{9.122}$$

where $s = 2$ (male progeny) or $s = 0$ (castrates).

The fresh feed requirement calculated on the basis of the net energy ($feL[i][j][k][l]$) or protein ($fpdiL[i][j][k][l]$) requirement not taking into account wasting of feed is calculated using equations (9.82) and (9.83). The fresh feed requirement ($ffL[i][j][k][l]$) taking into account wasting of feed is calculated from equation (9.84) or (9.85), dependent on the value of the parameter $feedcost$ in parameter file PARAS.TXT (see Section 14.1 on page 137). The *undiscounted* total cost for fattening lambs of categories 8 to 12, 33 to 37 and 42 to 47 is given by equation (9.86).

If there is fattening of female progeny, total feeding costs per pure-bred ($j = 1$) or cross-bred ($j = 2$) female lamb of category 3 (died in fattening) are calculated as one half of the weighted average of feeding costs for categories 8 to $7 + lf[1]$:

$$costfudL[3][j] = \frac{1}{2 \times l1skL[3][j]} \sum_{i=1}^{lf[1]} costfudL[i+7][j] \times ndiedfat[1][i][j]. \tag{9.123}$$

If there is fattening of male progeny, the total feeding costs per male lamb of category 28 (died in fattening) are

$$costfudL[28][j] = \frac{1}{2 \times l1skL[28][j]} \sum_{i=1}^{lf[2]} costfudL[i+32][j] \times ndiedfat[2][i][j]. \tag{9.124}$$

Finally, if there is fattening of castrates, the total feeding costs per castrate of category 48 (died in fattening) are

$$costfudL[48][j] = \frac{1}{2 \times l1skL[48][j]} \sum_{i=1}^{lf[0]} costfudL[i+42][j] \times ndiedfat[0][i][j].$$
(9.125)

### 9.4.6 Discounted total feed costs

Total feeding costs for pure-bred ($j = 1$) or cross-bred ($j = 2$) lambs of category $i$ ($i = 1, \ldots, PP$) *discounted* to the birth date of the animals ($costfL[i][j]$) is calculated by multiplying the undiscounted total feeding costs with the corresponding discounting coefficient:

$$costfL[i][j] = qaveL[i][j] \times costfudL[i][j] .$$
(9.126)

## 9.5 Costs for water

Water requirement is assumed to be dependent on the feeding ration. Therefore, input parameters are demanded for daily water requirement for each seasonal variant of all feeding rations (in input file INPUTS08.TXT - see Subsection 14.2.8 on page 146). Daily water requirement can be calculated on the base of dry matter intake as proposed by [8].

### 9.5.1 Ewes

Lactating and non-lactating ewes must be differentiated as done in the calculation of energy and protein requirement. The water requirement ($watlE[i][k][l]$) per lactating ewe of category $i$ fed with seasonal variant $l$ of feeding ration $k$ is simply the daily water requirement $dwatE[k][l]$ connected with seasonal variant $l$ of feeding ration $k$ multiplied with the number of days this variant of the feeding ration is fed. Formally we can write:

$$watlE[i][k][l] = dwatE[k][l] \times \sum_{t=k1}^{k2} \delta_l$$
(9.127)

where $k_1$ and $k_2$ are taken from equation (9.5) which uses the start and end dates for the individual feeding rations given in Tables 9.2 to 9.4 and $\delta_l$ is 1 if day $t$ is within feeding season $l$ or $\delta_l$ is 0 if day $t$ is not within feeding season $l$. The water requirement per non-lactating ewe ($watnlE[i][k][l]$) is calculated in the same way on the basis of the feeding rations given for barren ewes in Tables 9.2 to 9.4.

The equations for the calculation of the total water requirement ($watE[i][k][l]$) for a ewe of category $i$ ($i = (j - 1) \times nstgE + i1$ where $i1 = 3, \ldots, nstgE$ for $j = 1, \ldots, LL - 1$ and $i1 = 3$ for $j = LL$, $j$ is the number of the reproductive cycle and $i1$ the stage within the reproductive cycle, $nstgE = 5$ for the given version of the program) differ between feeding rations. The total water requirement for a ewe fed with feeding ration 1 in feeding season $l$ ($l = 1, \ldots, nfs$) is:

$$watE[i][1][l] = watlE[i][1][l] \times plambE[i] \times \frac{1}{l3E[j]} \sum_{b=0}^{1} PsuckE[b][j]$$
(9.128)

The appropriate equation for ewes fed with feeding ration 2 are:

$$watE[i][2][l] = watlE[i][2][l] \times plambE[i] \times \frac{1}{l3E[j]} \sum_{b=2}^{clt} PsuckE[b][j]$$
(9.129)

The total water requirement for a ewe fed with feeding rations $k = 3, 4$ or $5$ are calculated as:

$$watE[i][k][l] = watlE[i][k][l] \times plambE[i] + watnlE[i][k][l] \times (1 - plambE[i]) .$$
(9.130)

The *undiscounted* total costs for water ($costwatudE[i]$) per ewe of category $i$ ($i = (j-1) \times nstgE + i1$ where $i1 = 3, \ldots, nstgE$ for $j = 1, \ldots, LL - 1$ and $i1 = 3$ for $j = LL$, $j$ is the number of the reproductive cycle and $i1$ the stage within the reproductive cycle, $nstgE = 5$ for the given version of the program) are:

$$costwatudE[i] = prwat \times \sum_{k=1}^{fE} \sum_{l=1}^{nfs} watE[i][k][l] .$$
(9.131)

For the remaining categories ($i = (j-1) \times nstgE + i1$ where $i1 = 1, 2$ for $j = 1, \ldots, LL$) it is assumed that the ewes died or were culled on average in the middle of the appropriate time interval. Therefore, the costs for them are half the costs for the corresponding categories the costs were already calculated. For reproductive cycles $j = 1, \ldots, LL - 1$ is

$$
\begin{aligned}
costwatudE[(j-1) \times nstgE + 1] &= costwatudE[(j-1) \times nstgE + 2] \\
&= costwatudE[j \times nstgE]/2
\end{aligned}
$$
(9.132)

and the costs for $j = LL$ are

$$
\begin{aligned}
costwatudE[(j-1) \times nstgE + 1] &= costwatudE[(j-1) \times nstgE + 2] \\
&= costwatudE[TE]/2 .
\end{aligned}
$$
(9.133)

The total costs for water *discounted* to the birth of the animals ($costwatE[i]$) are for all categories $i$ of ewes ($i = 1, \ldots, TE$) :

$$costwatE[i] = qaveE[i] \times costwatudE[i] .$$
(9.134)

## 9.5.2   Rams

The water requirement ($watR[i][j][k][l]$) per ram of the breed of the flock ($j = 1$) or of the breed used for crossing in the flock ($j = 2$) of category $i$ fed with seasonal variant $l$ of feeding ration $k$ is the daily water requirement $dwatR[k][l]$ connected with seasonal variant $l$ of feeding ration $k$ multiplied with the number of days this variant of the feeding ration is fed:

$$watR[i][j][k][l] = dwatR[k][l] \times \sum_{t=k1}^{k2} \delta_l$$
(9.135)

where $k_1$ and $k_2$ are taken from equation (9.39) which uses the start and end dates for the individual feeding rations given in Table 9.6 and $\delta_l$ is 1 if day $t$ is within feeding season $l$ or $\delta_l$ is 0 if day $t$ is not within feeding season $l$.

The *undiscounted* total costs for water ($costwatudR[i][j]$) per ram of category $i$ ($i = 2, 4, \ldots, 4 \times RR - 2$) of the breed of the flock ($j = 1$) or of the breed used for crossing in the flock ($j = 2$) are:

$$costwatudR[i][j] = prwat \times \sum_{k=1}^{fR} \sum_{l=1}^{nfs} watR[i][j][k][l] .$$
(9.136)

For the remaining categories ($i = 1, 3, \ldots, 4 \times RR - 1$) it is assumed that the rams died or are culled for health problems on average in the middle of the appropriate

time interval. Therefore the costs for them are half the costs for the corresponding categories the costs of which were already calculated. We will now write $l$ for the number of the breeding cycle. Then we get for $l = 1, \ldots, RR - 1$

$$
\begin{aligned}
costwatudR[1 + nstgR(l-1)][j] &= costwatudR[3 + nstgR(l-1)][j] \\
&= costwatudR[nstgR \times l][j]/2 \quad (9.137)
\end{aligned}
$$

and for $l = RR$

$$
costwatudR[1 + nstgR(l-1)][j] = costwatudR[2 + nstgR(l-1)][j]/2 . \quad (9.138)
$$

In the last breeding cycle ($l = RR$), the rams are assumed to be sold or culled at the same time resulting in equal costs for both categories:

$$
costwatudR[3 + nstgR(l-1)][j] = costwatudR[2 + nstgR(l-1)][j] . \quad (9.139)
$$

The total costs for water *discounted* to the birth of the animals ($costwatR[i][j]$) are for all categories $i$ of rams of breed $j$ are:

$$
costwatR[i][j] = qaveR[i][j] \times costwatudR[i][j] . \quad (9.140)
$$

### 9.5.3 Lambs

The water requirement ($watL[i][j][k][l]$) per pure-bred ($j = 1$) or cross-bred ($j = 2$) lamb of category $i$ fed with seasonal variant $l$ of feeding ration $k$ is the daily water requirement $dwatL[k][l]$ connected with seasonal variant $l$ of feeding ration $k$ multiplied with the number of days this variant of the feeding ration is fed:

$$
watL[i][j][k][l] = dwatL[k][l] \times \sum_{t=k1}^{k2} \delta_l \quad (9.141)
$$

where $k_1$ and $k_2$ depend on the category of animals and the feeding ration in the same way as in Section 9.4. Their values are therefore given in equations (9.68), (9.90), (9.101), (9.107), (9.118) and (9.119) or in Table 9.10. $\delta_l$ is 1 if day $t$ is within feeding season $l$ or $\delta_l$ is 0 if day $t$ is not within feeding season $l$.

In category 14, the water requirement is separately calculated for mated and non-mated female lambs ($watL14m[j][l]$ and $watL14nm[j][l]$, respectively) using the same procedure as in equation (9.141). The total water requirement for category 14 fed with feeding ration 4 is then:

$$
\begin{aligned}
watL[14][j][4][l] &= watL14m[j][l] \times pmat[1][1][j] \\
&= +watL14nm[j][l] \times (1 - pmat[1][1][j]) . \quad (9.142)
\end{aligned}
$$

The *undiscounted* total costs for water ($costwatudL[i][j]$) per pure-bred ($j = 1$) or cross-bred ($j = 2$) lamb of category $i$ ($i = 5, 6, 8$ to $26, 30, 31, 33$ to $41, 43$ to $47$) are:

$$
costwatudL[i][j] = prwat \times \sum_{k=1}^{fL} \sum_{l=1}^{nfs} watL[i][j][k][l] . \quad (9.143)
$$

No costs are assumed for categories 1, 7 and 32 (and also for the empty category 27). For the remaining categories (2, 3, 4, 28, 29, 42 and 48) it is assumed that the lambs died or were culled for health problems on average in the middle of the appropriate time interval. Therefore the costs for them are the weighted averages of half the costs for the corresponding categories the costs of which were already calculated. The costs for water for these categories are calculated in the same way as the costs for feeding, just replace in the following equations $costfudL$ by $costwatudL$:

- Category 2: equation (9.87) if there is customary weaning or equation (9.93) if there is artificial rearing

- Category 3: equation (9.123)

- Category 4: equation (9.114)

- Category 28: equation (9.124)

- Category 29: equation (9.115)

- Category 42: equation (9.116)

- Category 48: equation (9.125)

Total costs for water for pure-bred ($j = 1$) or cross-bred ($j = 2$) lambs of category $i$ ($i = 1, \ldots, PP$) *discounted* to the birth date of the animals ($costwatL[i][j]$) are calculated by multiplying the undiscounted total water costs with the corresponding discounting coefficient:

$$costwatL[i][j] = qaveL[i][j] \times costwatudL[i][j] \ . \tag{9.144}$$

# Chapter 10

# Non-feed and total costs

Non-feed costs include veterinary costs, breeding costs, general labour costs, costs for bedding, costs for shearing, fixed costs, costs for removing and rendering dead animals, costs for buying animals, marketing costs, costs for tanning skins, milking costs and costs for cheese production. The latter two cost components accrue only for dairy ewes. Not each single item of the non-feed costs occurs in all categories of animals. All costs are discounted to the birth date of the animals.

Veterinary costs enclose costs for drenching against endo- and ecto-parasites and costs for further drugs and veterinary service. Breeding costs involve only costs for insemination and oestrus synchronisation (e.g. when mating ewes outside of the 'natural' period for seasonal breeds). General labour costs are the costs for labour of the shepherd(s) and seasonal workers without shearing and milking labour costs.

Fixed costs are miscellaneous costs dependent on the flock size, husbandry system and intensity of the sheep production system but independent of animal performance. They include depreciation costs for stables excluding facilities for milking dairy sheep, cost for energy, fuel, repairs, insurance of animals and building, overhead costs, hires, etc.

It is assumed that fixed costs for ewes and rams do not depend on the time the individual categories stay in the flock. It is assumed, for example, that the fixed costs for a ewe died during a reproductive cycle are the same as for a ewe that stays in the flock for the whole reproductive cycle. It is expected that the released stable place cannot be used for other purposes and can be occupied by new replacement only at the start of the next reproductive cycle (seasonality of mating and lambing). However, fixed costs for lambs depend on the time they stay in the flock. For example, less stable places are needed when mating female lambs at an age of 7-8 months than when mating them at 20 months.

Milking costs occur only in dairy sheep and include all costs connected with milking: labour costs for milking, equipment and energy for milking and milk cooling, depreciation costs for milking parlour, etc. Cost for cheese production include depreciation costs for the cheese production facility and labour and equipment costs connected with cheese production. They do not include costs for milk used for cheese processing.

## 10.1 Non-feed costs for ewes

The veterinary costs per ewe of category $i$ ($costvetE[i]$) are calculated as:

$$
\begin{aligned}
costvetE[i] \;=\; & (nendopE \times mwE[1] \times prendop + nectopE \times prectop + vetE) \\
& \times dcE[i] \times qaveE[i]/lengthrc \,.
\end{aligned}
\tag{10.1}
$$

In the first reproductive cycle, $mwE[1]$ is replaced by $(wlE[1] + mwE[1])/2$ which is the average weight of the ewe during the first reproductive cycle (see Section 5.8). General labour costs per ewe of category $i$ including lambs till weaning ($costlabE[i]$) are given by

$$costlabE[i] = qaveE[i] \times costAkh \times AkhE \times dcE[i]/365 . \tag{10.2}$$

The cost for shearing per ewe of category $i$ ($costsheE[i]$) are calculated as

$$costsheE[i] = qaveE[i] \times nsheE \times costshe0E \times dcE[i]/lengthrc . \tag{10.3}$$

Fixed costs per ewe of category $i$ including lambs till weaning ($costfixE[i]$) are

$$costfixE[i] = qaveE[i] \times costfix0E \times lengthrc . \tag{10.4}$$

Cost for bedding per ewe of category $i$ including lambs till weaning ($costbedE[i]$) are calculated as

$$costbedE[i] = qaveE[i] \times prstraw \times strawE \times \sum_{l=k1}^{k2} \delta_l \tag{10.5}$$

where $k1 = datlamb$ is equal for all categories, but $k2$ depends on the ewe's category through $dcE[i]$:

$$k2 = datlamb + dcE[i] - 1 \tag{10.6}$$

The quantity $\delta_l$ is 1 if day $l$ is within a season where the ewes are housed ($techE[l] = 1$), otherwise $\delta_l$ takes the value zero. Cost for breeding ($costbreedE[i]$) per ewe of category $i$ ($i = 1, \ldots, TE - nstg1E$) are calculated as

$$\begin{aligned} costbreedE[i] &= \big(pinsE[1] \times (1 - pcrossE[j]) \times (costins[1] + nreins \\ &\quad \times costreins[1]) + costoeinE + pinsE[2] \times pcrossE[j] \\ &\quad \times (costins[2] + nreins \times costreins[2])\big) \times qbreedE[i] \end{aligned} \tag{10.7}$$

where index $j$ in $pcrossE[j]$ refers to the number of the reproductive cycle. The value of $j$ can be calculated from $i$ in the following way:

$$j = \text{int}\left(\frac{i}{nstgE} - 0.01\right) + 1 . \tag{10.8}$$

The second part of equation (10.7)

$$pinsE[2] \times pcrossE[j] \times (costins[2] + nreins \times costreins[2])$$

is zero in production systems without crossing. Costs for tanned skin ($costskE[i]$) are calculated only for the categories $i = (j-1) \times nstgE + k$ where $k = 2$ or 3 and the number of the reproductive cycle $j$ ranges from 1 to $LL$:

$$costskE[i] = qendE[i] \times costtan \times pskE \times ptskE . \tag{10.9}$$

Marketing costs ($costmarkE[i]$) are calculated for the same ewe categories as the costs for tanned skin:

$$costmarkE[i] = qendE[i] \times costmarkcul . \tag{10.10}$$

Cost for removing and rendering dead animals ($costdiedE[i]$) are calculated only for the ewe categories $i = (j-1) \times nstgE + 1$ where $j = 1, \ldots, LL$:

$$costdiedE[i] = qendE[i] \times costdead \times wlE[j] . \tag{10.11}$$

Costs for milking ($costmilkE[i]$) and for cheese production $costcheeseE[i]$ are only calculated for dairy sheep (parameter $typeb = 1$ in file PARAS.TXT). These costs for a ewe of category $i$ with $i = (j-1) \times nstgE + k$ where $k = 1, \ldots, nstgE$ for $j = 1, \ldots LL - 1$ and $k = 1, \ldots, 3$ for $j = LL$ are given by the following equations

$$
\begin{aligned}
costmilkE[i] &= b \times costmilk0E \times (milkmpar[j] + a) \times plambE[i] \\
&\quad \times qmilkE[i] \quad\quad\quad\quad\quad\quad\quad\quad\quad\quad\quad\quad (10.12) \\
costcheeseE[i] &= b \times costcheese0E \times (milkmpar[j] + a) \times plambE[i] \\
&\quad \times pmilkch \times qmilkE[i]
\end{aligned}
$$

where

$$
b = \begin{cases} kmilkcE & \text{if } k = 1,2 \\ 1 & \text{if } k = 3, \ldots, nstgE \end{cases} \quad\quad\quad (10.13)
$$

and

$$
a = \begin{cases} 0 & \text{if } pmilkwm = 0 \\ milksw[j] & \text{if } pmilkwm > 0 \end{cases} . \quad\quad\quad (10.14)
$$

The total discounted non-feed costs ($costnfE[i]$) for category $i$ ($i = 1, \ldots, TE$) are the sum of all calculated cost items:

$$
\begin{aligned}
costnfE[i] &= costvetE[i] + costlabE[i] + costfixE[i] + costsheE[i] \\
&\quad + costbedE[i] + costbreedE[i] + costskE[i] \quad\quad\quad (10.15) \\
&\quad + costmarkE[i] + costdiedE[i] + costmilkE[i] + costcheeseE[i] .
\end{aligned}
$$

## 10.2   Non-feed costs for rams

The veterinary costs ($costvetR[i][j]$) per ram of category $i$ ($i = 1, \ldots, TR$) and breed $j$ ($j = 1$ : breed of the flock, $j = 2$ : breed used for crossing in the flock) are calculated as:

$$
\begin{aligned}
costvetR[i][j] &= (nendopR \times mwR[j] \times prendop + nectopR \times prectop + vetR) \\
&\quad \times dcR[i] \times qaveR[i][j]/lengthrc . \quad\quad\quad\quad\quad (10.16)
\end{aligned}
$$

In the first breeding cycle, $mwR[j]$ is replaced by $(wbR[1][j] + mwR[j])/2$ which is the average weight of a ram of breed $j$ during the first breeding cycle (see Section 5.9). General labour costs ($costlabR[i][j]$) per ram of category $i$ and breed $j$ are given by

$$
costlabR[i][j] = qaveR[i][j] \times costAkh \times AkhR \times dcR[i]/365 . \quad\quad (10.17)
$$

The shearing cost ($costsheR[i][j]$) per ram of category $i$ and breed $j$ are calculated as

$$
costsheR[i][j] = qaveR[i][j] \times nsheR[j] \times costshe0R \times dcR[i]/lengthrc . \quad (10.18)
$$

The fixed costs ($costfixR[i][j]$) per ram of category $i$ and breed $j$ are assumed to be equal for all categories and for both breeds:

$$
costfixR[i][j] = qaveR[i][j] \times costfix0R \times lengthrc . \quad\quad\quad (10.19)
$$

The costs for bedding ($costbedR[i][j]$) per ram of category $i$ and breed $j$ are calculated as

$$
costbedR[i][j] = qaveR[i][j] \times prstraw \times strawR \times dcR[i] \quad\quad\quad (10.20)
$$

whereby all-season housing is assumed. Costs for tanned skin ($costskR[i][j]$) are calculated only for the categories $i = (k-1) \times nstgR + 3$ where the number of the breeding cycle $k$ ranges from 1 to $RR$:

$$costskR[i][j] = qendR[i][j] \times costtan \times pskR \times ptskR .$$ (10.21)

The costs for marketing ($costmarkR[i][j]$) for a ram of breed $j$ are calculated for the categories

$$i = (k-1) \times nstgR + l$$ (10.22)

referring to stages $l = 2$ and 3 (see Subsection 3.2.2.1 on page 20):

$$costmarkR[i][j] = \begin{cases} qendR[i][j] \times costmarkbR & \text{for } l = 2 \\ qendR[i][j] \times costmarkcul & \text{for } l = 3 \end{cases}$$ (10.23)

where $k = 1, \ldots, RR$. Cost for removing and rendering dead animals ($costdiedR[i][j]$) are calculated only for the ram categories belonging to stage 1 ($i = (k-1) \times nstgR + 1$) where $k = 1, \ldots, RR$:

$$costdiedR[i][j] = qendR[i][j] \times costdead \times wbR[k][j] .$$ (10.24)

It is assumed that all rams for crossing in the flock are purchased whereas rams of the breed of the flock may or may not be purchased. The costs for purchasing rams ($costpurchR[i][j]$) of the breed of the flock ($j = 1$) or rams for crossing ($j = 2$) of category $i$ ($i = 1, \ldots, nstgR$) are then:

$$costpurchR[i][j] = \begin{cases} qpurchR \times prbR[j] \times ppurchMP & \text{for } j = 1 \\ qpurchR \times prbR[j] & \text{for } j = 2 \end{cases} .$$ (10.25)

The total discounted non-feed costs ($costnfR[i][j]$) per animal and breeding cycle for category $i$ ($i = 1, \ldots, TR$) are the sum of all calculated cost items:

$$\begin{aligned} costnfR[i][j] &= costvetR[i][j] + costlabR[i][j] + costfixR[i][j] \\ &\quad + costsheR[i][j] + costbedR[i][j] + costskR[i][j] \\ &\quad + costmarkR[i][j] + costdiedR[i][j] + costpurchR[i][j] . \end{aligned}$$ (10.26)

## 10.3 Non-feed costs for lambs

**Comment.** From technical reasons, equations for undiscounted costs are given first for several categories of the costs. The variable name for all kinds of undiscounted costs for lambs is of the form $cost \ldots udL$ where the dots are replaced by a string which specifies the costs (*vet* for veterinary costs, *lab* for labor costs etc.) The variable name of the corresponding discounted costs is then $cost \ldots L$. In the program, the variable names for discounted costs are also used for undiscounted costs. Therefore, the variables $cost \ldots udL$ are not given in Appendix B.

### 10.3.1 Veterinary costs

No veterinary costs are expected for stillborn lambs (category 1) and lambs sold immediately after weaning (categories 7 and 32). First the *undiscounted* veterinary costs ($costvetudL[i][j]$) are calculated for all categories. These costs for female ($s = 1$) and male ($s = 2$) lambs till weaning (categories $i = 5$ and $i = 30$) are:

$$\begin{aligned} costvetudL[i][j] &= nendopwL \times avww[s][j] \times prendop \\ &\quad + nectopwL \times prectop + vetwL \end{aligned}$$ (10.27)

where

$$s = \begin{cases} 1 & \text{for category 5} \\ 2 & \text{for category 30} \end{cases} . \tag{10.28}$$

If there is artificial rearing of lambs the veterinary costs for female and male categories $i = 6$ and $i = 31$ are calculated as:

$$\begin{aligned} costvetudL[i][j] & = nendoparL \times avwar[s][j] \times prendop \\ & + nectoparL \times prectop + vetarL \end{aligned} \tag{10.29}$$

where

$$s = \begin{cases} 1 & \text{for category 6} \\ 2 & \text{for category 31} \end{cases} . \tag{10.30}$$

The veterinary costs for lambs died from 24 hours until weaning (category 2) are

$$\begin{aligned} costvetudL[2][j] & = \big((costvetudL[5][j] + costvetudL[6][j]) \times sexrbf \\ & + (costvetudL[30][j] + costvetudL[31][j]) \\ & \times sexrbm\big)/2 \end{aligned} \tag{10.31}$$

where

$$costvetudL[6][j] = costvetudL[31][j] = 0$$

for customary weaning (no artificial rearing).

The veterinary costs for breeding female (category 14) and male (category 39) lambs from weaning (or the end of artificial rearing) until the first breding season are calculated as:

$$\begin{aligned} costvetudL[i][j] & = nendoprL[1] \times prendop \times (a + wrL[s][1][j])/2 \\ & + nectoprL[1] \times prectop + vetrL[1] \end{aligned} \tag{10.32}$$

where

$$a = \begin{cases} avww[s][j] & \text{for } typew = 1 \\ avwar[s][j] & \text{for } typew = 2 \end{cases} \tag{10.33}$$

and

$$s = \begin{cases} 1 & \text{for category } i = 14 \\ 2 & \text{for category } i = 39 \end{cases} . \tag{10.34}$$

The veterinary costs for breeding female (category $i = 13$) and male (category $i = 38$) lambs sold before their first breding season are:

$$\begin{aligned} costvetudL[i][j] & = dcL[i][j] \times \Big(nendoprL[1] \times prendop \times (a + wrL[s][1][j])/2 \\ & + nectoprL[1] \times prectop + vetrL[1]\Big)/(ager[s][1] - b) \end{aligned} \tag{10.35}$$

where

$$\begin{array}{llll} a = avww[s][j] & \text{and} & b = agewL & \text{for } typew = 1 \\ a = avwar[s][j] & \text{and} & b = agearL[1] & \text{for } typew = 2 \end{array} \tag{10.36}$$

and

$$s = \begin{cases} 1 & \text{for category } i = 13 \\ 2 & \text{for category } i = 38 \end{cases} . \tag{10.37}$$

For breeding female (category 18) and male (category 41) lambs between the first and the second breeding season, the veterinary costs are calculated as:

$$\begin{aligned} costvetudL[i][j] & = nendoprL[2] \times prendop \times (wnmat[s][j] + wrL[s][2][j])/2 \\ & + nectoprL[2] \times prectop + vetrL[2] \end{aligned} \tag{10.38}$$

where

$$s = \begin{cases} 1 & \text{for category } i = 18 \\ 2 & \text{for category } i = 41 \end{cases} . \tag{10.39}$$

For breeding female lambs between the second and the third breding season (category $i = 22$), the veterinary costs are calculated as:

$$\begin{aligned} costvetudL[22][j] \quad = \quad & nendoprL[2] \times prendop \times (wrL[1][3][j] + wrL[1][2][j])/2 \\ & + nectoprL[2] \times prectop + vetrL[2] \tag{10.40} \end{aligned}$$

The veterinary costs for breeding female lambs sold without being mated between the first and the second breeding season (category $i = 26$) are:

$$\begin{aligned} costvetudL[26][j] \quad = \quad & \frac{dcL[26][j]}{ager[1][2] - ager[1][1]} \times \Big( nendoprL[2] \times prendop \\ & \times (wnmat[1][j] + wP[26][j])/2 \\ & + nectoprL[2] \times prectop + vetrL[2] \Big) \tag{10.41} \end{aligned}$$

The veterinary costs for breeding female lambs culled (category $i = 17$) and breeding male lambs sold (category $i = 40$), both after the first breeding season, are:

$$\begin{aligned} costvetudL[i][j] \quad = \quad & \frac{dcL[i][j]}{ager[s][2] - ager[s][1]} \times \Big( nendoprL[2] \times prendop \\ & \times (wnmat[s][j] + wrL[s][2][j])/2 \tag{10.42} \\ & + nectoprL[2] \times prectop + vetrL[2] \Big) \end{aligned}$$

where

$$s = \begin{cases} 1 & \text{for category } i = 17 \\ 2 & \text{for category } i = 40 \end{cases} . \tag{10.43}$$

The veterinary costs for breeding female lambs culled after the second breeding season (category $i = 21$) are:

$$\begin{aligned} costvetudL[21][j] \quad = \quad & \frac{dcL[21][j]}{ager[1][3] - ager[1][2]} \times \Big( nendoprL[2] \times prendop \\ & \times (wrL[1][3][j] + wrL[1][2][j])/2 \\ & + nectoprL[2] \times prectop + vetrL[2] \Big) \tag{10.44} \end{aligned}$$

For pregnant female lambs sold after the first (category $i = 15$) and after the second (category $i = 19$) breding season, the veterinary costs are calculated as:

$$\begin{aligned} costvetudL[15][j] \quad = \quad & \frac{dcL[15][j]}{ager[1][2] - ager[1][1]} \times \Big( nendoprL[2] \times prendop \\ & \times (wmat[1][j] + wrL[1][2][j])/2 \\ & + nectoprL[2] \times prectop + vetrL[2] \Big) \tag{10.45} \end{aligned}$$

$$\begin{aligned} costvetudL[19][j] \quad = \quad & \frac{dcL[19][j]}{ager[1][3] - ager[1][2]} \times \Big( nendoprL[2] \times prendop \\ & \times (wrL[1][3][j] + wrL[1][2][j])/2 \\ & + nectoprL[2] \times prectop + vetrL[2] \Big) . \end{aligned}$$

For pregnant female lambs sold (category $i = 23$) and culled (category $i = 25$) after the third breeding season, the veterinary costs are

$$
\begin{aligned}
costvetudL[23][j] \;=\; & \frac{dcL[23][j]}{ager[1][3] - ager[1][2]} \times \Big( nendoprL[2] \times prendop \\
& \times (wP[23][j] + wrL[1][2][j])/2 \\
& + nectoprL[2] \times prectop + vetrL[2] \Big) \qquad (10.46)
\end{aligned}
$$

$$
\begin{aligned}
costvetudL[25][j] \;=\; & \frac{dcL[25][j]}{ager[1][3] - ager[1][2]} \times \Big( nendoprL[2] \times prendop \\
& \times (wrL[1][3][j] + wrL[1][2][j])/2 \\
& + nectoprL[2] \times prectop + vetrL[2] \Big) \; .
\end{aligned}
$$

Veterinary costs for pregnant female lambs used for replacement after the first (category $i = 16$), the second (category ($i = 20$) and the third (category $i = 24$) breeding period are calculated as:

$$
\begin{aligned}
costvetudL[i][j] \;=\; & nendopclFP \times (wrL[1][k][j] + wlFP[k])/2 \times prendop \\
& + nectopclFP \times prectop + vetclFP \qquad (10.47)
\end{aligned}
$$

where

$$
k = \begin{cases}
1 & \text{for category } i = 16 \\
2 & \text{for category } i = 20 \\
3 & \text{for category } i = 24
\end{cases} \qquad . \qquad (10.48)
$$

In fattening of pure-bred ($j = 1$) or cross-bred ($j = 2$) progeny of sex $s$ ($s = 1$ : female, $s = 2$ : male, $s = 0$ : castrates) of category $i$ fattened to target $k$ ($k = 1, \ldots, lf[s]$), the veterinary costs are

$$
\begin{aligned}
costvetudL[i][j] \;=\; & nendopf[s][k] \times prendop \times (a + wP[i][j])/2 \\
& + nectopf[s][k] \times prectop + vetf[s][k] \qquad (10.49)
\end{aligned}
$$

where

$$
\begin{array}{llll}
s = 1 & \text{and} & k = i - 7 & \text{for } i = 8, \ldots, 12 \\
s = 2 & \text{and} & k = i - 32 & \text{for } i = 33, \ldots, 37 \\
s = 0 & \text{and} & k = i - 42 & \text{for } i = 43, \ldots, 47
\end{array} \qquad (10.50)
$$

and

$$
a = \begin{cases}
avww[s][j] & \text{for } typew = 1 \\
avwar[s][j] & \text{for } typew = 2
\end{cases} \qquad . \qquad (10.51)
$$

Finally, the equations for the calculation of veterinary costs for lamb categories died or culled in different periods will be given. The way of calculation of the veterinary costs for these categories is equal to the manner of the calculation of other non-feed cost items. Therefore, explicit formulae will be given only for veterinary costs.

Veterinary costs per female (category $i = 3$) and male (category $i = 28$) lamb and castrate (category $i = 48$) that died in fattening are calculated as one half of the weighted averages of the veterinary costs for the appropriate categories $k$ in fattening ($k = 8, \ldots, 12$ for category 3, $k = 33, \ldots, 37$ for category 28 and $k = 43, \ldots, 47$ for category 48):

$$
costvetudL[i][j] = \frac{1}{2 \times l1skL[i][j]} \sum_k (costvetudL[k][j] \times ndiedfat[s][k - l][j])
$$

$$
(10.52)
$$

where

$$
\begin{array}{llll}
s = 1 & \text{and} & l = 7 & \text{for category } i = 3 \\
s = 2 & \text{and} & l = 32 & \text{for category } i = 28 \\
s = 0 & \text{and} & l = 42 & \text{for category } i = 48
\end{array}
\tag{10.53}
$$

The veterinary costs per female lamb died in the rearing period (category 4) is calculated as one half of the weighted average of the veterinary costs for categories 14, 18, 20 and 22:

$$
\begin{aligned}
costvetudL[4][j] \;=\; & \Big( costvetudL[14][j] \times (nrdied[1][1][j] + nspdied[1][1][j]) \\
& + costvetudL[18][[j] \times (nrdied[1][2][j] + nspdied[1][2][j]) \\
& + costvetudL[22][j] \times (nrdied[1][3][j] + nspdied[1][3][j]) \\
& + costvetudL[20][j] \times nrdiedmlFP[j] \Big) \Big/ (2 \times l1skL[4][j]).
\end{aligned}
\tag{10.54}
$$

The veterinary costs per male lamb died in the rearing period (category 29) are calculated as one half of the weighted average of the veterinary costs for categories 39 and 41:

$$
\begin{aligned}
costvetudL[29][j] \;=\; & \Big( costvetudL[39][j] \times (nrdied[2][1][j] + nspdied[2][1][j]) \\
& + costvetudL[41][j] \times (nrdied[2][2][j] + nspdied[2][2][j]) \Big) \\
& \Big/ (2 \times l1skL[29][j]) .
\end{aligned}
\tag{10.55}
$$

Similarly, the veterinary costs per male lamb of category 42 (culled during the rearing period) are also calculated as one half of the weighted average of the veterinary costs for categories 39 and 41:

$$
\begin{aligned}
costvetudL[42][j] \;=\; & \Big( costvetudL[39][j] \times (nrcull[2][1][j] + nspcull[2][1][j]) \\
& + costvetudL[41][j] \times (nrcull[2][2][j] + nspcull[2][2][j]) \Big) \\
& \Big/ (2 \times l1skL[42][j]).
\end{aligned}
\tag{10.56}
$$

The *discounted* veterinary costs ($costvetL[i][j]$) for pure-bred ($j = 1$) or cross-bred ($j = 2$) lambs of category $i$ ($i = 1, \ldots, PP$) are:

$$
costvetL[i][j] = qaveL[i][j] \times costvetudL[i][j] .
\tag{10.57}
$$

## 10.3.2  Labour costs

The labour costs for lambs till weaning and lambs sold immediately after weaning (categories 1, 2, 5, 7, 30 and 32) are included into the labour costs for ewes. Therefore the labour costs for these lamb categories are zero.

If there is artificial rearing of lambs (option $typew = 2$) the *undiscounted* labour costs for female and male lambs till the end of artificial rearing (categories $i = 6$ and $i = 31$) are

$$
costlabudL[i][j] = costAkh \times AkharL .
\tag{10.58}
$$

For female and male breeding lambs (categories $i = 13, \ldots, 26$ and $i = 38, \ldots, 41$) the undiscounted labour costs are

$$
costlabudL[i][j] = costAkh \times AkhrL \times dcL[i][j]/365) .
\tag{10.59}
$$

For lambs in fattening (categories $i = 8, \ldots, 12$, $i = 33, \ldots, 37$ and $i = 43, \ldots 47$ for female and male calves and castrates, respectively) the undiscounted labour costs are calculated as

$$costlabudL[i][j] = costAkh \times AkhfL \times dcL[i][j]/365) . \tag{10.60}$$

The undiscounted labour costs for the categories 3, 28, 48, 4, 29 and 42 are calculated in the same way as undiscounted veterinary costs. Replace *costvetudL*[i][j] by *costlabudL*[i][j] using the corresponding indices in equations (10.52) to (10.56).

The *discounted* labour costs (*costlabL*[i][j]) for pure-bred ($j = 1$) or cross-bred ($j = 2$) lambs of category $i$ ($i = 1, \ldots, PP$) are:

$$costlabL[i][j] = qaveL[i][j] \times costlabudL[i][j] . \tag{10.61}$$

### 10.3.3 Shearing costs

There are no shearing costs for stillborn lambs, lambs died until weaning or until the end of artificial rearing and lambs sold immediately after weaning or artificial rearing (categories $i = 1$, 2, 7 and 32). Again the *undiscounted* shearing costs (*costsheudL*[i][j]) will be calculated first. They are for lambs until weaning (categories $i = 5$ and 30):

$$costsheudL[i][j] = nshewL \times costshe0L \tag{10.62}$$

and shearing costs for lambs until the end of artificial rearing (categories $i = 6$ and 31) are calculated as follows:

$$costsheudL[i][j] = nshearL \times costshe0L . \tag{10.63}$$

For these four categories, costs are assumed to be independent of the breeding type of the progeny (index $j$).

In fattening of pure-bred ($j = 1$) or cross-bred ($j = 2$) progeny of sex $s$ ($s = 1$ : female, $s = 2$ : male, $s = 0$ : castrates) of category $i$ fattened to target $k$ ($k = 1, \ldots, lf[s]$), the shearing costs are

$$costsheudL[i][j] = nshefL[s][k] \times costshe0L \tag{10.64}$$

where $s$ and $k$ are given by equation (10.50).

For breeding female and male lambs of categories 14, 18, 22, 39 and 41 the shearing costs are calculated as

$$costsheudL[i][j] = nsherL[k] \times costshe0L \tag{10.65}$$

where

$$k = \begin{cases} 1 & \text{for categories i} = 14 \text{ and } 39 \\ 2 & \text{for categories i} = 18 \text{ and } 41 \\ 3 & \text{for category i} = 22 \end{cases} . \tag{10.66}$$

For pregnant female lambs used for replacement (categories 16, 20 and 24), the shearing costs are

$$costsheudL[i][j] = nsheFP \times costshe0L . \tag{10.67}$$

The shearing costs for categories 13 of female and 38 and 40 of male breeding lambs are calculated as follows:

$$
\begin{aligned}
costsheudL[13][j] &= \frac{dcL[13][j]}{ager[1][1] - a} \times nsherL[1] \times costshe0L \\
costsheudL[38][j] &= \frac{dcL[38][j]}{ager[2][1] - a} \times nsherL[1] \times costshe0L \qquad (10.68) \\
costsheudL[40][j] &= \frac{dcL[40][j]}{ager[2][2] - ager[2][1]} \times nsherL[2] \times costshe0L
\end{aligned}
$$

where $a$ is given by equation (8.11). For categories $i = 15$, 17 and 26 these costs are

$$costsheudL[i][j] = \frac{dcL[i][j]}{ager[1][2] - ager[1][1]} \times nsherL[2] \times costshe0L \qquad (10.69)$$

and for categories 19 and 21 the equation for shearing costs looks like

$$costsheudL[i][j] = \frac{dcL[i][j]}{ager[1][3] - ager[1][2]} \times nsherL[3] \times costshe0L \ . \qquad (10.70)$$

The shearing costs for categories 23 and 25 are calculated as follows:

$$costsheudL[i][j] = \frac{dcL[i][j]}{3 \times lengthrc - ager[1][3]} \times nsheFP \times costshe0L \ . \qquad (10.71)$$

The undiscounted shearing costs for the categories 3, 28, 48, 4, 29 and 42 are calculated in the same way as veterinary costs. Replace $costvetudL[i][j]$ by $costsheudL[i][j]$ using the corresponding indices in equations (10.52) to (10.56).

The *discounted* shearing costs ($costsheL[i][j]$) for pure-bred ($j = 1$) or cross-bred ($j = 2$) lambs of category $i$ ($i = 1, \ldots, PP$) are:

$$costsheL[i][j] = qaveL[i][j] \times costsheudL[i][j] \ . \qquad (10.72)$$

### 10.3.4 Fixed costs

Fixed costs for a lamb till weaning and for lambs sold immediately after weaning (categories $i = 1$, 2, 5, 7, 30 and 32) are included in the fixed costs for ewes and are set to zero therefore.

The same procedure as above is used, i.e. the *undiscounted* fixed costs ($costfixudL[i][j]$) will be calculated first. If there is artificial rearing of lambs, these costs per female (category $i = 6$) and male (category $i = 31$) lamb in artificial rearing are

$$costfixudL[i][j] = costfixarL \times dcL[i][j] \ . \qquad (10.73)$$

For breeding female and male lambs of categories $i = 14$, 18, 22, 26, 39 and 41, the fixed costs are calculated as

$$costfixudL[i][j] = costfixrL \times dcL[i][j] \ . \qquad (10.74)$$

For the categories of fattened lambs ($i = 8, \ldots, 12$ for females, $i = 33, \ldots, 37$ for males and $i = 43, \ldots, 47$ for castrates), the equation for fixed costs is

$$costfixudL[i][j] = costfixfL \times dcL[i][j] \ . \qquad (10.75)$$

For the categories of female and male breeding lambs ($i = 13$, 38 or 40) the fixed costs are

$$\begin{aligned}
costfixudL[13][j] &= costfixrL \times (ager[1][1] - a) \\
costfixudL[38][j] &= costfixrL \times (ager[2][1] - a) \qquad (10.76) \\
costfixudL[40][j] &= costfixrL \times (ager[2][2] - ager[2][1])
\end{aligned}$$

where $a$ is given by equation (8.11).

For pregnant female lambs used for replacement (categories 16, 20 and 24), the fixed costs are

$$\begin{aligned}
costfixudL[16][j] &= costfixrL \times (lengthrc - ager[1][1]) \\
costfixudL[20][j] &= costfixrL \times (2 \times lengthrc - ager[1][2]) \qquad (10.77) \\
costfixudL[24][j] &= costfixrL \times (3 \times lengthrc - ager[1][3]) \ .
\end{aligned}$$

The fixed costs for categories $i = 15$ and 17 are

$$costfixudL[i][j] = costfixrL \times (ager[1][2] - ager[1][1]) \ . \tag{10.78}$$

For categories $i = 19$ and 21, the fixed costs are calculated as

$$costfixudL[i][j] = costfixrL \times (ager[1][3] - ager[1][2]) \tag{10.79}$$

and for categories $i = 23$ and 25 the equation for fixed costs is

$$costfixudL[i][j] = costfixrL \times (3 \times lengthrc - ager[1][3]) \ . \tag{10.80}$$

The undiscounted fixed costs for the categories 3, 28, 48, 4, 29 and 42 are calculated similarly as veterinary costs. Replace $costvetudL[i][j]$ by $costfixudL[i][j]$ and write $l1skL[i][j]$ instead of $2 \times l1skL[i][j]$ using the corresponding indices in equations (10.52) to (10.56).

The *discounted* fixed costs ($costfixL[i][j]$) for pure-bred ($j = 1$) or cross-bred ($j = 2$) lambs of category $i$ ($i = 1, \ldots, PP$) are:

$$costfixL[i][j] = qaveL[i][j] \times costfixudL[i][j] \ . \tag{10.81}$$

### 10.3.5   Cost for bedding material

Costs for bedding material for lambs till weaning and for lambs sold immediately after weaning (categories $i = 1, 2, 5, 7, 30$ and 32) are included in the costs for bedding material for ewes and are set to zero therefore.

As above the *undiscounted* costs for bedding material ($costbedudL[i][j]$) will be calculated first. If there is artificial rearing of lambs the bedding costs for female (category $i = 6$) and male (category $i = 31$) lambs in artificial rearing are

$$costbedudL[i][j] = prstraw \times strawarL \times dcL[i][j] \ . \tag{10.82}$$

For breeding female (categories $i = 13, \ldots, 26$) and male lambs (categories $i = 38, \ldots, 41$), the costs for bedding material are calculated only for the period when animals are housed:

$$costbedudL[i][j] = prstraw \times strawrL \times \sum_{l=k1}^{k2} \delta_l \tag{10.83}$$

where $k1$ and $k2$ are the start and end dates of the given category of breeding lambs (they can be taken from Tables 9.8 and 9.9). The quantity $\delta_l$ is 1 if the considered date $l$ is within a season where the lambs are housed ($techbL[l] = 1$), otherwise $\delta_l$ takes the value zero.

Similarly the bedding costs for lambs in fattening (categories $i = 8$ to 12, 33 to 37 and 43 to 47) is calculated only if fattened lambs are housed:

$$costbedudL[i][j] \quad = \quad prstraw \times strawfL \times \sum_{l=k1}^{k2} \delta_l \tag{10.84}$$

where

$$k1 = \begin{cases} agewL & \text{for typew=1} \\ agearL & \text{for typew=2} \end{cases} \tag{10.85}$$

and

$$k2 = datlamb + agetP[i][j] - 1 \ . \tag{10.86}$$

The quantity $\delta_l$ is 1 if date $l$ is within a season where the lambs are housed ($techfatL[l] = 1$), otherwise $\delta_l$ takes the value zero.

The undiscounted costs for bedding material for the categories 3, 28, 48, 4, 29 and 42 are calculated in the same way as veterinary costs. Replace $costvetudL[i][j]$ by $costbedudL[i][j]$ using the corresponding indices in equations (10.52) to (10.56).

The *discounted* costs for bedding material ($costbedL[i][j]$) for pure-bred ($j = 1$) or cross-bred ($j = 2$) lambs of category $i$ ($i = 1, \ldots, PP$) are:

$$costbedL[i][j] = qaveL[i][j] \times costbedudL[i][j] \ . \tag{10.87}$$

## 10.3.6 Breeding costs

The breeding costs ($costbreedL[i][j]$) are calculated only for female breeding lambs intended for mating (categories 14, 18, 22). They are zero for all other categories. The *discounted* breeding costs for category 14 are

$$
\begin{aligned}
costbreedL[i][j] &= pmat[1][1][j] \times \Big( pinsFP[j] \times (costins[j] + nreins \\
&\quad \times costreins[j]) + costoeinFP \Big) \times qbreedL[i]
\end{aligned}
\tag{10.88}
$$

and for categories 18 and 22 the discounted breeding costs are calculated as

$$
\begin{aligned}
costbreedL[i][j] &= \big( pinsFP[j] \times (costins[j] + nreins \times costreins[j]) \\
&\quad + costoeinFP \big) \times qbreedL[i] \ .
\end{aligned}
\tag{10.89}
$$

## 10.3.7 Cost to tan skin

Costs to tan skin ($costskL[i][j]$) are calculated only for lambs culled or slaughtered. These costs are zero for the other categories. *Discounted* costs to tan skin for lambs slaughtered after weaning or after artificial rearing (categories 7 and 31) are:

$$costskL[i][j] = \begin{cases} qendL[i][j] \times costtan \times pskwL \times ptskwL & \text{for } typew = 1 \\ qendL[i][j] \times costtan \times pskarL \times ptskarL & \text{for } typew = 2 \end{cases} \ . \tag{10.90}$$

For slaughtered breeding lambs (categories $i = 17, 21, 25$ and $42$), these costs are

$$costskL[i][j] = qendL[i][j] \times costtan \times pskrL \times ptskrL \ . \tag{10.91}$$

For lambs slaughtered after fattening (categories $i = 8$ to $12$, $33$ to $37$ and $43$ to $47$), costs to tan skin are

$$costskL[i][j] = qendL[i][j] \times costtan \times pskfL \times ptskfL \ . \tag{10.92}$$

## 10.3.8 Marketing costs

Marketing costs for a lamb of category $i$ and of breeding type $j$ ($costmarkL[i][j]$) are calculated for lambs sold for slaughter or sold as breeding animals. For female ($i = 7$) and male ($i = 32$) lambs sold at weaning or at the end of artificial rearing, the *discounted* marketing costs are:

$$costmarkL[i][j] = qendL[i][j] \times costmarkwL \times a \tag{10.93}$$

where

$$a = \begin{cases} avww[s][j] & \text{for } typew = 1 \\ avwar[s][j] & \text{for } typew = 2 \end{cases} \tag{10.94}$$

and

$$s = \begin{cases} 1 & \text{for category } i = 7 \\ 2 & \text{for category } i = 32 \end{cases} \ . \tag{10.95}$$

For lambs slaughtered after fattening, the marketing costs are:

$$costmarkL[i][j] = qendL[i][j] \times costmarkfL \times wP[i][j] \ . \tag{10.96}$$

For categories of female and male lambs sold for breeding purposes (categories $i = 13, 15, 19, 23, 26, 38$ and $40$), the marketing costs are

$$costmarkL[i][j] = qendL[i][j] \times costmarkrL[s] \tag{10.97}$$

where

$$s = \left\{ \begin{array}{ll} 1 & \text{for categories 13, 15, 19, 23 and 26} \\ 2 & \text{for categories 38 and 40} \end{array} \right. \ . \tag{10.98}$$

For categories of male and female lambs culled in rearing for different reasons (categories $i = 17, 21, 25$ and $42$), the marketing costs are

$$costmarkL[i][j] = qendL[i][j] \times costmarkcul \ . \tag{10.99}$$

The marketing costs are zero for the remaining categories not given here.

### 10.3.9  Cost for removing and rendering dead animals

The cost for removing and rendering a dead animal ($costdiedL[i][j]$) are calculated only for categories of lambs that died (categories $i = 2, 3, 4, 28, 29$ and $48$). These costs discounted to the birth date of the animals are:

$$costdiedL[i][j] = qendL[i][j] \times costdead \times wP[i][j] \ . \tag{10.100}$$

For the remaining categories these costs are assumed to be zero.

### 10.3.10  Total non-feed costs for lambs

The total non-feed costs ($costnfL[i][j]$) per lamb of category $i$ ($i = 1, \ldots, PP$) and breeding type $j$ ($j = 1, 2$) discounted to the animal's birth date are the sum of the above calculated discounted cost components:

$$\begin{aligned} costnfL[i][j] \ = \ & costvetL[i][j] + costlabL[i][j] + costsheL[i][j] \\ & + costfixL[i][j] + costbedL[i][j] + costbreedL[i][j] \\ & + costskL[i][j] + costmarkL[i][j] + costdiedL[i][j] \ . \end{aligned} \tag{10.101}$$

Some of the cost components may be zero for several categories or/and for a breeding type.

## 10.4  Total costs

The total costs ($costE[i]$) per ewe of category $i$ ($i = 1, \ldots, TE$) discounted to the ewe's birth date are calculated as the sum of the feed costs, water costs and non-feed costs:

$$costE[i] = costfE[i] + costwatE[i] + costnfE[i] \ . \tag{10.102}$$

The total costs ($costR[i][j]$) per ram of category $i$ ($i = 1, \ldots, TR$) and of the breed of the flock ($j = 1$) or of the breed used for crossing in the flock ($j = 2$) discounted to the ram's birth date are:

$$costR[i][j] = costfR[i][j] + costwatR[i][j] + costnfR[i][j] \ . \tag{10.103}$$

Similarly, the total costs ($costL[i][j]$) for a pure-bred ($j = 1$) or cross-bred ($j = 2$) lamb of category $i$ ($i = 1, \ldots, PP$) discounted to the lamb's birth date are given by the equation:

$$costL[i][j] = costfL[i][j] + costwatL[i][j] + costnfL[i][j] \ . \tag{10.104}$$

# Chapter 11

# Revenues

## 11.1  Calculation of the milk price

The milk price is calculated only in production systems with dairy sheep (option $typeb = 1$ in file PARAS.TXT). The milk price depends on the pricing system used. There is a great variety in pricing systems for milk. Usually, the milk price depends on milk quality and on milk composition. The program allows accounting the average milk price for somatic cell count, milk fat and milk protein content. Five different options are taken into account (see first input parameter in input file INPUTS11.TXT, Section 14.2.11, for details). Choose among these options that one which is adequate for your system. If you will not find an appropriate option describing the situation in your production system, contact the authors of the program. In the following subsections, the calculation of milk price for each of the five options is described in some detail.

### 11.1.1  Option 1 for *milkprice*

**The milk price does neither depend on the somatic cell count nor on the protein and/or the fat content.**

The milk price is an input parameter. Prepare input file INPUTS11.TXT as shown in the Example for part A of INPUTS11.TXT on page 158. The number of milk quality classes according to somatic cell count ($nSCC$) is automatically set to 1 in the program.

### 11.1.2  Option 2 for *milkprice*

**The milk price ($prmilk$) depends (only) on somatic cell count.**

Several milk quality classes for somatic cell count are assumed. Insert a number >1 for the number of these classes ($nSCC$) in file INPUTS11.TXT. In the same input file, insert $nSCC$ numbers in the vector of base prices per kg milk in quality class $i$ ($prSCC[i-1]$) and $nSCC-1$ numbers in the vector of upper limits for the somatic cell count in the individual milk quality classes. Further input parameters are the mean somatic cell score and the phenotypic standard deviation of the somatic cell score. Assuming a normal distribution for the somatic cell score, the proportion of sold milk in each quality class $i$ ($pSCC[i-1]$) is calculated. Then, the milk price is calculated as follows:

$$prmilk = \sum_{i=0}^{nSCC-1} pSCC[i] \times prSCC[i] \, . \qquad (11.1)$$

### 11.1.3 Option 3 for *milkprice*

**The milk price depends (only) on the fat and/or the protein content.**

Assume that there are $nfat$ and/or $nprot$ threshold values for fat and/or protein content (a special case is a zero number of threshold values). That means there will be $nfat+1$ ($nprot+1$) classes (intervals) for fat (protein) content. Within each class (interval), a linear regression on fat (protein) content is assumed which is described by three parameters: a constant ($b_0$), the regression coefficient ($b_1$) and a reference value ($x_r$) for fat or protein content for which the basic milk price is payed:

$$y = b_0 + b_1(x - x_r) \qquad (11.2)$$

where $y$ is the value to be added to the basic milk price ($prmilkb$), an input parameter in part A of file INPUTS11.TXT, for the given value of $x$, $x$ being milk fat or milk protein content. For some more details and for the way how to describe a concrete situation in the input file INPUTS11.TXT see Section 14.2.11.

The milk price is calculated as

$$prmilk = prmilkb + \sum_{i=1}^{nfat+1} F_i + \sum_{i=1}^{nprot+1} P_i \qquad (11.3)$$

where $F_i$ is the value from the $i$th class of fat content which is added to the basic milk price and $P_i$ is the appropriate value from the $i$th class of protein content. For calculating these values, it is assumed that the milk fat and milk protein content are normally distributed with a given mean and standard deviation (input parameters). From this normal distribution, the proportion of the individual classes can be calculated. For the special case that $b_0 \neq 0$ and $b_1 = 0$, $F_i$ or $P_i$ are simply calculated by multiplying the proportion of fat (protein) content values in class $i$ by the constant $b_0$. If the regression coefficient $b_1$ is different from zero, the given interval is subdivided into 500 intervals of equal width. For each interval, the proportion of fat (protein) content values being within is calculated and multiplied by the mean $x$-value of the interval and the regression coefficient $b_1$. $F_i$ or $P_i$ are then calculated as the sum of these 500 values.

### 11.1.4 Option 4 for *milkprice*

**The milk price ($prmilk$) depends both on somatic cell count (SCC) and fat and/or protein content. The base prices for quality classes according to SCC are set first and then these prices are corrected for fat and/or protein content.**

First, a preliminary milk price is calculated according to equation (11.1). The further correction on the fat and/or protein content of the milk is carried out using equation (11.3) where the preliminary milk price calculated before is inserted for the variable $prmilkb$.

### 11.1.5 Option 5 for *milkprice*

**The milk price ($prmilk$) depends both on somatic cell count (SCC) and fat and/or protein content. The base price for milk (milk carrier or milk with given fat and/or protein content) is determined first. Then this price is corrected for the real fat and/or protein content. At the last step, a further correction of the price for milk quality classes based on SCC is carried out.**

First, a basic milk price ($prmilkb$, input parameter in part A of INPUTS11.TXT) must be given. Then equation (11.3) is used to adjust the price for the fat and/or

protein content of the milk. Let us write $prmilkfp$ for the resulting (preliminary) milk price. For each quality class $i$ of milk according to somatic cell count, a multiplicative ($facSCC[i]$) and an additive ($prSCC[i]$) price adjustment factor are read from INPUTS11.TXT. Then the final milk price is:

$$prmilk = \sum_{i=0}^{nSCC-1} pSCC[i] \left( prmilkfp \times facSCC[i] + prSCC[i] \right) \qquad (11.4)$$

where $pSCC[i]$ has the same meaning as in (11.1). Several of the multiplicative ($facSCC[i]$) and additive ($prSCC[i]$) price adjustment factors may take a value of zero. No change of the milk price means that the multiplicative adjustment factor is 1 and the additive factor zero. If you want add or subtract a constant to or from the milk price in the given milk quality class, the multiplicative adjustment factor is 1 and the additive factor is a positive or a negative constant, respectively. If you want the final milk price to be 30% of the preliminary price, set the multiplicative constant to 0.3 and the additive constant to 0. If you desire to set the milk price to a constant independent off the preliminary price, set the multiplicative factor to zero and the additive factor to the constant. See also examples for input file INPUTS11.TXT in Section 14.2.11 on page 156.

## 11.2 Revenues from ewes

The total revenues from an ewe of category $i$ ($i = 1, \ldots, TE$) per reproductive cycle consist of revenues from wool, culled animals, raw skin, tanned skin and manure. In milk sheep, also revenues from sold milk, cheese and cheese whey are included. All revenues are discounted to the birth date of the animal.

Revenues from wool from an ewe of category $i$ ($i = 1, \ldots, TE$) per reproductive cycle ($revwE[i]$) are calculated as

$$revwE[i] = qaveE[i] \times nsheE \times wsheE \times prwoolE \times dcE[i]/lengthrc . \qquad (11.5)$$

Different pricing systems for slaughter animals may be used. The variable $priceS$ is used to indicate the variant of the pricing system for adult sheep (ewes and rams) and negatively selected breeding lambs. The variants are (see also description of file INPUTS12.TXT on page 162):

1          According to live weight without taking into account conformation

2          According to live weight taking into account conformation

3          According to carcass weight not accounting for carcass quality

4          According to EU evaluation system (quality classes for fleshiness and quality classes for fat covering)

If necessary, further variants may be included in the program later on.

Revenues from culled ewes ($revcE[i]$) are available only for categories $i$ with $i = (j - 1) \times nstgE + k$ where $j = 1, \ldots, LL$ and $k = 2, 3$. If the culled animals are paid per live weight, the revenues are calculated as:

$$revcE[i] = qendE[i] \times (wlE[j] + \delta \times adgE \times dcE[i]) \times prlwS[1] \qquad (11.6)$$

where $\delta = 1$ for $j = 1$ and $\delta = 0$ for $j \geq 2$. The price $prlwS[1]$ is an input parameter for pricing system 1 ($priceS = 1$) and is calculated as average price over the quality

classes of adult sheep ($l = 1$ : pure-bred animals, $l = 2$ : cross-bred animals or rams of the breed used for crossing in the flock)

$$prlwS[l] = \sum_{i=1}^{nclS} pclS[l][i] \times prclS[i] \tag{11.7}$$

for pricing system 2 ($priceS = 2$). In pricing systems 3 and 4, animals are paid per carcass weight and the revenues are calculated as

$$revcE[i] = qendE[i] \times (wlE[j] + \delta \times adgE \times dcE[i]) \times prcwS[1] \times dresE/100 \tag{11.8}$$

where again $\delta = 1$ for $j = 1$ and $\delta = 0$ for $j \geq 2$. The price $prcwS[1]$ is an input parameter for pricing system 3 ($priceS = 3$) and is calculated as average price over the classes for fleshiness and fat covering of adult sheep ($l = 1$ : pure-bred animals, $l = 2$ : cross-bred animals or rams of the breed used for crossing in the flock)

$$prcwS[l] = prrefS \sum_{i=1}^{nclflS} \sum_{j=1}^{nclfcS} pclfcS[l][i][j] \times prclfcS[i][j] \tag{11.9}$$

for pricing system 4 ($priceS = 4$).

Revenues from raw skin ($revskrE[i]$) and from tanned skin ($revsktE[i]$) are calculated for the same categories as revenues from culled ewes, i.e. for categories $i$ with $i = (j - 1) \text{ x } nstgE + k$ where $j = 1, \ldots, LL$ and $k = 2, 3$. They are:

$$
\begin{aligned}
revskrE[i] &= qendE[i] \times prskrE \times pskE \times (1 - ptskE) \\
revsktE[i] &= qendE[i] \times prsktE \times pskE \times ptskE
\end{aligned}
\tag{11.10}
$$

Revenues from manure per ewe of category $i$ ($i = 1, \ldots, TE$) including lambs till weaning ($revmanE[i]$) are calculated as

$$revmanE[i] = qaveE[i] \times prman \times manE \times \sum_{l=k1}^{k2} \delta_l \tag{11.11}$$

where $k1 = datlamb$ is equal for all categories, but $k2$ depends on the ewe's category through $dcE[i]$:

$$k2 = datlamb + dcE[i] - 1 \tag{11.12}$$

The quantity $\delta_l$ is 1 if day $l$ is within a season where the ewes are housed ($techE[l] = 1$), otherwise $\delta_l$ takes the value zero.

Revenues from milk ($revmilkE[i]$) and cheese including cheese whey ($revcheeseE[i]$) are only calculated for dairy sheep (parameter $typeb = 1$ in file PARAS.TXT). These revenues from a ewe of category $i$ with $i = (j-1) \times nstgE + k$ where $k = 1, \ldots, nstgE$ for $j = 1, \ldots LL - 1$ and $k = 1, \ldots, 3$ for $j = LL$ are given by the following equations

$$
\begin{aligned}
revmilkE[i] &= b \times prmilk \times (milkmpar[j] + a) \times plambE[i] \\
&\times (1 - pmilkch) \times qmilkE[i]
\end{aligned}
\tag{11.13}
$$

$$
\begin{aligned}
revcheeseE[i] &= b \times (prcheese + prwhey \times cheesewhey) \times (milkmpar[j] + a) \\
&\times plambE[i] \times \frac{pmilkch}{milkch} \times qmilkE[i]
\end{aligned}
$$

where

$$
b = \begin{cases} kmilkcE & \text{if } k = 1, 2 \\ 1 & \text{if } k = 3, \ldots, nstgE \end{cases}
\tag{11.14}
$$

and

$$
a = \begin{cases} 0 & \text{if } pmilkwm = 0 \\ milksw[j] & \text{if } pmilkwm > 0 \end{cases} .
\tag{11.15}
$$

The total discounted revenues ($revE[i]$) from an ewe of category $i$ ($i = 1, \ldots, TE$) per reproductive cycle are

$$
\begin{aligned}
revE[i] \quad = \quad & revwE[i] + revcE[i] + revskrE[i] + revsktE[i] + revmanE[i] \\
& + revmilkE[i] + revcheeseE[i]) \; .
\end{aligned}
\tag{11.16}
$$

## 11.3 Revenues from rams

The total revenues from rams are formed by revenues from wool, culled animals, raw and tanned skin, sold animals and manure. Some components of the total revenues may be zero for certain ram categories. All revenues are discounted to the birth date of the animal.

Revenues from wool ($revwR[i][j]$) per breeding cycle from a ram of category $i$ ($i = 1, \ldots, TR$) and of the breed of the flock ($j = 1$) or of the breed used for crossing in the flock ($j = 2$) are calculated as

$$
revwR[i][j] = qaveR[i][j] \times nsheR[j] \times wsheR[j] \times prwoolR[j] \times dcR[i]/lengthrc \; .
\tag{11.17}
$$

Different pricing systems for slaughter animals may be used. A survey of the pricing systems is given in Section 11.2. Revenues from culled rams ($revcR[i][j]$) are available only for categories $i$ with $i = (r-1) \times nstgR + 3$ where $r = 1, \ldots, RR$. If the culled animals are paid per live weight, the revenues are calculated as:

$$
revcR[i][j] = qendR[i][j] \times (wbR[r][j] + \delta \times adgR[j] \times dcR[i]) \times prlwS[j]
\tag{11.18}
$$

where $\delta = 1$ for $r = 1$ and $\delta = 0$ for $r \geq 2$. The price $prlwS[j]$ ($j = 1, 2$) is an input parameter for pricing system 1 ($priceS = 1$) and is calculated as average price over the quality classes according to equation (11.7) for pricing system 2 ($priceS = 2$). In pricing systems 3 and 4, animals are paid per carcass weight and the revenues are calculated as

$$
revcR[i][j] = qendR[i][j] \times (wbR[r][j] + \delta \times adgR[j] \times dcR[i]) \times prcwS[j] \times dresR[j]/100
\tag{11.19}
$$

where again $\delta = 1$ for $r = 1$ and $\delta = 0$ for $r \geq 2$. The price $prcwS[j]$ ($j = 1, 2$) is an input parameter for pricing system 3 ($priceS = 3$) and is calculated as average price over the classes for fleshiness and fat covering according to equation (11.9) for pricing system 4 ($priceS = 4$).

Revenues from raw skin ($revskrR[i][j]$) and from tanned skin ($revsktR[i][j]$) are calculated for the same categories as revenues from culled rams, i.e. for categories $i$ with $i = (r-1) \times nstgR + 3$ where $r = 1, \ldots, RR$. They are:

$$
\begin{aligned}
revskrR[i][j] \quad = \quad & qendR[i][j] \times prskrR[j] \times pskR \times (1 - ptskR) \\
revsktR[i][j] \quad = \quad & qendR[i][j] \times prsktR[j] \times pskR \times ptskR \; .
\end{aligned}
\tag{11.20}
$$

Revenues from manure ($revmanR[i][j]$) for all categories of rams ($i = 1, \ldots, TR$) and breeds ($j = 1, 2$) are

$$
revmanR[i][j] = qaveR[i][j] \times prman \times manR \times dcR[i] \; .
\tag{11.21}
$$

Revenues from sold rams of breed $j$ ($revsoldR[i][j]$) are calculated only for categories $i$ with $i = (r-1) \times nstgR + 2$ and $r = 1, \ldots, RR$:

$$
revsoldR[i][j] = qendR[i][j] \times prsbR[j] \; .
\tag{11.22}
$$

The total revenues ($revR[i][j]$) from a ram of category $i$ ($i = 1, \ldots, TR$) and breed $j$ ($j = 1, 2$) per breeding cycle are

$$
\begin{aligned}
revR[i][j] \quad = \quad & revwR[i][j] + revcR[i][j] + revskrR[i][j] + revsktR[i][j] \\
& + revmanR[i][j] + revsoldR[i][j] \; .
\end{aligned}
\tag{11.23}
$$

## 11.4 Revenues from lambs

**Comment.** From technical reasons, equations for undiscounted revenues are given first for several categories of revenues. The variable name for all kinds of undiscounted revenues from lambs is of the form $rev\ldots udL$ where the dots are replaced by a string which specifies the costs ($w$ for wool, $c$ for culled animals etc.). The variable name of the corresponding discounted revenues is then $rev\ldots L$. In the program, the variable names for discounted revenues are also used for undiscounted revenues. Therefore, the variables $rev\ldots udL$ are not given in Appendix B.

Revenues from lambs come from wool, slaughter animals, raw and tanned skin, sold breeding lambs and manure. Some components of the total revenues may be zero for certain lamb categories.

### 11.4.1 Revenues from wool

*Undiscounted* revenues from wool ($revwudL[i][j]$) from pure-bred ($j = 1$) or cross-bred ($j = 2$) lambs of sex $s$ ($s = 1$ : female, $s = 2$ : male) until weaning (categories $i = 5$ and $30$) are:

$$revwudL[i][j] = nshewL \times wshewL[s][j] \times prwoolL[j] \qquad (11.24)$$

where $s = 1$ for $i = 5$ and $s = 2$ for $i = 30$. The corresponding revenues from lambs during artificial rearing are calculated as follows:

$$revwudL[i][j] = nshearL \times wshearL[s][j] \times prwoolL[j] \qquad (11.25)$$

with $s = 1$ for $i = 6$ and $s = 2$ for $i = 31$.

In fattening of pure-bred ($j = 1$) or cross-bred ($j = 2$) progeny of sex $s$ ($s = 1$ : female, $s = 2$ : male, $s = 0$ : castrates) of category $i$ fattened to target $k$ ($k = 1, \ldots, lf[s]$), the revenues from wool are

$$revwudL[i][j] = nshefL[s][k] \times wshefL[s][j] \times prwoolL[j] \qquad (11.26)$$

where $s$ and $k$ are given by the following equation:

$$\begin{array}{llll} s = 1 & \text{and} & k = i - 7 & \text{for } i = 8, \ldots, 12 \\ s = 2 & \text{and} & k = i - 32 & \text{for } i = 33, \ldots, 37 \\ s = 0 & \text{and} & k = i - 42 & \text{for } i = 43, \ldots, 47 \end{array} \qquad (11.27)$$

For categories $i = 14$, $18$ and $22$ of female lambs ($s = 1$) and for categories $i = 39$ and $41$ of male lambs ($s = 2$) the revenues from wool are calculated as

$$revwudL[i][j] = nsherL[k] \times wsherL[s][j] \times prwoolL[j] \qquad (11.28)$$

where

$$k = \begin{cases} 1 & \text{for } i = 14, 39 \\ 2 & \text{for } i = 18, 41 \\ 3 & \text{for } i = 22 \end{cases} \qquad (11.29)$$

For categories $i = 16$, $20$ and $24$ of female lambs the revenues from wool are

$$revwudL[i][j] = nsheFP \times wsherL[1][j] \times prwoolL[j] \ . \qquad (11.30)$$

For categories $i = 13$, $15$, $17$, $19$, $21$, $23$ and $25$ of female lambs ($s = 1$) and for category $i = 40$ of male lambs ($s = 2$), the revenues from wool are calculated as

$$revwudL[i][j] = \frac{dcL[i][j]}{A} \times (nsherL[k] \times wsherL[s][j] \times prwoolL[j]) \qquad (11.31)$$

where

$$A = \begin{cases} ager[1][1] - agewL & \text{for} \quad i = 13 \quad \text{and} \quad typew = 1 \\ ager[1][1] - agearL & \text{for} \quad i = 13 \quad \text{and} \quad typew = 2 \\ ager[1][2] - ager[1][1] & \text{for} \quad i = 15, 17, 26 \\ ager[1][3] - ager[1][2] & \text{for} \quad i = 19, 21, 23, 25 \\ ager[2][2] - ager[2][1] & \text{for} \quad i = 40 \end{cases} \tag{11.32}$$

and

$$k = \begin{cases} 1 & \text{for } i = 13 \\ 2 & \text{for } i = 15, 17, 26, 40 \\ 3 & \text{for } i = 19, 21, 23, 25 \end{cases} \tag{11.33}$$

Revenues from wool per female (category $i = 3$) or male (category $i = 28$) lamb or castrate (category $i = 48$) that died in fattening are calculated as one half of the weighted averages of the revenues from wool for the appropriate categories $k$ in fattening ($k = 8, \ldots, 12$ for category 3, $k = 33, \ldots, 37$ for category 28 and $k = 43, \ldots, 47$ for category 48:

$$revwudL[i][j] = \frac{1}{2 \times l1skL[i][j]} \sum_k (revwudL[k][j] \times ndiedfat[s][k-l][j]) \tag{11.34}$$

where

$$\begin{array}{llll} s = 1 & \text{and} & l = 7 & \text{for category } i = 3 \\ s = 2 & \text{and} & l = 32 & \text{for category } i = 28 \\ s = 0 & \text{and} & l = 42 & \text{for category } i = 48 \end{array} \tag{11.35}$$

Revenues from wool per female lamb died in the rearing period (category 4) are calculated as one half of the weighted average of the revenues from wool for categories 14, 18, 20 and 22:

$$\begin{aligned} revwudL[4][j] &= \Big( revwudL[14][j] \times (nrdied[1][1][j] + nspdied[1][1][j]) \\ &\quad + revwudL[18][[j] \times (nrdied[1][2][j] + nspdied[1][2][j]) \\ &\quad + revwudL[22][j] \times (nrdied[1][3][j] + nspdied[1][3][j]) \\ &\quad + revwudL[20][j] \times nrdiedmlFP[j] \Big) \Big/ (2 \times l1skL[4][j]). \end{aligned} \tag{11.36}$$

Revenues from wool per male lamb died in the rearing period (category 29) are calculated as one half of the weighted average of the revenues from wool for categories 39 and 41:

$$\begin{aligned} revwudL[29][j] &= \Big( revwudL[39][j] \times (nrdied[2][1][j] + nspdied[2][1][j]) \\ &\quad + revwudL[41][j] \times (nrdied[2][2][j] + nspdied[2][2][j]) \Big) \\ &\quad \Big/ (2 \times l1skL[29][j]) . \end{aligned} \tag{11.37}$$

Similarly, the revenues from wool per male lamb of category 42 (culled during the rearing period) are also calculated as one half of the weighted average of the revenues from wool for categories 39 and 41:

$$\begin{aligned} revwudL[42][j] &= \Big( revwudL[39][j] \times (nrcull[2][1][j] + nspcull[2][1][j]) \\ &\quad + revwudL[41][j] \times (nrcull[2][2][j] + nspcull[2][2][j]) \Big) \\ &\quad \Big/ (2 \times l1skL[42][j]). \end{aligned} \tag{11.38}$$

The *discounted* revenues from wool ($revwL[i][j]$) for pure-bred ($j = 1$) or cross-bred ($j = 2$) lambs of category $i$ ($i = 1, \ldots, PP$) are:

$$revwL[i][j] = qaveL[i][j] \times revwudL[i][j] \; . \tag{11.39}$$

## 11.4.2 Revenues from slaughter animals

Revenues from slaughter animals ($revcL[i][j]$) are calculated only for categories $i = 7$ to 12, 17, 21, 25, 32 to 37 and 42 to 47. Different pricing systems for slaughter animals may be used. First the *undiscounted* revenues ($revcudL[i][j]$) are calculated.

### 11.4.2.1 Undiscounted revenues from culled breeding lambs

For female lambs culled after the first (category $i = 17$), the second ($i = 21$) or the third ($i = 25$) breeding season and for males culled in the rearing period ($i = 42$), the same pricing systems as given for ewes (see Section 11.2 on page 111) may be used.

If the culled animals are paid per live weight, the revenues from pure-bred ($j = 1$) or cross-bred ($j = 2$) animals of these categories are calculated as:

$$revcudL[i][j] = wP[i][j] \times prlwS[j] \; . \tag{11.40}$$

The price $prlwS[j]$ is an input parameter for pricing system 1 ($priceS = 1$) and is calculated as average price over the quality classes according to equation (11.7) for pricing system 2 ($priceS = 2$).

In pricing systems 3 and 4, animals are paid per carcass weight and the revenues are calculated as

$$revcudL[i][j] = wP[i][j] \times prcwS[j] \times dresrL[j]/100 \; . \tag{11.41}$$

The price $prcwS[j]$ is an input parameter for pricing system 3 ($priceS = 3$) and is calculated as average price over the classes for fleshiness and fat covering according to equation (11.9) for pricing system 4 ($priceS = 4$).

### 11.4.2.2 Undiscounted revenues from lambs slaughtered after weaning or after artificial rearing

Four different pricing systems for lambs slaughtered after weaning (categories 7 and 32) may be used. The variable $pricewL$ is used to indicate the variant of the pricing system. The variants are:

1         According to live weight without taking into account conformation

2         According to live weight taking into account conformation

3         According to carcass weight not accounting for carcass quality

4         According to EU evaluation system with classes for carcass weight (A: $\leq 7$ kg, B: $> 7$ kg and $\leq 10$ kg, C: $> 10$ kg and $\leq 13$ kg) and meat quality classes 1 (best class) and 2 within each weight class. Lambs with a carcass weight $> 13$ kg are evaluated in the same way as adult sheep or fattened lambs according to EU evaluation system (quality classes for fleshiness and fat covering). In the following text, lambs weighing $\leq 13$ kg are called *light lambs* and lambs weighing $> 13$ kg are called *heavy lambs*.

If the culled animals are paid per live weight, the revenues per pure-bred ($j = 1$) or cross-bred ($j = 2$) lamb of categories $i = 7$ or $32$ are calculated as:

$$revcudL[i][j] = wP[i][j] \times prlwwL[j] . \qquad (11.42)$$

The price $prlwwL[j]$ is an input parameter for pricing system 1 ($pricewL = 1$) and is calculated as average price over the quality classes

$$prlwwL[j] = \sum_{i=1}^{nclwL} pclwL[j][i] \times prclwL[i] \qquad (11.43)$$

for pricing system 2 ($pricewL = 2$).

In pricing systems 3 and 4, animals are paid per carcass weight. The revenues from slaughter animals of categories $i = 7$ or $32$ are calculated for pricing system 3 as

$$revcudL[i][j] = wP[i][j] \times prcwwL[j] \times dreswL[j]/100 \qquad (11.44)$$

where the price $prcwwL[j]$ is an input parameter.

For calculating the revenues for pricing system 4, first the mean carcass weight ($mcwwL[i][j]$) and the standard deviation for the distribution of the carcass weight ($sigmacwwL[i][j]$) for pure-bred ($j = 1$) or cross-bred ($j = 2$) female ($i = 1$) and male ($i = 2$) lambs must be calculated:

$$
\begin{aligned}
mcwwL[i][j] &= wP[k][j] \times dreswL[j]/100 \\
sigmacwwL[i][j] &= vcwwL \times mcwwL[i][j]/100
\end{aligned}
\qquad (11.45)
$$

where

$$k = \begin{cases} 7 & \text{for } i = 1 \\ 32 & \text{for } i = 2 \end{cases} . \qquad (11.46)$$

Assuming for each sex and type of breeding (pure-breeding and cross-breeding) a normal distribution of the carcass weight with the mean $mcwwL[i][j]$ and standard deviation $sigmacwwL[i][j]$, the relative frequencies ($pclcwwL[i][r][j]$) in carcass weight classes A to C ($r = 1, \ldots, 3$) and for the class of heavy lambs (carcass weight $> 13$ kg, $r = 4$) are calculated. It is

$$\sum_{r=1}^{4} pclcwwL[i][r][j] = 1 \quad \text{for all } i \text{ and } j . \qquad (11.47)$$

In the next step, the relative frequencies ($pclcwL[i][r][s][j]$) for the combinations of weight classes A to C ($r = 1, \ldots, 3$) and quality classes 1 and 2 ($s = 1, 2$) are calculated:

$$pclcwL[i][r][s][j] = \frac{pclcqwL[r][s][j] \times pclcwwL[i][r][j]}{1 - pclcwwL[i][4][j]} . \qquad (11.48)$$

It holds that

$$\sum_{r=1}^{3} \sum_{s=1}^{2} pclcwL[i][r][s][j] = 1 \quad \text{for all } i \text{ and } j . \qquad (11.49)$$

The average price ($prcwawL[i][j]$) per kg carcass weight specific for sex $i$ and breeding type $j$ is then

$$prcwawL[i][j] = \sum_{r=1}^{3} \sum_{s=1}^{3} pclcwL[i][r][s][j] \times prclcwwL[r][s] . \qquad (11.50)$$

Furthermore, the average price ($prcwbwL[j]$) for pure-bred ($j = 1$) and cross-bred ($j = 2$) heavy lambs must be calculated:

$$prcwbwL[j] = prrefwL \sum_{r=1}^{nclflwL} \sum_{s=1}^{ncfcwL} pclfcwL[j][r][s] \times prclfcwL[r][s] \ . \quad (11.51)$$

The average price per kg carcass weight ($prcwcwL[i][j]$) for categories 7 (sex $i = 1$) and 32 (sex $i = 2$) is then:

$$prcwcwL[i][j] = (1-pclcwwL[i][4][j]) \times prcwawL[i][j] + pclcwwL[i][4][j] \times prcwbwL[j] \ . \quad (11.52)$$

Finally, the revenues per lamb of categories 7 and 32 are:

$$\begin{aligned} revcudL[7][j] &= wP[7][j] \times prcwcwL[1][j] \times dreswL[j]/100 \\ revcudL[32][j] &= wP[32][j] \times prcwcwL[2][j] \times dreswL[j]/100 \ . \end{aligned} \quad (11.53)$$

### 11.4.2.3 Undiscounted revenues from fattened lambs

In fattened lambs (categories 8 to 12, 33 to 37 and 43 to 47), the same pricing systems as in adult sheep may be used (see Section 11.2 on page 111). Instead of the variable $priceS$ the variable $pricefL$ will be used to indicate the variant of the pricing system. By using different variables distinct pricing systems for adult sheep and fattened lambs will be possible. The carcass weight of the fattened lambs is assumed to take values above 13 kg.

If the culled animals are paid per live weight, the revenues are calculated as:

$$revcudL[i][j] = wP[i][j] \times prlwfL[j] \ . \quad (11.54)$$

The price $prlwfL[j]$ ($j = 1, 2$) is an input parameter for pricing system 1 ($pricefL = 1$) and is calculated as average price over the quality classes

$$prlwfL[j] = \sum_{i=1}^{nclfL} pclfL[j][i] \times prclfL[i] \quad (11.55)$$

for pricing system 2 ($pricefL = 2$).

In pricing systems 3 and 4, animals are paid per carcass weight and the revenues are calculated as

$$revcudL[i][j] = wP[i][j] \times prcwfL[j] \times dresfL[k][l][j]/100 \quad (11.56)$$

where

$$\begin{aligned} k &= 1 \quad \text{and} \quad l = i - 7 \quad \text{for } i = 8, \dots, 12 \\ k &= 2 \quad \text{and} \quad l = i - 32 \quad \text{for } i = 33, \dots, 37 \\ k &= 0 \quad \text{and} \quad l = i - 42 \quad \text{for } i = 43, \dots, 47 \end{aligned} \quad (11.57)$$

The price $prcwfL[j]$ is equal to the input parameter $prcwfL0$ for all categories for pricing system 3 ($pricefL = 3$) and is calculated as average price over the classes for fleshiness and fat covering

$$prcwfL[j] = prreffL \sum_{s=1}^{nclflS} \sum_{t=1}^{nclfcS} pclfcfL[j][s][t] \times prclfcfL[s][t] \quad (11.58)$$

for pricing system 4 ($pricefL = 4$).

#### 11.4.2.4 Discounted revenues from slaughtered animals

The *discounted* revenues from a slaughtered animal ($revcL[i][j]$) for pure-bred ($j = 1$) or cross-bred ($j = 2$) lamb of category $i$ ($i = 1, \ldots, PP$) are:

$$revcL[i][j] = qendL[i][j] \times revcudL[i][j] \ . \tag{11.59}$$

### 11.4.3 Revenues from raw and tanned skin

*Discounted* revenues from raw and tanned skin ($revskrL$ and $revsktL$) are calculated for pure-bred ($j = 1$) and cross-bred ($j = 2$) lambs of categories $i = 7$ to $12$, $17$, $21$, $25$, $32$, $33$ to $37$ and $42$ to $47$. The revenues are given by the equations:

$$\begin{aligned}
revskrL[i][j] &= qendL[i][j] \times prskrL[j] \times a \times (1 - b) \\
revsktL[i][j] &= qendL[i][j] \times prsktL[j] \times a \times b
\end{aligned} \tag{11.60}$$

where

$$\begin{array}{llll}
a = pskfL & \text{and} & b = ptskfL & \text{for } i = 8 - 12, 33 - 37 \text{ and } 43 - 47 \\
a = pskrL & \text{and} & b = ptskrL & \text{for } i = 17, 21, 25 \text{ and } 42 \\
a = pskwL & \text{and} & b = ptskwL & \text{for } i = 7, 32 \text{ and } typew = 1 \\
a = pskarL & \text{and} & b = ptskarL & \text{for } i = 7, 32 \text{ and } typew = 2
\end{array} \ . \tag{11.61}$$

### 11.4.4 Revenues from manure

Revenues from manure occur in categories of progeny which are housed at least for a certain time period. First undiscounted revenues are calculated. These revenues from a lamb in fattening (categories $i = 8$ to $12$, $33$ to $37$ and $43$ to $47$) are calculated as:

$$revmanudL[i][j] = prman \times manfL \times \sum_{l=k1}^{k2} \delta_l \tag{11.62}$$

where

$$k1 = \begin{cases} agewL & \text{for typew=1} \\ agearL & \text{for typew=2} \end{cases} \tag{11.63}$$

and

$$k2 = datlamb + agetP[i][j] - 1 \ . \tag{11.64}$$

The quantity $\delta_l$ is 1 if date $l$ is within a season where the lambs are housed ($techfatL[l] = 1$), otherwise $\delta_l$ takes the value zero.

For breeding female (categories $i = 13, \ldots, 25$) and male lambs (categories $i = 38, \ldots, 42$), the revenues from manure are:

$$revmanudL[i][j] = prman \times manbL \times \sum_{l=k1}^{k2} \delta_l \tag{11.65}$$

where $k1$ and $k2$ are the start and end dates of the given category of breeding lambs (they can be taken from Tables 9.8 and 9.9). The quantity $\delta_l$ is again 1 if the considered date $l$ is within a season where the lambs are housed ($techbL[l] = 1$), otherwise $\delta_l$ takes the value zero.

If there is artificial rearing of lambs revenues from manure of a female (category $i = 6$) or male (category $i = 31$) lamb in artificial rearing are

$$revmanudL[i][j] = prman \times manarL \times dcL[i][j] \ . \tag{11.66}$$

Revenues from manure per animal of categories 3, 28 and 48 are calculated according to equation (11.34) where $revwudL[i][j]$ must be replaced by $revmanudL[i][j]$. Similarly, revenues per animal of categories 4, 29 and 42 are calculated according to equations (11.36), (11.37) and (11.38), respectively, where again $revwudL[i][j]$ must be replaced by $revmanudL[i][j]$.

The *discounted* revenues from manure ($revmanL[i][j]$) per pure-bred ($j = 1$) or cross-bred ($j = 2$) lamb of category $i$ ($i = 1, \ldots, PP$) are:

$$revmanL[i][j] = qaveL[i][j] \times revmanudL[i][j] \ . \tag{11.67}$$

## 11.4.5  Revenues from sold breeding animals

Revenues from sold breeding animals occur for breeding females of categories 13, 15, 19, 23 and 26 and for breeding males of categories 38 and 40. If the breeding lambs are paid per animal, the *undiscounted* revenues are input parameters in file INPUTS10.TXT. If the breeding lambs are paid for live weight, the prices per kg live weight ($prsbL[i][j]$) are read from the same input file and the revenues ($revsbL[i][j]$) from sold pure-bred ($j = 1$) or cross-bred ($j = 1$) breeding lambs of category $i$ are then calculated as

$$revsbL[i][j] = prsbL[i][j] \times wP[i][j] \ . \tag{11.68}$$

To get the *discounted* revenues, the undiscounted revenues are multiplied by $qendL[i][j]$.

## 11.4.6  Total revenues per lamb

The total revenues ($revL[i][j]$) from a pure-bred ($j = 1$) or cross-bred ($j = 2$) lamb of category $i$ ($i = 1, \ldots, PP$) discounted to the birth date of the animal are:

$$
\begin{aligned}
revL[i][j] \quad = \quad & revwL[i][j] + revcL[i][j] + revskrL[i][j] + revsktL[i][j] \\
& + revmanL[i][j] + revsbL[i][j] \ . 
\end{aligned} \tag{11.69}
$$

# Chapter 12

# Profit and economic values

## 12.1 Profit per ewe and year

For calculating the profit per ewe and year, the total revenues and costs and the subsidies per ewe and year are needed. The total subsidies per ewe and year are calculated as:

$$Tsub = subR \times \frac{365}{lengthrc} \sum_{j=1}^{crossing} (l1skL[38][j] + l1skL[40][j]) + subE . \quad (12.1)$$

The total costs per ewe and per reproductive cycle for ewes ($TcostsE$), rams ($TcostsR$) and lambs ($TcostsL$) are calculated by multiplying the costs per animal of each category that occurs in the flock with the number of animals of each category per ewe and reproductive cycle for the stationary state of the ewe flock:

$$
\begin{aligned}
TcostsE &= \sum_{i=1}^{TE} costE[i] \times l1E[i] \\
TcostsR &= \sum_{j=1}^{crossing} neweR[j]\Big(\sum_{i=1}^{TR} costR[i][j] \times l1R[i]\Big) \\
TcostsL &= \sum_{i=1}^{PP} \sum_{j=1}^{crossing} costL[i][j] \times l1skL[i][j] .
\end{aligned}
\quad (12.2)
$$

Similarly, the total revenues per ewe and per reproductive cycle from ewes ($TrevE$), rams ($TrevR$) and lambs ($TrevL$) are calculated:

$$
\begin{aligned}
TrevE &= \sum_{i=1}^{TE} revE[i] \times l1E[i] \\
TrevR &= \sum_{j=1}^{crossing} neweR[j]\Big(\sum_{i=1}^{TR} revR[i][j] \times l1R[i]\Big) \\
TrevL &= \sum_{i=1}^{PP} \sum_{j=1}^{crossing} revL[i][j] \times l1skL[i][j] .
\end{aligned}
\quad (12.3)
$$

The total costs ($Tcosts$) and revenues ($Trev$) per ewe per year for the whole

production system are:

$$
\begin{aligned}
Tcosts &= \frac{365}{lengthrc}(TcostsE + TcostsR + TcostsL + costpurchFP) \\
Trev &= \frac{365}{lengthrc}(TrevE + TrevR + TrevL) \tag{12.4}
\end{aligned}
$$

where

$$
costpurchFP = npurchFP \times kdif \times (costL[i][1] + costlamb - revL[i][1]) \tag{12.5}
$$

with $i = 5$ for customary weaning and $i = 6$ for artificial rearing. The variable *costlamb* (costs for ewes and rams which should be allotted to one weaned lamb) is calculated as follows:

$$
costlamb = (TcostsE - TrevE + TcostsR - TrevR)/a \tag{12.6}
$$

where $a = NwL[0]$ for customary weaning and $a = NarL[0]$ for artificial rearing. If a negative value of *costlamb* is calculated this value is set to zero.

Total profit (*Tprof*) per ewe and year is calculated as the difference of total revenues and total costs increased by governmental subsidies:

$$
Tprof = Trev - Tcosts + Tsub . \tag{12.7}
$$

The profitability (in per cent) of the production system including (*profsub*) or excluding subsidies (*profnsub*) is calculated as:

$$
\begin{aligned}
profsub &= 100 \times Tprof/Tcosts \\
profnsub &= 100 \times (Trev - Tcosts)/Tcosts . \tag{12.8}
\end{aligned}
$$

## 12.2 Definition of traits

Generally, four groups of traits are of interest in sheep: growth traits, carcass traits, wool production traits and functional traits (reproduction and health). For dairy sheep, milk production traits are to be attached. If there is crossing in the flock, the economic value for a trait is calculated separately for pure-bred and cross-bred animals.

### 12.2.1 Growth traits

Growth is assumed to be the same trait in all categories of animals. Intra-breed differences between sexes and litter sizes the animals are from are assumed to be expressed by constant factors. Therefore, for the calculation of economic values for growth, a reference growth trait can be defined. Live weights or growth rates of females born as singles, which are specific for the breeding type (pure-bred or cross-bred), are mostly used as reference growth traits.

When calculating the economic weights for growth traits, the average values of the appropriate reference traits are changed. The related growth traits will then change automatically when running the program (see Sections 5.2 and 5.3). Though the economic values are expressed per unit of the reference trait (mostly defined for females) and per ewe and year, they also include the economic effect of the changes in all related growth traits in other sexes.

To allow for changing the growth curve of sheep by selection using different weightings for the individual parts of the growth curve, each part of the growth curve was evaluated separately keeping the remaining part of the growth curve unchanged. The following growth traits were defined:

**Birth weight.** The effects of birth weight on lambing performance (dystocia occurrence) or lambs survival are not included when calculating the economic weight of birth weight as data on lambing performance were not available and lamb survival is evaluated separately.

**Average daily gain from birth till weaning**

**Average daily gain in artificial rearing** (only for option *typew* = 2)

For these three traits, the weight or gain of a female born as single is the reference trait. As alternative traits for average daily gain from birth to weaning or in artificial rearing, weaning weight and weight at the end of artificial rearing may be defined. Their economic values are easily obtained by a simple conversion of the economic values of the appropriate daily gain.

Changes in the growth traits till weaning or till the end of artificial rearing have an impact on the feeding costs and veterinary costs for treatment again parasites. Furthermore, the weights of animals in the subsequent rearing or fattening period at fixed age will change causing modifications in costs and revenues of further animal categories.

If weaned lambs (or lambs at the end of artificial rearing) are paid according to their slaughter weight (e.g. weight classes are built) the effect of changed proportions of animals in each slaughter weight class is included in the economic value of these traits.

A further trait is

**Daily gain in rearing of breeding animals.** The reference trait is daily gain of females from weaning or from the end of artificial rearing to first breeding.

The economic value of the trait takes into account effects of proportional changes in growth rates of all categories of breeding females and males in the whole rearing period.

Changes in the values of the above mentioned growth trait influence mainly nutrition costs, costs for drenching against ecto- and endo-parasites and revenues from animals sold at a given age. Furthermore, changes in the proportions of female and male lambs that can be mated in the first breeding season after their weaning are assumed to be caused by changes in the mean live weight.

If there is fattening, the following trait is considered:

**Daily gain in fattening.** The reference trait is daily gain of females fattened to target 1; if there is no fattening of females, the reference trait is daily gain of males fattened to target 1; if there is no fattening of females and males daily gain of castrates fattened to target 1 is the reference trait.

The economic value of the trait takes into consideration effects of proportional changes in growth rates of all categories of fattened animals.

A change in the growth rate during fattening influences nutrition costs for fattened animals and revenues from slaughtered animals (if fattening is to fixed slaughter age) or fixed costs (if fattening is to fixed weight). Furthermore, drenching costs may increase if there is drenching again ecto- and endo-parasites in fattening.

The last growth trait is

**Mature weight.** The reference trait is mature weight of ewes.

A proportional change in mature weight of rams is assumed. Changing mature weight will affect the minimal weight of breeding females and males when used for reproduction for the first time which is taken into consideration in the calculation of the economic value. Possible correlated changes occurring in the birth weight,

carcass value or milk yield are not included in the economic value of mature weight as the mentioned traits are evaluated separately. Therefore, changes in mature weight influence mainly nutrition costs and revenues from culled mature animals. In some extent, the structure of female progeny is influenced.

## 12.2.2 Carcass traits

Carcass quality traits can be evaluated only if the pricing system for slaughter animals takes into account carcass quality be it on the base of live or slaughtered animals (options 2 or 4 for pricing system in files INPUTS13.TXT and INPUTS14.TXT). Dressing percentage is evaluated only if animals are payed according to carcass weight (options 3 or 4 for pricing systems in files INPUTS13.TXT and INPUTS14.TXT). The following carcass traits were defined:

**Dressing percentage of lambs sold at weaning** or at the end of artificial rearing for slaughter (only considered if $pricewL = 3$ or 4).

No differences are made between sexes.

**Dressing percentage of lambs in fattening** (only considered if $pricefL = 3$ or 4). The reference trait is dressing percentage of females fattened to target 1; if there is no fattening of females dressing percentage of males fattened to target 1 is the reference trait; if there is no fattening of female and male lambs dressing percentage of castrates fattened to first target 1 is the reference trait.

Proportional changes are assumed in dressing percentage of all other categories of fattened animals. For this purpose the initial relations between the values of $dresfL[k][i][j]$ are expressed as coefficients $kdresfL[k][i][j]$. The procedure is the same as for $adgP[k_s + i][j]$ and $kadgfat[k][i][j]$ described in detail in Sections 5.2 and 5.3.

**Dressing percentage of adult sheep** (only considered if $priceS = 3$ or 4). The reference trait is dressing percentage of pure-bred ewes and for rams from the breed of the ewe flock; dressing percentage of rams of the breed used for crossing in the ewe flock is the reference trait for cross-bred animals.

Proportional changes are assumed in dressing percentage of all other categories of adult sheep. The procedure for realizing these changes in the program is similar as for $adgP[k_s + i][j]$ and $kadgfat[k][i][j]$ described in detail in Sections 5.2 and 5.3.

**Average quality class for lambs at weaning** or at the end of artificial rearing when paid for live weight (only considered if $pricewL = 2$).

No differences are made between sexes. The average quality class ($avclwL[j]$) for pure-bred ($j = 1$) or cross-bred ($j = 2$) lambs is calculated as

$$avclwL[j] = \sum_{i=1}^{nclwL} i \times pclwL[j][i] \; . \tag{12.9}$$

**Average quality class for fattened lambs** when paid for live weight (only considered if $pricefL = 2$).

As in lambs at weaning, no differences are made between sexes and the average quality class ($avclfL[j]$) for pure-bred ($j = 1$) or cross-bred ($j = 2$) lambs is calculated in the same way:

$$avclfL[j] = \sum_{i=1}^{nclfL} i \times pclfL[j][i] \; . \tag{12.10}$$

**Average quality class for adult sheep** when paid for live weight (only considered if $priceS = 2$).

As in lambs at weaning, no differences are made between sexes and the average quality class ($avclS[j]$) for pure-bred ($j = 1$) or cross-bred ($j = 2$) animals is calculated in the same way:

$$avclS[j] = \sum_{i=1}^{nclS} i \times pclS[j][i] \ . \tag{12.11}$$

**Average class for fleshiness for adult sheep** (only considered if $priceS = 4$).

The average class for fleshiness ($avfleshS[j]$) for pure-bred ($j = 1$) or cross-bred ($j = 2$) adult sheep is given by the equation

$$avfleshS[j] = \sum_{i=1}^{nclflS} i \times \sum_{k=1}^{nclfcS} pclfcS[j][i][k] \ . \tag{12.12}$$

**Average class for fat covering for adult sheep** (only considered if $priceS = 4$).

The average class for fat covering ($avfcS[j]$) for pure-bred ($j = 1$) or cross-bred ($j = 2$) adult sheep is calculated in the similar way as the average class for fleshiness:

$$avfcS[j] = \sum_{k=1}^{nclfcS} k \times \sum_{i=1}^{nclflS} pclfcS[j][i][k] \ . \tag{12.13}$$

**Average class for fleshiness for fattened lambs** and/or for heavy lambs (carcass weight > 13 kg) slaughtered after weaning or after artificial rearing (only considered if $pricefL = 4$ or $pricewL = 4$ and $typeb > 2$).

**Average class for fat covering for fattened lambs** and/or for heavy lambs (carcass weight > 13 kg) slaughtered after weaning or after artificial rearing (only considered if $pricefL = 4$ or $pricewL = 4$ and $typeb > 2$).

The average classes for fleshiness and fat covering only for fattened lambs ($avfleshfL[j]$ and $avfcfL[j]$) or only for heavy lambs slaughtered after weaning or artificial rearing ($avfleshwL[j]$ and $avfcwL[j]$) are calculated in the same way as for adult sheep. For obtaining the corresponding equations, just replace $'S'$ in all variables by $'fL'$ or $'wL'$, respectively, in equations (12.12) and (12.13). The index $j$ stands for pure-bred ($j = 1$) or cross-bred ($j = 2$) animals. The average classes for fleshiness and fat covering ($avfleshL[j]$ and $avfcL[j]$) jointly calculated for fattened lambs and heavy lambs after weaning or artificial rearing are:

$$
\begin{aligned}
avfleshL[j] &= favfL[j] \times avfleshfL[j] + favwL[j] \times avfleshwL[j] \\
avfcL[j] &= favfL[j] \times avfcfL[j] + favwL[j] \times avfcwL[j] \tag{12.14}
\end{aligned}
$$

where

$$
\begin{aligned}
favfL[j] &= \frac{favfL0[j]}{favfL0[j] + favwL0[j]} \\
favwL[j] &= \frac{favwL0[j]}{favfL0[j] + favwL0[j]} \tag{12.15}
\end{aligned}
$$

with

$$favfL0[j] = \sum_i l1skL[i][j] \tag{12.16}$$

where the sum is over all categories $i$ of fattened animals and

$$favwL0[j] = l1skL[7][j] \times pclcwwL[1][4][j] + l1skL[32][j] \times pclcwwL[2][4][j] \ . \tag{12.17}$$

**Average class for carcass quality for lambs slaughtered after weaning** or artificial rearing (only considered if $pricewL = 4$).

The average class for carcass quality ($avcqwL[j]$) for pure-bred ($j = 1$) or cross-bred ($j = 2$) light lambs (carcass weight $\leq 13$ kg) slaughtered at weaning or after artificial rearing is calculated as follows:

$$
\begin{aligned}
avcqwL[j] \ = \ & \sum_{i=1}^{nclcqwL} i \times \Big( \sum_{k=1}^{nclcwwL} pclcqwL[k][i][j] \times \big( pclcwwL[1][k][j] \\
& \times l1skL[7][j] + pclcwwL[2][k][j] \times l1skL[32][j] \big) \Big) \\
& \Big/ \Big( l1skL[7][j] \times (1 - pclcwwL[1][nclcwwL + 1][j]) \\
& + l1skL[32][j] \times (1 - pclcwwL[2][nclcwwL + 1][j]) \Big) \ .
\end{aligned}
\tag{12.18}
$$

It is assumed that dressing percentage and the traits describing carcass quality have impact only on the revenues from culled animals. No changes in costs are taken into account when calculating the economic values for carcass traits.

## 12.2.3 Functional traits

Among the functional traits, reproduction and health traits are most important for sheep. The following traits were defined and evaluated:

**Conception rate of female lambs.**

The reference trait is the conception rate of pure-bred ($j = 1$) or cross-bred ($j = 2$) female lambs in their first breeding season after weaning $conrateFP[1][j]$. Proportional changes in the conception rate of female lambs in their second and third breeding season are assumed when calculating the economic value of the trait. Changes in the conception rate of female lambs influence the structure of progeny and the average age and weight of ewes at first lambing, but the structure of ewe flock stays the same. Therefore, the trait has an impact on the total revenues and costs per ewe and year through changing the number of animals in several progeny categories and on nutrition and drenching costs of ewes as well as on revenues from culled ewes.

**Average conception rate of ewes.**

Average conception rate of ewes ($avconrateE$) is calculated as

$$avconrateE = \frac{1}{1 - l4E[LL]} \sum_{i=1}^{LL-1} l4E[i] \times conrateE[i] \ . \tag{12.19}$$

Proportional changes in the conception rate of ewes on each parity are assumed when calculating the economic value of the trait. Changes in this traits influence the age structure of the ewe flock (a new stationary state is calculated) with consequences on the number of lambs born and weaned, milk yield and number of culled ewes, resulting in changes of all revenues and costs for ewes and progeny.

**Average litter size per lambed ewe.**

The average litter size per ewe lambing ($avlitpE[j]$, i.e. number of lambs born per ewe lambing) in reproductive cycle $j$ ($j = 1, \ldots, LL$) is given by the equation

$$avlitpE[j] = \sum_{i=1}^{clt}(i \times Pltype[i][j]) \tag{12.20}$$

and the litter size per ewe lambing in the flock calculated as weighted average over parities ($avlitE$) is

$$avlitE = \frac{1}{Nlamb} \sum_{j=1}^{LL} l3E[j] \times avlitpE[j] \; . \tag{12.21}$$

A proportional change in litter size on each parity is assumed when calculating the economic weight for litter size. Litter size is handled as categorical trait when its economic value is calculated, i.e. an underlying normal distribution is assumed. The survival rate of lambs within each litter size does not change when changing the average litter size. However, litter size will have an impact on the total losses of lambs at lambing and till weaning or till the end of artificial rearing. Litter size will also influence the number and average weight in progeny categories resulting in changes in revenues and costs of these categories. Furthermore, the nutrition costs for lactation and revenues and cost associated with changes in milk yield will be affected. If lambs are paid according to their slaughter weight (e.g. weaned lambs are graded according to slaughter weight) the effect of changing frequencies in the individual slaughter weight classes on the average price for slaughter weight is included into the economic value of litter size.

**Average survival rate of lambs at lambing** (till 24 hours after lambing) for the given average litter size.

This trait ($avsur24hL[j]$) expressed in per cent is defined as quotient of the number of lambs alive at 24 hours after birth and the number of lambs born in total (including aborts and stillbirth):

$$avsur24hL[j] = 100 \times Na24hL[j]/NbtL[j] \; . \tag{12.22}$$

Average survival rate of lambs at lambing is calculated for both breeding types $j$ ($j = 1$ : pure-bred lambs, $j = 2$ : cross-bred lambs). The economic weight of the trait is calculated via changing the variable $pdiedbL[i][j]$ in equal proportions for all litter sizes $i$. Changes in the trait have a similar impact on revenues and costs as changes in average litter size.

**Average survival rate of lambs till weaning** (from 24 hours after birth, only considered if there is customary weaning, i.e. $typew = 1$.)

This trait ($avsurwL[j]$) is defined as quotient of the number of lambs alive at weaning and the number of lambs alive at 24 hours after birth:

$$avsurwL[j] = 100 \times NwL[j]/Na24hL[j] \; . \tag{12.23}$$

It is expressed in per cent and calculated for both pure-bred ($j = 1$) and cross-bred ($j = 2$) lambs.

**Average survival rate of lambs till the end of artificial rearing** (from 24 hours after birth, only considered if there is artificial rearing, i.e. $typew = 2$.)

This trait ($avsurarL[j]$) is defined as quotient of the number of lambs alive at the end of artificial rearing and the number of lambs alive at 24 hours after birth:

$$avsurarL[j] = 100 \times NarL[j]/Na24hL[j] \ . \tag{12.24}$$

As the preceding trait, also this trait is expressed in per cent and calculated for both pure-bred ($j = 1$) and cross-bred ($j = 2$) lambs.

Proportional change of survival rates within each litter size is assumed when changing the average survival rate of lambs till weaning. In case of artificial rearing of lambs, proportional changes of survival rates within each litter size are assumed for both periods, from 24 hours after birth till early weaning and from early weaning till the end of artificial rearing. Changes in both traits (average survival rate till weaning or till the end of artificial rearing) have a similar impact on revenues and costs as average litter size, but an impact on milk yield of ewes is not expected.

**Productive lifetime of ewes** measured as average number of reproductive cycles per ewe.

This trait ($avlifelE$) is calculated as the reciprocal value of the relative frequency of ewes in first reproductive cycle:

$$avlifelE = 1/l4E[1] \ . \tag{12.25}$$

**Productive lifetime of ewes** measured in years from the date of first lambing.

This trait ($avlifeyE$) is calculated as

$$avlifeyE = \frac{1}{365 \times l4E[1]} \sum_{i=1}^{LL} \sum_{j=1}^{nstg1E} l1E[k] \times (dcE[k] + (i-1) \times lengthrc) \tag{12.26}$$

where $k = (i-1) \times nstgE + j$.

When calculating the economic value of productive lifetime, the proportions of ewes died and culled for health problems (input variables $pdiedE[i]$ and $pcullhE[i]$ in input file INPUTS01.TXT) are changed by the same proportion each. In dairy sheep, the proportions of ewes culled for low milk production do not change. So, the productive lifetime as defined here is the functional lifetime of ewes and expresses the health status of animals. The consequence of changing productive lifetime is an altered structure of the ewe flock (a new stationary state is calculated) causing changes in all revenues and costs connected with ewes. The frequencies of categories of reared breeding females as well as the revenues and costs associated with these categories will also be modified as the number of female lambs needed for replacement will be changed.

Average productive lifetime of ewes in number of reproductive cycles does not take into account that some ewes do not stay in the flock the whole reproductive cycle. Alternatively, the average productive lifetime in years takes into account the real time a ewe stays in the flock.

## 12.2.4   Milk production traits

Milk production traits are evaluated only for dairy sheep. Somatic cell score is assigned to milk production traits from practical reasons. Though somatic cell score is a functional trait expressing udder health, it is recorded only in milked sheep.

The reference trait for the calculation of the economic value of milk yield can be defined in different ways. In this program version, two variants are allowed:

**Milk yield in the standardized milking period** according to the recommendations of the ICAR [9].

The total milk yield in the standardized milking period per ewe per reproductive cycle ($tmilkmst$) is calculated from the lactation curve as follows:

$$tmilkmst = \sum_{i=0}^{clt} \sum_{j=1}^{LL} (ktlsl[i] \times ktlp[j] \times PsuckE[i][j] \times$$
$$\left( awo \sum_{t=agewL}^{agewL+dmilkst} t^{bwo} \mathrm{e}^{-cwo \times t} \right) . \tag{12.27}$$

The length of the standardized milking period ($dmilkst$) depends on the breed and the production system. Therefore, this parameter is in input parameter (in input file INPUTS06.TXT) which has to be defined by the user.

**Daily milk production averaged over the whole lactation.**

Average daily milk production ($avmilkd$) is calculated as follows:

$$avmilkd = \frac{tmilkw + tmilkm}{datdry - datlamb} . \tag{12.28}$$

The effect of changing milk production of an ewe in the whole lactation is included in the economic values of both milk yield traits. When calculating the economic values, the parameter $a$ ($awo$ in the program) of the lactation curve (6.1) is modified to cause changes both in the total and in the daily milk yield. The selection of the appropriate milk yield trait is on the responsibility of the user. The program will always calculate both traits for dairy ewes.

**Fat content** (in percent).

**Fat yield** (in kg).

Fat yield in the standardized milking period ($fatymst$) is calculated as

$$fatymst = tmilkmst \times \frac{fat}{100} . \tag{12.29}$$

A change in the average fat content has always an impact on feeding costs. Changes in the revenues from milk are included only if milk is sold at least partly as raw milk and if the pricing system of milk takes into account the fat content. The trait is alternatively expressed as fat yield during the standardized milking period, but the change in fat yield is assumed to be always caused by a change in fat content and not in milk yield.

**Protein content** (in percent).

**Protein yield** (in kg).

Milk protein yield in the standardized milking period ($protymst$) is calculated as

$$protymst = tmilkmst \times \frac{prot}{100} . \tag{12.30}$$

As in fat yield, the change in protein yield is assumed to be always caused by a change in protein content and not in milk yield.

**Somatic cell score.**

The somatic cell score ($SCS$) is calculated from the somatic cell count ($SCC$, defined as the average number of somatic cells per ml milk) as follows [3, 6, 12]:

$$SCS = \log_2 \left( \frac{SCC}{100000} \right) + 3 \qquad (12.31)$$

where $\log_2$ is 'logarithmus dualis', the logarithm to the basis 2. For simplicity, the natural logarithm (ln) may be used instead:

$$SCS = \ln \left( \frac{SCC}{100000} \right) / 0.69314718 + 3 \ . \qquad (12.32)$$

In the opposite way, the somatic cell count can be calculated from the somatic cell score:

$$SCC = 100000 \times 2^{SCS-3} \ . \qquad (12.33)$$

The economic value of somatic cell score is expressed per change in average SCS.

### 12.2.5 Wool production traits

In the present version of the program the only wool trait evaluated is

**Fleece weight** (in kg) defined as amount of greasy wool per shearing. Fleece weight in different animal categories (ewes, rams, lambs) is assumed to be the same trait.

Intra-breed differences in fleece weight between sexes and age categories are assumed to show constant ratios. Therefore, for the calculation of the economic value, the fleece weight of the individual categories is related to the fleece weight of adult rams.

Alteration in feed requirement is considered when changing fleece weight. The cost of shearing are generally paid per animal and are not expected to change for additionaly fleece weight. Only the benefit in additional revenues from extra weight of fleece sold is therefore included in the economic value of fleece weight.

## 12.3 Calculation of economic values of traits

The *marginal economic value* is generally defined as the partial derivative of the profit function with respect to the trait considered [14]. It is expressed per given unit of the trait and per time interval (here per ewe entering a reproductive cycle and per year). When using complex bio-economic models instead of simple profit functions (as in the present program) the exact partial derivative must be replaced by an approximate method, by a numeric derivative (difference quotient). The profit the estimation of economic weights is based on is calculated for a commercial population of sheep of the given breed or breed combination. The methodology used for the calculation of economic values is different for traits with continuous variation and for categorical traits.

### 12.3.1 Economic values for traits with continuous variation

The numeric derivative of profit with respect to the considered trait is calculated by increasing and decreasing the average value of the trait $TV_{av}$ by 0.5%. Let $TV_h$ be the higher value of the trait considered which was derived as $TV_h = 1.005 TV_{av}$. Similarly, $TV_l$ is calculated by decreasing the average trait value by the same amount: $TV_l = 0.995 TV_{av}$. Furthermore, let $TP_h$ and $TP_l$ be the total profit belonging to

the first or the second of these values, respectively. The partial derivative is then approximated by the following difference quotient:

$$ev = \frac{TP_h - TP_l}{TV_h - TV_l} \ . \tag{12.34}$$

The marginal economic value is expressed in monetary units (MU) per unit of the trait per ewe and year.

Table 12.1 gives a survey of the traits with continuous variation and of the variables which are changed to calculate the economic value of these traits. That means, not in all cases the average value of the trait is changed directly. Some traits are complex quantities which are calculated from a series of parameters. For example, average conception rate of ewes is calculated from the conception rates in the individual lactations. For that reason, the conception rate in all lactations is changed in the way described above for calculating the economic value of the average conception rate. Total milk is calculated from the sum of daily milk yield of ewes on different lactations. In this trait a change in parameter $a$ (*awo* in the program) of the lactation curve (6.1) proved to be useful for the calculation of economic weights.

## 12.3.2 Economic values for categorical traits

The economic values for categorical traits (e.g. fleshiness and fat covering) are calculated according to [24]. The calculation is based on a threshold model. The underlying normal distribution is shifted to the left and to the right, each time by 0.05 standard deviations. The resulting changes in the distribution are converted to changes in the average class. For the numerical expression of the average class, the numbers 1 to $N$ are assigned to the individual classes. Let $p_i$ be the frequency of animals in class $i$. Then the average class $AC$ is calculated simply as

$$AC = \sum_{i=1}^{N} i \times p_i \ . \tag{12.35}$$

Let $AC_h$ be the average class for shifting the distribution to higher values of the trait and let $AC_l$ be the average class for shifting the distribution to lower values of the trait. Furthermore, let $TP_h$ and $TP_l$ be the total profit belonging to the first or the second of these values, respectively. Then the marginal economic value $ev$ is calculated as change of total profit related to a change in the average class:

$$ev = \frac{TP_h - TP_l}{AC_h - AC_l} \ . \tag{12.36}$$

For the evaluation of the trait "average class", at least two classes must be occupied with numbers. If all data are in one class only, there is no variation in the given trait, a selection is not possible and the estimation of an economic value for this trait is senseless.

The economic value of several traits has to be calculated from a two-dimensional distribution. For example, there is given one joint table of frequencies for fleshiness and fat covering. In such situations, the distribution of the investigated trait was shifted within all levels of the second trait whereby the marginal frequencies of the second trait stayed unchanged. This procedure ensured the calculation of independent economic weights for both traits of the frequency table. A survey of categorical traits the economic values are calculated for is given in Table 12.2. The frequencies the changes of which the calculation of the economic values is based on are also given in this table.

Table 12.1: Variables changed in the calculation of economic weights for traits with continuous variation

| Trait | Variable(s) changed |
|---|---|
| Birth weight ($bwL[1][1][k]$) | $bwL[i][j][k]$ |
| Daily gain from birth till weaning ($adgbwL[1][1][k]$) or weaning weight ($wwL[1][1][k]$) | $adgbwL[i][j][k]$ |
| Daily gain in artificial rearing ($adgwarL[1][1][k]$) or weight at the end of artificial rearing ($warL[1][1][k]$) | $adgwarL[i][j][k]$ |
| Daily gain in rearing of breeding animals ($adgr[1][1][k]$)[a] | $adgr[i][j][k]$ |
| Daily gain in fattening ($adgP[i_0][j]$)[b] | $adgP[i][j]$[c] |
| Mature weight ($mwE[1]$ or $mwE2$) | $mwE[1]$, $mwR[1]$ or $mwE2$, $mwR[2]$ |
| Dressing percentage of lambs at weaning or at the end of artificial rearing ($dreswL[i]$) | $dreswL[i]$ |
| Dressing percentage of fattened lambs ($dresfL[i_0][j_0][k]$)[d] | $dresfL[i][j][k]$ |
| Dressing percentage of adult sheep ($dresE$ or $dresR[2]$) | $dresE$, $dresR[1]$, $dresrL[1]$ or $dresR[2]$, $dresrL[2]$ |
| Conception rate of female lambs ($conrateFP[1][j]$) | $conrateFP[i][j]$ |
| Average conception rate of ewes ($avconrateE$) | $conrateE[i]$ |
| Average survival rate of lambs at lambing ($avsur24hL[j]$) | $pdiedbL[i][j]$ |
| Average survival rate of lambs till weaning ($avsurwL[j]$) | $pdiedwL[i][j]$ |
| Average survival rate of lambs till the end of artificial rearing ($avsurarL[j]$) | $pdiedwL[i][j]$, $pdiedarL[i][j]$ |
| Productive lifetime of ewes in reproductive cycles ($avlifelE$) or in years ($avlifeyE$) | $pdiedE[i]$, $pcullhE[i]$ |
| Total milk yield in the standardized milking period ($tmilkst$) or average daily milk yield for the whole milking period ($avmilkd$) | $awo$ |
| Milk fat content ($fat$) or milk fat yield ($fatymst$) in the standardized milking period | $fat$ |
| Milk protein content ($prot$) or milk protein yield ($protymst$) in the standardized milking period | $prot$ |
| Somatic cell score ($mSCS$) | $mSCS$ |
| Fleece weight per shearing ($wsheR[j]$) | $wsheE$, $wsheR[j]$, $wshewL[i][j]$, $wshearL[i][j]$, $wsherL[i][j]$, $wshefL[i][j]$ |

[a]If there are no cross-bred females, $adgr[2][1][2]$ is taken as reference trait for cross-bred animals
[b]Index $i_0$ is the index for the category which is used as reference category (see Section 5.2 )
[c]$i = 8, \ldots, 7 + lf[1]$, $33, \ldots, 32 + lf[2]$ and $43, \ldots, 42 + lf[0]$
[d]For explanations of the indices $i_0$ and $j_0$ see Section 5.2

Table 12.2: Frequencies changed in the calculation of economic weights for categorical traits

| Trait | Frequencies changed |
|---|---|
| Average quality class for lambs at weaning or at the end of artificial rearing when paid for live weight ($avclwL[j]$) | $pclwL[j][i]$ |
| Average quality class for fattened lambs when paid for live weight ($avclfL[j]$) | $pclfL[j][i]$ |
| Average quality class for adult sheep when paid for live weight ($avclS$) | $pclS[j][i]$ |
| Average class for fleshiness for adult sheep ($avfleshS[j]$) | $pclfcS[j][i][k] \Big/ \sum\limits_{k=1}^{nclfcS} pclfcS[j][i][k]$ |
| Average class for fat covering for adult sheep ($avfcS[j]$) | $pclfcS[j][i][k] \Big/ \sum\limits_{i=1}^{nclflS} pclfcS[j][i][k]$ |
| Average class for fleshiness for fattened lambs and heavy lambs after weaning ($avfleshL[j]$) | $pclfcfL[j][i][k] \Big/ \sum\limits_{k=1}^{nclfcfL} pclfcfL[j][i][k],$ $pclfcwL[j][i][k] \Big/ \sum\limits_{k=1}^{nclfcwL} pclfcwL[j][i][k]$ |
| Average class for fat covering for fattened lambs and heavy lambs after weaning($avfcL[j]$) | $pclfcfL[j][i][k] \Big/ \sum\limits_{i=1}^{nclflfL} pclfcfL[j][i][k],$ $pclfcwL[j][i][k] \Big/ \sum\limits_{i=1}^{nclflwL} pclfcwL[j][i][k]$ |
| Average class for carcass quality of lambs slaughtered after weaning or at the end of artificial rearing ($avcqwL[j]$) | $pclcqwL[i][k][j]$ |
| Average litter size for lambing ewes ($avlitE$) | $Pltype[i][j]$ |

### 12.3.3 Calculation of economic values if there is cross-breeding

In the case of two progeny types in the evaluated population (i.e. pure-bred and cross-bred progeny), the trait level is increased (decreased) separately for both progeny types and two economic values are calculated for each trait: an economic value for trait $i$ expressed in the pure-bred progeny of the breed of the flock ($ev[i][1]$) and an economic value for trait $i$ expressed in the cross-bred progeny ($ev[i][2]$). Both economic values are given per unit of the trait and per ewe in the modelled production system per year.

If no crossing is used in the ewe flock (option $ewopt = 0$ in the parameter file PARAS.TXT), the economic values are calculated only for traits expressed in pure-bred progeny and $ev[i][1]$ is printed in the results file as economic value. If crossing is used in the flock and only economic values for the breed used for crossing in the flock are of interest (option $ewopt = 1$), economic values are calculated only for traits expressed in cross-bred progeny and $ev[i][2]$ is printed.

If crossing is used in the flock and only economic values for the breed of the flock are of interest (option $ewopt = 2$), economic values are calculated for traits expressed in pure-bred and in cross-bred progeny and $ev[i][0]$ is printed which is calculated as:

$$ev[i][0] = ev[i][1] + \frac{1}{2}ev[i][2] \ . \tag{12.37}$$

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# Chapter 13

# Installing and running the program

## 13.1 List of files in the installation package

**PARAS.TXT** Parameter file which contains the most important parameters for running the program EWSH1 (see Section 14.1).

**INPUTSxx.TXT with xx = 01, 02, 03, 04, 05, 06, 08, 09, 10, 11, 12, 13, 14**
Data input files (see Section 14.2). The files INPUTS11.TXT, INPUTS13.TXT and INPUTS14.TXT are optional. File INPUTS11.TXT is only needed for dairy sheep. File INPUTS13.TXT is only read if lambs are sold for slaughter after weaning or artificial rearing and file INPUTS14.TXT is used only if there is fattening in the system.

**TEXTS_OUT.TXT** This files contains text for writing the results for the program EWSH1. See also Section 14.3.

**ewsh1.exe** Executable program file for program EWSH1.

**license (in subdirectory DOC)** This file contains the license conditions. Read them carefully and do not use the program package ECOWEIGHT if you do not agree with the license conditions.

**ECOWEIGHT02.pdf (in subdirectory DOC)** Manual for the program EWSH1. You can read and print it with the AcrobatReader or any other program which can handle pdf-files.

**ewsh1.c (in subdirectory SRC)** Source code of the program EWSH1.

## 13.2 Installation

### 13.2.1 Under LINUX

The program EWSH1 comes to you as a compressed tar-file with the name ECOWEIGHT02_{# of version}.tgz, for example ECOWEIGHT02_5_1_1.tgz contains the programs from version 5.1.1 of the program package. Copy this file to a directory of your choice and enter the command

tar xvf ECOWEIGHT02_{# of version}.tgz

for uncompressing and unarchiving the file. All files necessary for running the program EWSH1 will be installed in the same directory. The subdirectory DOC will contain the file with the license conditions and the manual of the program as pdf-file. The subdirectory SRC will contain the source code of the program.

For compiling the source code using the compiler gcc you must use the option -lm, because otherwise the mathematical functions would not work:

gcc -lm -o ewsh1.exe ewsh1.c

### 13.2.2   Under Microsoft Windows

The Windows version of the program is distributed as zip file. It contains the compiled program *ewsh1.exe*. The program was compiled under Cygwin (http://www.cygwin.com) and runs only in the presence of the file cygwin1.dll which is part of the Windows distribution. If you intend to change the source code and to compile the program you are recommended to install Cygwin which is freely available. When compiling the source code, use the following statement:

gcc -Wl,–stack=55000000 -o ewsh1.exe ewsh1.c

Alternatively it should be possible to use commercial C compilers (we did not test commercial compilers).

## 13.3   Running the program

You are recommended to create one directory for each calculation where you will copy and edit all files you will need. The program may be also in this directory or may be copied to a directory for executable files, e.g. to the directory /usr/local/bin in LINUX.

Edit the parameter file PARAS.TXT and the data input files INPUTS.xx to get there your data. Enter under LINUX *./ewsh1.exe* if the program file is in the same directory as the data files) or simply *ewsh1.exe* if the program file is in a directory for executable files.

Under Windows, enter *ewsh1.exe* to start the program. The program will ask you to type the name of the output file the results will be written to. Press ENTER after typing the name of the file.

After finishing the program, you will find all results in the result file. This file is a text file and can be edited by any text editor or word processor.

## 13.4   General remarks

Several checks of input parameters are included in the programs. For example, certain input parameters have to sum to one. A warning will appear if these input parameters are invalid and the program will stop. You will be told which input parameters to correct before restarting the program. In general, it is your responsibility to use input parameters which are realistic and fit together, because it is impossible to predict any possible erroneous combinations of input parameters. Do not forget to have always a critical look on your results before using them for further purposes.

# Chapter 14

# Input files

**Important remark:** When editing the input files, keep attention *not to change quotation marks*. All files are read as sequential files and the program recognizes the beginning and the end of texts on the basis of quotation marks. Adding or deleting a quotation mark will cause the program to break down or to calculate wrong results.

**Monetary unit:** In all input files the abbreviation MU is used for monetary unit. All values in the distributed version of the program refer to Euros. You can globally replace the abbreviation MU by the abbreviation of your monetary unit in all data input files (INPUTSxx.TXT) and in the input file TEXTS_OUT.TXT using any text editor; the results file will then contain the monetary unit specified by you.

**Language of the program:** The program will need just the numbers for calculations. The texts are read in and printed out to the result file as they are. Therefore, you can freely change the text in all input files as long as you do not modify the quotation marks. For example, you can translate all texts in the input files to another language what will cause the appropriate part of the result file to be printed in the same language as the input files (may be there are some exceptions where the English text will be remained). The length of the texts can be changed, but each text must start and finish with quotation marks. A great part of the text for the results file is read from the file TEXTS_OUT.TXT. You can translate all the text in this file. But be very careful not to change quotation marks.

## 14.1   Parameter file PARAS.TXT

This file contains basic information for running the program EWSH1. At the beginning of the file between the first two quation marks you can write any text characterizing your calculation. Then the value of a parameter is always followed by its description. Modify the values of the parameters according to your needs. The file contains the following parameters:

- Type of weaning (*typew*)

  - 1: Customary weaning
  - 2: Early weaning followed by artificial rearing with milk replacer

- Type of progeny (*crossing*)

- – 1: Only pure-bred progeny
- – 2: Pure-bred and cross-bred progeny

- Number of variants (different groups) for fattening of surplus female progeny ($lf[1]$)

    - – 0: No fattening of surplus female progeny
    - – 1, 2, 3, 4 or 5: The number of variants for fattening is 1, 2, 3, 4 or 5, respectively. Numbers greater than 5 are not allowed.

- Number of variants (different groups) for fattening of surplus male progeny ($lf[2]$)

    - – 0: No fattening of surplus male progeny
    - – 1, 2, 3, 4 or 5: The number of variants for fattening is 1, 2, 3, 4 or 5, respectively. Numbers greater than 5 are not allowed.

- Number of variants (different groups) for fattening of castrates ($lf[0]$)

    - – 0: No fattening of castrates progeny
    - – 1, 2, 3, 4 or 5: The number of variants for fattening is 1, 2, 3, 4 or 5, respectively. Numbers greater than 5 are not allowed.

- Type of breed (*typeb*)

    - – 1: Dairy sheep
    - – 2: Meat sheep or other non-dairy sheep with known lactation curve
    - – 3: Meat sheep or other non-dairy sheep with unknown lactation curve

- Method for calculating the feed costs (*feedcost*)

    - – 1: Feed costs are calculated from the net energy and protein requirements
    - – 2: Feed costs are calculated only from the net energy requirements

- Female replacement (*femrep*)

    - – 1: Own replacement females are reared
    - – 2: A part of replacement females are purchased

- Option for calculating economic weights (*ewopt*)

    - – 0: Economic weights are calculated only for traits expressed in pure-bred progeny (when no crossing is used in the ewe flock)
    - – 1: Economic weights are calculated only for traits expressed in cross-bred progeny (when only economic weights for the breed used for crossing in the flock are of interest)
    - – 2: Economic weights are calculated only for the breed of the flock from traits expressed both in pure-bred and cross-bred progeny

## 14.2 Data input files

### 14.2.1 Input file INPUTS01.TXT

This file contains input parameters for calculating the ewe flock structure. They are:

- Number of reproductive cycles ($LL$, must be between 4 and 15)

- Fraction of ewes entering reproductive cycle $i$ that will die in this cycle ($pdiedE[i]$, $i = 1, \ldots, LL$). All values $pdiedE[i]$ must be in the range from 0 to 1.

- Fraction of ewes entering reproductive cycle $i$ ($i = 1, \ldots, LL$) that were voluntarily culled for low milk production ($pcullmE[i]$, $i = 1, \ldots, LL$). All values $pcullmE[i]$ must be in the range from 0 to 1. These values are read only for dairy ewes.

- Fraction of ewes entering reproductive cycle $i$ ($i = 1, \ldots, LL$) that were involuntarily culled for health problems other than failure to conceive ($pcullhE[i]$, $i = 1, \ldots, LL$). All values $pcullhE[i]$ must be in the range from 0 to 1.

- Conception rate of ewes in reproductive cycle $i$ ($conrateE[i]$, $i = 1, \ldots, LL - 1$). All values $conrateE[i]$ must be in the range from 0 to 1.

- Fraction of barren ewes in reproductive cycle $i$ that will be kept to the next reproductive cycle ($pbarrE[i]$, $i = 1, \ldots, LL - 1$). All values $pbarrE[i]$ must be in the range from 0 to 1.

- Fraction of female lambs crossed with other breeds ($pcrossE[0]$)

- Fraction of ewes crossed with other breeds in reproductive cycle $i$ ($pcrossE[i]$, $i = 1, \ldots, LL - 1$). All values $pcrossE[i]$ must be in the range from 0 to 1.

The following five inputs contain dates. All dates are given in the format 'year month day'. The number of the year must be relative, the earliest dates must always be in year 0, the next year is year 1 etc.:

- Date of lambing ($datlamb$)

- Date of weaning ($datwL$)

- Date of the beginning of the breeding season ($datbbs$)

- Date of the end of the breeding season ($datebs$)

- Date of drying off of ewes ($datdry$). This date is read only for dairy sheep (option 1 of the type of the sheep breed in PARAS*.TXT).

The last input is the annual discount rate ($u$).

### 14.2.2 Input file INPUTS02.TXT

This file contains the following input parameters for calculating the structure of the ram population:

- Number of breeding cycles ($RR$, must be between 1 and 5)

- Fraction of rams that died in breeding cycle $i$ ($pdiedR[i]$, $i = 1, \ldots, RR$)

- Fraction of rams sold as breeding animals in breeding cycle $i$ ($psoldR[i]$, $i = 1, \ldots, RR$)

- Fraction of rams entering breeding cycle $i$ that were culled for health or for age ($pcullR[i]$, $i = 1, \ldots, RR$)

The following equation must be fulfilled for the last breeding cycle $RR$:

$$pdiedR[RR] + psoldR[RR] + pcullR[RR] = 1 \ . \tag{14.1}$$

## 14.2.3 Input file INPUTS03.TXT

This file contains the following input parameters for calculating the structure of the progeny of the ewe flock.

- Number of classes for litter size, e.g. singles, twins, triplets ($clt$). $clt$ is an integer in the range from 1 to $CLT - 1$ where $CLT$ is set to 5 in the program.

- Fraction of lambings in individual classes for litter size for all reproductive cycles ($Pltype[i][j]$, $i = 1, \ldots, clt$, $j = 1, \ldots, LL$). Row: litter size (the number of rows must be equal to the number of classes for litter size), column: reproductive cycle (the number of columns equals the number of reproductive cycles). It holds that $0 \leq Pltype[i][j] \leq 1$ and $\sum_{i=1}^{clt} Pltype[i][j] = 1$ for all $j$ ($j = 1, \ldots, LL$).

- Fraction of lambs stillborn or died until 24 hours for the individual classes for number of dead lambs $j$ within each litter size $i$ ($pdiedbtL[i][j]$, $i = 1, \ldots, clt$; $j = 1, \ldots, i$). Rows are the litter sizes ($i = 1, \ldots, clt$), columns are number of lambs dead within each litter size ($j = 1, \ldots, i$). The fraction of purebred lambs (of both sexes) stillborn or died until 24 hours for the individual classes for litter size ($pdiedbL[i][1]$, $i = 1, \ldots, clt$) is assumed to be the same as the fraction of crossbred lambs (of both sexes) stillborn or died until 24 hours for the individual classes for litter size ($pdiedbL[i][2]$, $i = 1, \ldots, clt$) and is calculated as:

$$pdiedbL[i][1] = \sum_{j=1}^{i} pdiedbtL[i][j] \tag{14.2}$$

- Lambs died till weaning as proportion of lambs born alive (lambs alive at 24 hours after birth) for all classes of litter size ($pdiedwL[i][1]$, $i = 1, \ldots, clt$)

- Lambs died from early weaning till the end of artificial rearing with milk replacer as proportion of lambs alive at early weaning for all classes of litter size ($pdiedarL[i][1]$, $i = 1, \ldots, clt$). This parameter is needed only for option 2 of the type of weaning (see parameter file PARAS.TXT on page 137).

The following parameters are given as separate input rows for pure-bred ($j = 1$) and cross-bred ($j = 2$) female and male progeny[1]:

- Birth weights of female ($s = 1$) and male ($s = 2$) progeny born in litter size $i$ within each breeding type $j$ ($bwL[s][i][j]$, $i = 1, \ldots, clt$, $j = 1, 2$).

- Weaning weight of female ($s = 1$) and male ($s = 2$) progeny born in litter size $i$ within each breeding type $j$ ($wwL[s][i][j]$, $i = 1, \ldots, clt$, $j = 1, 2$).

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[1]The values for the cross-bred progeny are ignored in all input files if the parameter *crossing* in the parameter file PARAS.TXT is set to 1, that means if there is only pure-bred progeny.

- Weight of female ($s = 1$) and male ($s = 2$) progeny born in litter size $i$ within each breeding type $j$ at the end of artificial rearing ($warL[s][i][j]$, $i = 1, \ldots, clt$, $j = 1, 2$). This parameter is needed only for option 2 of the type of weaning (see parameter file PARAS.TXT on page 137).

- Age of lambs at the end of artificial rearing ($agearL$). This parameter is read only for option 2 of the type of weaning (see file PARAS.TXT on page 137).

### 14.2.4 Input file INPUTS05.TXT

This file contains input parameters for surplus progeny. These parameters are needed for calculating the structure of the progeny and for the description of growth. The file includes values for pure-bred and cross-bred progeny.[2] The two items (four inputs) are read always:

- Fraction of pure-bred ($j = 1$) or cross-bred ($j = 2$) weaned surplus female progeny ($psp[1][i][j]$) sold in different categories $i$ ($i = 1, \ldots, csp[1]$). $i = 1$: sold at weaning for slaughter, $i = 2$: sold as breeding animals, $i = 3, \ldots 7$: fattened to target 1 to 5, respectively. It must be $\sum_{i=1}^{csp[1]} psp[1][i][j] = 1$ for $j = 1, 2$.

- Fraction of pure-bred ($j = 1$) or cross-bred ($j = 2$) weaned surplus male progeny ($psp[2][i][j]$) sold in different categories $i$ ($i = 1, \ldots, csp[2]$). $i = 1$: sold at weaning for slaughter, $i = 2$: sold as breeding animals, $i = 3$: castrated, $i = 4, \ldots 8$: fattened to target 1 to 5, respectively. It must be $\sum_{i=1}^{csp[2]} psp[2][i][j] = 1$ for $j = 1, 2$.

- Not mated pure-bred ($j = 1$) or cross-bred ($j = 2$) female progeny sold before the first breeding season as proportion of surplus female progeny intended for selling without mating ($ps13[j]$)

The following inputs are read only if there is fattening of female progeny (The four inputs in the description are seven inputs in the input file as some inputs were summarized in the manual).

- In the first two inputs, up to 5 targets for fattening of female progeny have to be defined. The number of targets for fattening ($lf[1]$) must be given in the parameter file PARAS.TXT on page 137. In the first input ($ulf[1][i]$), the units for targets 1 to $lf[1]$ for fattening must be defined. Write 1 for kg or 2 for days. In the next input ($vlf[1][i]$), write the values for targets 1 to $lf[1]$ for fattening. Each value is either in kg (code 1 in the input above) or in days (code 2 in the input above).

- In the next input, the code for target $i$ ($i =1$ to $lf[1]$) is given ($clf[1][i]$) that determines if the given target $i$ is for pure-bred (code 1) or for cross-bred female progeny (code 2) or for both groups (code 0).

- Average daily gain of pure-bred ($j = 1$) or cross-bred ($j = 2$) female progeny ($adgP[7 + i][j]$) in fattening to target $i$ ($i =1$ to $lf[1]$). In the input for pure-bred progeny, type 0 for average daily gain if the code $clf[1][i] = 2$. In the input for cross-bred progeny, type 0 for average daily gain if the code $clf[1][i] = 1$. That means, if the given breeding type is not fattened to the given target, zeros indicate missing values.

- Survival rate of pure-bred ($i = 1$) or cross-bred ($i = 2$) female progeny in fattening to target $i$ ($surfat[1][i][j]$, $i = 1, \ldots, lf[1]$)

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[2]See footnote 1.

The following inputs are read only if there is fattening of male progeny.

- In the following two inputs, up to 5 targets for fattening of male progeny have to be defined in the same way as for female progeny through the variables $ulf[2][i]$ and $vlf[2][i]$. The number of targets for fattening ($lf[2]$) must be given in the parameter file PARAS.TXT on page 137.

- In the next input, the code for target $i$ ($i =$1 to $lf[2]$) is given ($clf[2][i]$) that determines if the given target $i$ is for pure-bred (code 1) or for cross-bred male progeny (code 2) or for both groups (code 0).

- Average daily gain of pure-bred ($j = 1$) or cross-bred ($j = 2$) male progeny ($adgP[32 + i][j]$) in fattening to target $i$ ($i =$1 to $lf[2]$). In the input for pure-bred progeny, type 0 for average daily gain if the code $clf[2][i] = 2$. In the input for cross-bred progeny, type 0 for average daily gain if the code $clf[2][i] = 1$. That means, if the given breeding type is not fattened to the given target, zeros indicate missing values.

- Survival rate of pure-bred ($j = 1$) or cross-bred ($j = 2$) male progeny in fattening to target $i$ ($surfat[2][i][j]$, $i = 1, \ldots, lf[2]$)

The following inputs are read only if there is fattening of castrates.

- In the following two inputs, up to 5 targets for fattening of castrates have to be defined in the same way as for female progeny through the variables $ulf[0][i]$ and $vlf[0][i]$.. The number of targets for fattening ($lf[0]$) must be given in the parameter file PARAS.TXT on page 137.

- In the next input, the code for target $i$ ($i =$1 to $lf[0]$) is given ($clf[0][i]$) that determines if the given target $i$ is for pure-bred (code 1) or for cross-bred castrates (code 2) or for both groups (code 0).

- Fraction of pure-bred ($j = 1$) or cross-bred ($j = 2$) castrates ($psp[0][i][j]$) fattened to to target $i$ ($i = 1, \ldots, lf[0]$). The input values must sum to 1. In the program they are recalculated so that they are expressed as fraction of the weaned surplus male progeny so that holds $\sum_{i=1}^{lf[0]} psp[0][i][j] = psp[2][3][j]$ for $j = 1, 2$.

- Average daily gain of pure-bred ($j = 1$) or cross-bred ($j = 2$) castrates ($adgP[42 + i][j]$) in fattening to target $i$ ($i =$1 to $lf[0]$). In the input for pure-bred progeny, type 0 for average daily gain if the code $clf[0][i] = 2$. In the input for cross-bred progeny, type 0 for average daily gain if the code $clf[0][i] = 1$. That means, if the given breeding type is not fattened to the given target, zeros indicate missing values.

- Survival rate of pure-bred ($j = 1$) or cross-bred ($j = 2$) castrates in fattening to target $i$ ($surfat[0][i][j]$, $i = 1, \ldots, lf[0]$)

### 14.2.5 Input file INPUTS04.TXT

This file contains input parameters for the progeny of the ewe flock reared for breeding for the interval from weaning to mature weight or to selling. These parameters are needed for calculating the structure of the progeny and for the description of growth. The file includes values for pure-bred and cross-bred progeny. The individual parameters are read only if they are relevant for the given production system.

- Mature weight of ewes. If crossing is applied, two values are given, for the pure-bred ewe in the flock ($mwE[1]$) and for the breed the rams of which are used for crossing in the flock ($mwE2$).

- Proportion of mature weight at which pure-bred ($i = 1$) or cross-bred ($i = 2$) female progeny can be mated for the first time ($pwrepFP[i]$)[3]

- Average daily gain of pure-bred ($j = 1$) or cross-bred ($j = 2$) female breeding progeny from weaning (for $i = 1$) or from breeding season $i - 1$ (for $i > 1$) to breeding season $i$ ($adgr[1][i][j]$, $i = 1, \ldots, bs[1] - 1$).

- Coefficient of variation of the weight of pure-bred ($j = 1$) or cross-bred ($j = 2$) female breeding progeny in the first breeding season ($sigmawr[1][j]$)

- Reared pure-bred ($j = 1$) or cross-bred ($j = 2$) female progeny intended for selling as breeding animals before mating as proportion of surplus weaned female progeny intended for selling ($psold[1][0][j]$)

- Conception rate of pure-bred ($j = 1$) or cross-bred ($j = 2$) female progeny in the individual breeding seasons ($conrateFP[i][j]$, $i = 1, \ldots, bs[1]$)

- Fraction of barren pure-bred ($j = 1$) or cross-bred ($j = 2$) female progeny after breeding season $i$ kept to the next breeding season ($pbarrFP[i][j]$, $i = 1, \ldots, bs[1] - 1$)

- Survival rate of pure-bred ($j = 1$) or cross-bred ($j = 2$) female progeny from weaning (for $i = 1$) or from breeding season $i - 1$ (for $i > 1$) to breeding season $i$ ($surbs[1][i][j]$, $i = 1, \ldots, bs[1]$)

- Survival rate of pure-bred ($i = 1$) or cross-bred ($i = 2$) female progeny from mating to lambing ($surmlFP[i]$)

- Length of pregnancy ($lpreg$)

- Live weight gain during flushing of ewes ($wgfE$)

- Live weight gain during flushing of female breeding lambs ($wgfL$)

- Age of pure-bred ($i = 1$) or cross-bred ($i = 2$) breeding female lambs sold before the first breeding season ($agetP[13][i]$). The age must be between the age of lambs at weaning or at the end of artificial rearing and the age at the beginning of the 1st breeding season.

- Age of pure-bred ($i = 1$) or cross-bred ($i = 2$) breeding female lambs sold between the first and the second breeding season ($agetP[26][i]$).

- Days in pregnancy when pregnant female lambs are sold ($dpregsFP$)

- Interval between the end of the appropriate breeding season and time of culling female lambs for failure to conceive ($dnpregcFP$)

- Fraction of pure-bred females needed for own replacement purchased from outside the flock ($ppurchFP$). This value must be less than 1.

- Fraction of pure-bred males needed for own replacement purchased from outside the flock ($ppurchMP$)[4]

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[3] Note please that variables specific for female progeny only contain "FP" in their name. In variables which are defined both for female and male progeny and, in some cases, also for castrates, the first index indicates the sex where 1 stands for female progeny. In most variables, the index referring to the sex of progeny is the first index.

[4] Note please that variables specific for male progeny only contain "MP" in their name. In variables which are defined both for female and male progeny and, in some cases, also for castrates, the first index indicates the sex where 2 stands for male progeny. In most variables, the index referring to the sex of progeny is the first index.

- Mature weight of rams ($mwR[i]$). If crossing is applied, two values are given, for the pure-bred rams in the flock ($i = 1$) and for the breed rams of which are used for crossing in the flock ($i = 2$).

- Proportion of mature weight at which rams can be used for breeding ($pwrepMP$)

- Average daily gains of pure-bred ($j = 1$) or cross-bred ($j = 2$) male breeding progeny from weaning (for $i = 1$) or from breeding season $i - 1$ (for $i > 1$) to breeding season $i$ ($adgr[2][i][j]$, $i = 1, \ldots, bs[2]$)

- Coefficient of variation of the weight of pure-bred ($j = 1$) or cross-bred ($j = 2$) male breeding progeny at the first breeding season ($sigmawr[2][j]$)

- Reared pure-bred ($j = 1$) or cross-bred ($j = 2$) male progeny intended for selling as breeding animals before the first breeding season as proportion of surplus weaned male progeny intended for selling ($psold[2][1][j]$)

- Survival rate of pure-bred ($j = 1$) or cross-bred ($j = 2$) male progeny from weaning (for $i = 1$) or from breeding season $i-1$ (for $i > 1$) to breeding season $i$ ($surbs[2][i][j]$, $i = 1, \ldots, bs[2]$)

- Culling rate of male progeny from weaning (for $i = 1$) or from breeding season $i - 1$ (for $i > 1$) to breeding season $i$ ($cullbsMP[i][j]$, $i = 1, \ldots, bs[2]$); $bs[2]$ is fixed to 2 in the given version of the program.

- Age of pure-bred ($j = 1$) or cross-bred ($j = 2$) breeding male lambs sold before the first breeding season ($i = 38$) or between the first and second breeding season ($i = 40$) ($agetP[i][j]$)

- Age of purchased pure-bred male for flock replacement ($i = 1$) or of male for crossing in the flock ($i = 2$) ($agepurMP[i]$)

- Weight of purchased pure-bred male for flock replacement ($i = 1$) or of male for crossing in the flock ($i = 2$) ($wpurMP[i]$)

- Ewes to young ram ratio in the breeding season ($ratioyoungR$)

- Ewes to old ram ratio in the breeding season ($ratiooldR$)

- Heterotic effect for mature weight ($hetmw$)

## 14.2.6 Input file INPUTS06.TXT

This file contains input parameters for the calculation of milk production on the basis of the Wood function [28]. It is only read if the lactation curve is known (options 1 or 2 for the type of breed *typeb* in the parameter file PARAS.TXT). The file contains the following input parameters:

- Parameter $a$ ($awo$) for lactation curve (6.1)

- Parameter $b$ ($bwo$) for lactation curve (6.1)

- Parameter $c$ ($cwo$) for lactation curve (6.1)

- Parity for which the lactation curve was defined ($placE$)

- Number of suckled lambs for which the lactation curve was defined ($nsl$)

- Adjustment factors for the lactation curve ($ktlp[i]$) for each parity $i$ ($i = 1, \ldots, LL$)

- Adjustment factors for the lactation curve ($ktlsl[i]$) for the number of suckled lambs $i$ ($i = 0, \ldots, clt$)

- Proportion of milk for sale produced by ewes from lambing till weaning ($pmilkwm$). This parameter is read only for dairy sheep.

- Coefficient expressing the decrease of milk yield in ewes culled for health problems or died during the reproductive cycle in relation to ewes with complete normal lactations ($kmilkcE$)

- Length of the standardized milking period in days ($dmilkst$). This parameter is read only for dairy sheep.

- Proportion of milk produced in the flock for cheese production ($pmilkch$). This parameter is read only for dairy sheep.

The following parameters until the end of the file are only read if cheese is produced.

- Input 1 if the following regression equation is used (the next three parameters) for the calculation of the milk amount needed for 1 kg cheese or input 2 if van Slyke's formula is used ($cy$)

The following three parameters refer to the regression equation (6.16). If the linear relationship is not known, set the regression coefficients to zero and insert only a constant.

- Constant (intercept) in the regression equation ($ach$)

- Regression coefficient for fat content ($bch$)

- Regression coefficient for protein content ($cch$)

The next parameters are needed for van Slyke's formula given in equations (6.17) until (6.19).

- Fat recovered in cheese as fraction ($rfat$)

- Casein recovered in cheese as fraction ($rcas$)

- Casein as fraction of protein in milk ($casprot$)

- Moisture of cheese in % ($moich$)

- Fat content in cheese in % ($fatch$)

## 14.2.7 Input file INPUTS07.TXT

This file contains input parameters for the calculation of milk production if the lactation curve is unknown (option 3 for the type of breed *typeb* in the parameter file PARAS.TXT). The file contains the following input parameters:

- Milk per ewe till weaning ($basemilkw$)

- Parity for which the foregoing milk yield was given ($placE$)

- Number of suckling lambs for which the foregoing milk yield was given ($nsl$)

- Adjustment factors for milk yield according to parity $i$ ($ktlp[i]$, $i = 1, \ldots LL$).

- Adjustment factors for milk yield for the number of suckling lambs $i$ ($ktlsl[i]$, $i = 1, \ldots, clt$).

### 14.2.8  Input file INPUTS08.TXT

This file contains input parameters for calculating the nutrition costs:

- Number of different feeding seasons ($nfs$) during the year (e.g. summer and winter feeding periods, dry and wet feeding periods). The number should not be greater than 4.

- Code of the feeding season on January 1st ($valfs[0]$)

- Number of changes of the feeding season during the year ($nchfs$)

- The following two inputs (Start date of a new feeding season and code of the new feeding season) are replicated as many times as is the number of changes in the feeding season during the year given in the preceding input:

  - Start date of a new feeding season ($datchfs[i]$, $i = 1, \ldots, nchfs$)
  - Code of the new feeding season ($valfs[i]$, $i = 1, \ldots, nchfs$)

- Length of the flushing period for males before starting the breeding season ($flushbbR$)

- Time interval from the end of breeding season to selling of breeding rams ($dselR$)

- Average temperature during feeding season $i$ of the year ($tp[i]$ for $i = 1, \ldots, nfs$)

- Dry matter in feeding rations for rams ($drymR[i][j]$ for $i = 1, \ldots, fR$ and $j = 1, \ldots, nfs$)

- Net energy content in dry matter of feeding rations for rams ($nedR[i][j]$ for $i = 1, \ldots, fR$ and $j = 1, \ldots, nfs$)

- Protein content in dry matter of feeding rations for rams ($pdidR[i][j]$ for $i = 1, \ldots, fR$ and $j = 1, \ldots, nfs$)

- Feed losses through wasting for feeding rations for rams ($lossfR[i][j]$ for $i = 1, \ldots, fR$ and $j = 1, \ldots, nfs$)

- Price for fresh feed for feeding rations for rams ($prfR[i][j]$ for $i = 1, \ldots, fR$ and $j = 1, \ldots, nfs$)

- Length of the flushing period of ewes before the breeding season ($flushbbE$)

- Length of the flushing period of ewes after the start of the breeding season ($flushabE$)

- Interval from the end of the breeding season to culling of ewes for failure to conceive ($dnpregcE$)

- Husbandry system in the ewe flock in individual seasons ($techE[i]$, $i = 1, \ldots, nfs$, 1: housed ewes, 2: lowland ewes out-of-doors, 3: ewes on hill grazing, the first number is for the season starting on 1 January)

- Coefficient for activity allowance for housed ewes ($ktE[1]$)[5]

- Coefficient for activity allowance for lowland ewes out-of-door ($ktE[2]$)

- Coefficient for activity allowance for ewes on hill grazing ($ktE[3]$)

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[5]For details see [2].

- Length of period of high pregnancy where a special feeding ration is applied to ewes ($dshpE$)

- Fat content in milk ($fat$)

- Protein content in milk ($prot$)

- Dry matter in feeding rations for ewes ($drymE[i][j]$ for $i = 1, \ldots, fE$ and $j = 1, \ldots, nfs$)

- Net energy content in dry matter of feeding rations for ewes ($nedE[i][j]$ for $i = 1, \ldots, fE$ and $j = 1, \ldots, nfs$)

- Protein content in dry matter of feeding rations for ewes ($pdidE[i][j]$ for $i = 1, \ldots, fE$ and $j = 1, \ldots, nfs$)

- Feed losses through wasting for feeding rations for ewes ($lossfE[i][j]$ for $i = 1, \ldots, fE$ and $j = 1, \ldots, nfs$)

- Price for fresh feed for feeding rations for ewes ($prfE[i][j]$ for $i = 1, \ldots, fE$ and $j = 1, \ldots, nfs$)

- Husbandry system for rearing breeding lambs in individual seasons ($techbL[i]$, 1: housed lambs, 2: lowland lambs out-of-doors, 3: lambs on hill grazing)

- Husbandry system for fattened lambs in individual seasons ($techfatL[i]$, the same codes as in the husbandry system for rearing breeding lambs are used.)

- Daily wool production per lamb till weaning ($dwoolptwL$)

- Coefficients for activity allowance for housed in-door lambs, lowland lambs out-of-door and lambs on hill grazing ($ktL[1]$ to $ktL[3]$)

- Net energy content of milk (nutrition value for lambs, $nemilk$)

- Protein content (PDI) in milk (nutrition value for lambs, $pdimilk$)

- Dry matter content in fresh matter for all seasonal variants $i = 1, \ldots, nfs$ of supplemental feeding ration 1 for lambs till weaning ($drymL[1][i]$)

- Net energy content in dry matter for all seasonal variants $i = 1, \ldots, nfs$ of supplemental feeding ration 1 for lambs till weaning ($nedL[1][i]$)

- Protein content in dry matter for all seasonal variants of supplemental feeding ration 1 for lambs till weaning ($pdidL[1][i]$)

- Feed losses through wasting for all seasonal variants of supplemental feeding ration 1 for lambs till weaning ($lossfL[1][i]$)

- Price of fresh matter for all seasonal variants of supplemental feeding ration 1 for lambs till weaning ($prfL[1][i]$)

The next six inputs are only read if there is artificial rearing.

- Daily wool production per lamb in artificial rearing ($dwoolptarL$)

- Dry matter content in fresh matter for all seasonal variants of feeding ration 2 for lambs from weaning to the end of artificial rearing ($drymL[2][i]$)

- Net energy content in dry matter for all seasonal variants of feeding ration 2 for lambs from weaning to the end of artificial rearing ($nedL[2][i]$)

- Protein content in dry matter for all seasonal variants of feeding ration 2 for lambs from weaning to the end of artificial rearing ($pdidL[2][i]$)

- Feed losses through wasting for all seasonal variants of feeding ration 2 for lambs from weaning to the end of artificial rearing ($lossfL[2][i]$)

- Price of fresh matter for all seasonal variants of feeding ration 2 for lambs from weaning to the end of artificial rearing ($prfL[2][i]$)

- Daily wool production of a female ($i = 1$) or male ($i = 2$) pure-bred ($j = 1$) or cross-bred ($j = 2$) lamb in the rearing period ($dwoolptrL[i][j]$)

- Dry matter content in fresh matter for all seasonal variants of feeding ration 3 (flushing) for female breeding lambs ($drymL[3][i]$)

- Net energy content in dry matter for all seasonal variants of feeding ration 3 (flushing) for female breeding lambs ($nedL[3][i]$)

- Protein content in dry matter for all seasonal variants of feeding ration 3 (flushing) for female breeding lambs ($pdidL[3][i]$)

- Feed losses through wasting for all seasonal variants of feeding ration 3 (flushing) for female breeding lambs ($lossfL[3][i]$)

- Price of fresh matter for all seasonal variants of feeding ration 3 (flushing) for female breeding lambs ($prfL[3][i]$)

- Dry matter content in fresh matter for all seasonal variants of feeding ration 4 for female and male breeding lambs ($drymL[4][i]$)

- Net energy content in dry matter for all seasonal variants of feeding ration 4 for female and male breeding lambs ($nedL[4][i]$)

- Protein content in dry matter for all seasonal variants of feeding ration 4 for female and male breeding lambs ($pdidL[4][i]$)

- Feed losses through wasting for all seasonal variants of feeding ration 4 for female and male breeding lambs ($lossfL[4][i]$)

- Price of fresh matter for all seasonal variants of feeding ration 4 for female and male breeding lambs ($prfL[4][i]$)

- Dry matter content in fresh matter for all seasonal variants of feeding ration 5 (high pregnancy) for female breeding lambs ($drymL[5][i]$)

- Net energy content in dry matter for all seasonal variants of feeding ration 5 (high pregnancy) for female breeding lambs ($nedL[5][i]$)

- Protein content in dry matter for all seasonal variants of feeding ration 5 (high pregnancy) for female breeding lambs ($pdidL[5][i]$)

- Feed losses through wasting for all seasonal variants of feeding ration 5 (high pregnancy) for female breeding lambs ($lossfL[5][i]$)

- Price of fresh matter for all seasonal variants of feeding ration 5 (high pregnancy) for female breeding lambs ($prfL[5][i]$)

- Length of the flushing period of female breeding lambs before the breeding season ($flushbbL$)

- Length of the flushing period of female breeding lambs after the start of the breeding season ($flushabL$)

The next five inputs are needed only if fattening of female lambs exists. The number of rows for each parameter is given by the number of targets for fattened females $lf[1]$ and the number of columns is given by the number of seasonal variants $nfs$. Index $k$ is the feeding ration and index $i$ is the seasonal variant.

- Dry matter content in fresh matter for all seasonal variants of feeding rations 6 to $5 + lf[1]$ ($lf[1] \leq 5$) for fattening of female lambs ($drymL[k][i]$)

- Net energy content in dry matter for all seasonal variants of feeding rations 6 to $5 + lf[1]$ for fattening of female lambs ($nedL[k][i]$)

- Protein content in dry matter for all seasonal variants of feeding rations 6 to $5 + lf[1]$ for fattening of female lambs ($pdidL[k][i]$)

- Feed losses through wasting for all seasonal variants of feeding rations 6 to $5 + lf[1]$ for fattening of female lambs ($lossfL[k][i]$)

- Price of fresh matter for all seasonal variants of feeding rations 6 to $5 + lf[1]$ for fattening of female lambs ($prfL[k][i]$)

The next five inputs are needed only if fattening of male lambs exists. The number of rows for each parameter is given by the number of targets for fattened males $lf[2]$ and the number of columns is given by the number of seasonal variants $nfs$.

- Dry matter content in fresh matter for all seasonal variants of feeding rations 11 to $10 + lf[2]$ ($lf[2] \leq 5$) for fattening of male lambs ($drymL[k][i]$)

- Net energy content in dry matter for all seasonal variants of feeding rations 11 to $10 + lf[2]$ for fattening of male lambs ($nedL[k][i]$)

- Protein content in dry matter for all seasonal variants of feeding rations 11 to $10 + lf[2]$ for fattening of male lambs ($pdidL[k][i]$)

- Feed losses through wasting for all seasonal variants of feeding rations 11 to $10 + lf[2]$ for fattening of male lambs ($lossfL[k][i]$)

- Price of fresh matter for all seasonal variants of feeding rations 11 to $10 + lf[2]$ for fattening of male lambs ($prfL[k][i]$)

The next five inputs are needed only if fattening of castrates exists. The number of rows for each parameter is given by the number of targets for fattened males $lf[0]$ and the number of columns is given by the number of seasonal variants $nfs$.

- Dry matter content in fresh matter for all seasonal variants of feeding rations 16 to $15 + lf[0]$ ($lf[0] \leq 5$) for fattening of castrates ($drymL[k][i]$)

- Net energy content in dry matter for all seasonal variants of feeding rations 16 to $15 + lf[0]$ for fattening of castrates ($nedL[k][i]$)

- Protein content in dry matter for all seasonal variants of feeding rations 16 to $15 + lf[0]$ for fattening of castrates ($pdidL[k][i]$)

- Feed losses through wasting for all seasonal variants of feeding rations 16 to $15 + lf[0]$ for fattening of castrates ($lossfL[k][i]$)

- Price of fresh matter for all seasonal variants of feeding rations 16 to $15 + lf[0]$ for fattening of castrates ($prfL[k][i]$)

The following inputs refer to water requirement of ewes, rams and lambs.

- Amount of water per day per ewe for all seasonal variants of feeding rations 1 to 5. One row corresponds to one feeding ration and the numbers within the row refer to the seasonal variants of the feeding rations. Enter equal numbers of all seasonal variants within a feeding ration if there are no differences in the water amount between seasons ($dwatE[k][i]$)

- Amount of water per day per ram for all seasonal variants of feeding rations 1 to 2 ($dwatR[k][i]$)

- Amount of water per day per lamb for all seasonal variants of feeding ration 1 ($dwatL[1][i]$)

- Amount of water per day per lamb for all seasonal variants of feeding ration 2 ($dwatL[2][i]$). These data are read only of there is artificial rearing.

- Amount of water per day per lamb for all seasonal variants of feeding rations 3 to 5 ($dwatL[k][i]$)

- Amount of water per day per fattened female lamb for all seasonal variants of feeding rations 6 to $5 + lf[1]$ ($dwatL[k][i]$). These data are only read if there is fattening of female lambs.

- Amount of water per day per fattened male lamb for all seasonal variants of feeding rations 11 to $10+lf[2]$ ($dwatL[k][i]$). These data are only read if there is fattening of male lambs.)

- Amount of water per day per fattened female lamb for all seasonal variants of feeding rations 16 to $15 + lf[0]$ ($dwatL[k][i]$). These data are only read if there is fattening of castrates.

- Price for water ($prwat$)

### 14.2.9  Input file INPUTS09.TXT

This file contains input parameters for the calculation of non-feed costs in the sheep flock and in lamb fattening. First the parameters for ewes are given:

- Number of drenchings against worm (endo-parasites) per ewe per reproductive cycle ($nendopE$)

- Costs for drugs against worm (endo-parasites) per kg life weight and per drenching ($prendop$)

- Number of treatments against ecto-parasites per ewe per reproductive cycle ($nectopE$)

- Costs for drugs against ecto-parasites per treatment and per animal ($prectopE$)

- Average costs for veterinary service and drugs (except for parasite treatment) per ewe per reproductive cycle ($vetE$)

- Number of man-hours per ewe and year including lambs till weaning and excluding milking and cheese production ($AkhE$)

- Cost per man-hour including insurance ($costAkh$)

- Number of shearings per ewe per reproductive cycle ($nsheE$)

- Cost per shearing per ewe ($costshe0E$)

- Other miscellaneous costs independent on animal performance (fixed costs) per stable place per day for ewes including lambs till weaning ($costfix0E$)

- Amount of material for bedding per housed ewe (including lambs till weaning) per day ($strawE$)

- Price of material for bedding ($prstraw$)

- Proportion of insemination in ewes intended for pure-breeding and for cross-breeding ($pinsE[j]$)

- Cost per insemination (price for dose and labour) for pure-breeding and cross-breeding ($costins[j]$)

- Costs per re-insemination for pure-breeding and cross-breeding ($costreins[j]$)

- Number of re-inseminations per oestrus ($nreins$)

- Average conception rate of ewes after insemination ($coninsE$)

- Cost for induction and oestrus synchronisation per ewe and reproductive cycle ($costoeinE$)

- Costs for tanning skin ($costtan$)

- Proportion of culled ewes that give skin to the shepherd ($pskE$)

- Proportion of skins of ewes which are sold as tanned skin ($ptskE$)

- Marketing costs (e.g. transport, advertising) per animal to be culled ($costmarkcul$)

- Cost for removing and rendering a dead animal of any category ($costdead$)

- Cost for milking per kg milk (variable costs, e.g. energy for cooling, labour, etc. ($costmilk0E$))

- Cost for processing 1 kg milk to cheese (facilities, labour, etc. without costs for milk) ($costcheese0E$)

The next part of the file contains the parameters for rams:

- Number of drenchings against worm (endo-parasites) per ram per reproductive cycle ($nendopR$)

- Number of treatments against ecto-parasites per ram per reproductive cycle ($nectopR$)

- Average costs for veterinary service and drugs (except of parasite treatment) per ram and reproductive cycle ($vetR$)

- Number of man-hours per ram and year ($AkhR$)

- Number of shearings per ram of the breed of the flock and of the breed used for crossing in the flock, per reproductive cycle ($nsheR[j]$)

- Cost for shearing a ram ($costshe0R$)

- Other miscellaneous costs independent on animal performance (fixed costs) per stable place per day for rams ($costfix0R$)

- Amount of material for bedding per ram per day ($strawR$)

- Proportion of culled rams that give skin to the shepherd ($pskR$)

- Proportion of skins of rams which are sold as tanned skin ($ptskR$)

- Marketing costs (e.g. transport, advertising) per breeding ram ($costmarkbR$)

- Price per breeding ram purchased for pure-breeding ($j = 1$) or cross-breeding ($j = 2$) ($prbR[j]$)

Here start the parameters for lambs.

- Costs per shearing of a lamb ($costshe0L$)

- Marketing costs (e.g. transport, advertising) per kg live weight of lambs sold at weaning or at the end of artificial rearing ($costmarkwL$)

- Number of drenchings against worm (endo-parasites) per lamb till weaning ($nendopwL$)

- Number of treatments against ecto-parasites per lamb till weaning ($nectopwL$)

- Average costs for veterinary service and drugs (except of parasite treatment) per lamb till weaning ($vetwL$)

- Number of shearings per lamb till weaning ($nshewL$)

- Proportion of slaughtered lambs at weaning that give skin to the shepherd ($pskwL$)

- Proportion of skins from lambs slaughtered at weaning sold as tanned skin ($ptskwL$)

- Number of drenchings against worm (endo-parasites) from early weaning till the end of artificial rearing ($nendoparL$)

- Number of treatments against ecto-parasites per lamb from early weaning till the end of artificial rearing ($nectoparL$)

- Average costs for veterinary service and drugs (except of parasite treatment) per lamb in artificial rearing ($vetarL$)

- Number of man-hours per lamb in the period of artificial rearing ($AkharL$)

- Other miscellaneous costs independent on animal performance (fixed costs) per stable place per day for lambs in artificial rearing ($costfixarL$)

- Amount of material for bedding per lamb per day in artificial rearing ($strawarL$)

- Number of shearings per lamb during artificial rearing ($nshearL$)

- Proportion of slaughtered lambs after artificial rearing that give skin to the shepherd ($pskarL$)

- Proportion of skins from lambs slaughtered after artificial rearing sold as tanned skin ($ptskarL$)

- Number of drenchings against worm (endo-parasites) per female or male breeding lamb from weaning or the end of artificial rearing till the 1st breeding season ($nendoprL[1]$)

- Number of drenchings against worm (endo-parasites) per female or male breeding lamb from the 1st to 2nd or from the 2nd to 3rd breeding season ($nendoprL[2]$)

- Number of drenchings against worm (endo-parasites) per female breeding lamb from conceiving to lambing (*nendopclFP*)

- Number of treatments against ecto-parasites per female or male breeding lamb from weaning or the end of artificial rearing till the 1st breeding season (*nectoprL*[1])

- Number of treatments against ecto-parasites per female or male breeding lamb from the 1st to 2nd or from the 2nd to 3rd breeding season (*nectoprL*[2])

- Number of treatments against ecto-parasites per female breeding lamb from conceiving to lambing (*nectopclFP*)

- Average costs for veterinary service and drugs (except of parasite treatment) per female or male breeding lamb from weaning (or the end of artificial rearing) till the 1st breeding season (*vetrL*[1])

- Average costs for veterinary service and drugs (except of parasite treatment) per female or male breeding lamb from the 1st to the 2nd or from the 2nd to the 3rd breeding season (*vetrL*[2])

- Average costs for veterinary service and drugs (except of parasite treatment) per female breeding lamb from conceiving to lambing (*vetclFP*)

- Number of man-hours per female or male breeding lamb in rearing per year (*AkhrL*)

- Number of shearings per female (or male) breeding lamb in rearing from weaning or the end of artificial rearing till breeding season 1 and from breeding season $i$ to breeding season $i+1$ (*nsherL*[i], $i = 1, \ldots, bs[1] - 1$)

- Number of shearings per female breeding lamb from conceiving to lambing (*nsheFP*)

- Other miscellaneous costs independent on animal performance (fixed costs) per stable place per day per female or male breeding lamb (*costfixrL*)

- Amount of material for bedding per male or female breeding lamb in rearing per day if lambs are housed (*strawrL*)

- Proportion of insemination in pure-bred and cross-bred female lambs (*pinsFP*[j])

- Cost for induction and oestrus synchronisation per female lamb per breeding season (*costoeinFP*)

- Proportion of slaughtered breeding lambs that give skin to the shepherd (*pskrL*)

- Proportion of skins of slaughtered breeding lambs sold as tanned skin (*ptskrL*)

- Marketing costs (e.g. transport, advertising) per female and male breeding lamb (*costmarkrL*[i])

- Number of drenchings against worm (endo-parasites) per female lamb in fattening to target $l$ (*nendopf*[1][l], $l = 1, \ldots, lf[1]$)

- Number of treatments against ecto-parasites per female lamb in fattening to target $l$ (*nectopf*[1][l], $l = 1, \ldots, lf[1]$)

- Average costs for veterinary service and drugs (except of parasite treatment) per female lamb in fattening to target $l$ (*vetf*[1][l], $l = 1, \ldots, lf[1]$)

- Number of shearings per female lamb in fattening to target $l$ ($nshefL[1][l]$, $l = 1, \ldots, lf[1]$)

- Number of drenchings against worm (endo-parasites) per male lamb in fattening to target $l$ ($nendopf[2][l]$, $l = 1, \ldots, lf[2]$)

- Number of treatments against ecto-parasites per male lamb in fattening to target $l$ ($nectopf[2][l]$, $l = 1, \ldots, lf[2]$)

- Average costs for veterinary service and drugs (except of parasite treatment) per male lamb in fattening to target $l$ ($vetf[2][l]$, $l = 1, \ldots, lf[2]$)

- Number of shearings per male lamb in fattening to target $l$ ($nshefL[2][l]$, $l = 1, \ldots, lf[2]$)

- Number of drenchings against worm (endo-parasites) per castrate in fattening to target $l$ ($nendopf[0][l]$, $l = 1, \ldots, lf[0]$)

- Number of treatments against ecto-parasites per castrate in fattening to target $l$ ($nectopf[0][l]$, $l = 1, \ldots, lf[0]$)

- Average costs for veterinary service and drugs (except of parasite treatment) per castrate in fattening to target $l$ ($vetf[0][l]$, $l = 1, \ldots, lf[0]$)

- Number of shearings per castrate in fattening to target $l$ ($nshefL[0][l]$, $l = 1, \ldots, lf[0]$)

- Number of man-hours per male or female lamb or castrate in fattening per year ($AkhfL$)

- Other miscellaneous costs independent on animal performance (fixed costs) per stable place per day for lambs in fattening ($costfixfL$)

- Amount of material for bedding per female or male lamb or castrate in fattening per day if lambs are housed ($strawfL$)

- Proportion of lambs slaughtered after fattening that give skin to the shepherd ($pskfL$)

- Proportion of skins of lambs slaughtered after fattening sold as tanned skin ($ptskfL$)

- Marketing costs (e.g. transport, advertising) per kg live weight of lambs sold after fattening ($costmarkfL$)

- Price coefficient for purchasing female replacement. The coefficient expresses the relative price of purchased replacement compared to the costs of own replacement ($kdif$)

### 14.2.10   Input file INPUTS10.TXT

This file contains input parameters for calculating revenues except of revenues from slaughter animals and milk:

- Price per kg wool of ewes ($prwoolE$)

- Amount of wool gained per shearing per ewe ($wsheE$)

- Price per raw skin of ewes ($prskrE$)

- Price per tanned skin of ewes ($prsktE$)

- Daily amount of manure per ewe (including lambs till weaning) if the ewes are housed ($manE$)

- Price per kg sheep manure ($prman$)

- Price per kg wool of rams of breed $j$ ($prwoolR[j]$ where $j = 1$ : rams for pure-breeding, $j = 2$ : rams for cross-breeding)

- Amount of wool gained per shearing per ram of breed $j$ ($wsheR[j]$ where $j = 1$ : rams for pure-breeding, $j = 2$ : rams for cross-breeding)

- Price per raw skin from rams of breed $j$ ($prskrR[j]$ where $j = 1$ : rams for pure-breeding, $j = 2$ : rams for cross-breeding)

- Price per tanned skin from rams of breed $j$ ($prsktR[j]$ where $j = 1$ : rams for pure-breeding, $j = 2$ : rams for cross-breeding)

- Amount of manure per ram per day ($manR$)

- Price per sold ram of the breed of the flock ($prsbR[1]$)

- Price per sold ram of the breed used for crossing in the flock ($prsbR[2]$)

- Price per kg wool of pure-bred ($j = 1$) or cross-bred ($j = 2$) lambs ($prwoolL[j]$)

- Amount of wool gained per shearing per pure-bred ($j = 1$) or cross-bred ($j = 2$) female ($s = 1$) or male ($s = 2$) lamb until weaning ($wshewL[s][j]$)

- Amount of wool gained per shearing per pure-bred ($j = 1$) or cross-bred ($j = 2$) female ($s = 1$) or male ($s = 2$) lamb during artificial rearing ($wshearL[s][j]$)

- Amount of wool gained per shearing per pure-bred ($j = 1$) or cross-bred ($j = 2$) female ($s = 1$) or male ($s = 2$) lamb or castrate ($s = 0$) in fattening ($wshefL[s][j]$)

- Amount of wool gained per shearing per reared pure-bred ($j = 1$) or cross-bred ($j = 2$) breeding female ($s = 1$) or male ($s = 2$) lamb ($wsherL[s][j]$)

- Price per raw skin of pure-bred ($j = 1$) and cross-bred ($j = 2$) lambs ($prskrL[j]$)

- Price per tanned skin of pure-bred ($j = 1$) and cross-bred ($j = 2$) lambs ($prsktL[j]$)

- Daily amount of manure per female or male lamb or castrate in fattening if animals are housed ($manfL$)

- Daily amount of manure per lamb in artificial rearing ($manarL$)

- Daily amount of manure per male or female breeding lamb in rearing if animals are housed ($manbL$)

- Option for the price for breeding lambs. Insert 1 if the price for breeding lambs is given per animal or insert 2 if the price for breeding lambs is given per kg live weight.

The following 4 items (8 inputs in the input file) are read only if the price for breeding lambs is given per animal.

- Price per sold pure-bred ($j = 1$) or cross-bred ($j = 2$) breeding female before mating (category 13, age $< 1$ year, $revsbL[13][j]$)[6]

---

[6] The price per sold breeding animal is identical to the revenues $revsbL[i][j]$ of the given category. Therefore, no special variables are introduced for the price but the values are read directly to the corresponding revenues. This is also valid for the following three inputs.

- Price per not mated pure-bred ($j = 1$) or cross-bred ($j = 2$) breeding female (category 26) sold between the first and the second breeding season ($revsbL[26][j]$)

- Price per sold pregnant pure-bred ($j = 1$) and cross-bred ($j = 2$) breeding female lamb conceived in the 1st, 2nd or 3rd breeding season after its weaning (categories $i = 15$, 19 and 23, respectively, $revsbL[i][j]$)

- Price per sold pure-bred ($j = 1$) and cross-bred ($j = 2$) breeding male lamb before the 1st or 2nd breeding season after its weaning (categories $i = 38$ and 40, respectively, $revsbL[i][j]$)

The following 4 items (8 inputs in the input file) are read only if the price for breeding lambs is given per kg live weight.

- Price for sold pure-bred ($j = 1$) or cross-bred ($j = 2$) breeding females before mating (category 13, age $< 1$ year, $prsbL[13][j]$)

- Price for not mated pure-bred ($j = 1$) or cross-bred ($j = 2$) breeding females (category 26) sold between the first and the second breeding season ($prsbL[26][j]$)

- Price for sold pregnant pure-bred ($j = 1$) and cross-bred ($j = 2$) breeding female lambs conceived in the 1st, 2nd or 3rd breeding season after its weaning (categories $i = 15$, 19 and 23, respectively, $prsbL[i][j]$)

- Price for sold pure-bred ($j = 1$) and cross-bred ($j = 2$) breeding male lambs before the 1st or 2nd breeding season after its weaning (categories $i = 38$ and 40, respectively, $prsbL[i][j]$)

- Governmental subsidy per sold breeding ram ($subR$)

- Governmental subsidy per ewe and year ($subE$)

## 14.2.11   Input file INPUTS11.TXT

This file is needed only for dairy sheep ($typeb = 1$ in parameter file PARAS.TXT) and contains parameters which are needed for the calculation of the milk price, revenues from milk and cheese. According to the option for the calculation of the milk price (see Section 11.1), different sets of parameters are read. The value of the parameters which are not read in the given run is of no impact on the results; they can be simply ignored. The parameters mainly refer to fat and protein content in milk and to somatic cell count or somatic cell score. A great variety of pricing systems can be parametrised by this file. The following input parameters in Parts A to E are to be specified in dependence of the parameter *milkprice*, the option for the calculation of the milk price:

- Option for the calculation of the milk price (*milkprice*)

  - 1: The milk price does neither depend on the somatic cell count nor on the protein and/or the fat content.
  - 2: The milk price depends only on somatic cell count.
  - 3: The milk price depends only on the protein and/or fat content.
  - 4: The milk price depends on both somatic cell count (SCC) and fat and/or protein content. The base prices for quality classes according to SCC are set first and then these prices are corrected for fat and/or protein content.

- 5: The milk price depends on both somatic cell count (SCC) and fat and/or protein content. The base price for milk (milk carrier or milk with given fat and/or protein content) is determined first. Then this price is corrected for the real fat and/or protein content. In the last step, a further correction of the price for milk quality classes based on SCC is carried out.

**Part A**

- Base price for milk (*prmilkb*). This is the milk price not taking into account the fat and protein content and the somatic cell score. Its value is read for *milkprice* = 1, 3 or 5. The base price for milk is set to zero if *milkprice* = 2 or 4.

**Part B** The following part of the input file (until the next comment commencing with "/\*") is read only if the option for the calculation of the milk price (*milkprice*) takes one of the following values: 3, 4 or 5.

- Parameter *nfat* for the dependence of the milk price on the milk fat content. Insert -1 if the milk price does not depend on fat content. Insert 0 if the milk price depends linearly over the whole range on fat content (there is only one regression equation). Insert a positive integer (number of threshold values) if the dependence changes at one or more values (threshold values) of the fat content.

- Threshold values for milk fat (*thfat[i]* where $i = 0, \ldots, nfat - 1$). If *nfat* takes values -1 or 0 insert zero. If $nfat > 0$ insert *nfat* threshold values.

- Parameter *nprot* for the dependence of the milk price on the milk protein content. Insert -1 if the milk price does not depend on protein content. Insert 0 if the milk price depends linearly over the whole range on protein content (there is only one regression equation). Insert a positive integer (number of threshold values) if the dependence changes at one or more values (threshold values) of the protein content.

- Threshold values for milk protein (*thprot[i]* where $i = 0, \ldots, nprot - 1$). If *nprot* takes values -1 or 0 insert zero. If $nprot > 0$ insert *nprot* threshold values.

- Constants (intercepts), regression coefficients and reference values for fat content in individual classes (*rf[i][j]*). The whole range of the fat content is divided by the *nfat* threshold values into $nfat+1$ classes where the first class is the range between 0% and the first threshold value, the second class in the range between the first and the second threshold value, ..., and the last class is the range between the last threshold value and 100%. For all classes (rows in the matrix), three numbers have to be given. The first number $b_0$ is a constant (intercept). The second number $b_1$ is the regression coefficient. The third number $x_r$ is a reference value which is subtracted from the fat content. The regression equation has therefore the following form:

$$y = b_0 + b_1(x - x_r) \tag{14.3}$$

where $x$ is the milk fat content and $y$ is the value which is to be added to the basic milk price.

- Constants (intercepts), regression coefficients and reference values for protein content in individual classes (*rp[i][j]*). See explanations above.

- Phenotypic standard deviation for milk fat content ($sigmafat$)

- Phenotypic standard deviation for milk protein content ($sigmaprot$)

**Part C** The next part of the input file is read only if the option for the calculation of the milk price ($milkprice$) takes one of the following values: 2, 4 or 5.

- Mean of somatic cell score in the ewe flock ($mSCS$)

- Phenotypic standard deviation of somatic cell score in the ewe flock ($sigmaSCS$)

- Number of milk quality classes ($nSCC$) according to somatic cell count (this value is automatically set to 1 for $milkprice = 1$ or 3)

- Upper limits for somatic cell count ($tSCC[i]$, where $i = 0, \ldots, nSCC - 1$) in the individual milk quality classes (the 1st class being the best)

**Part D** The following vector of parameters is read for $milkprice = 2$ or 4:

- Vector of base prices per kg milk in quality class $i$ ($prSCC[i]$ with $i = 0$ to $nSCC - 1$ where $nSCC$ is the number of milk quality classes according to somatic cell count)

**Part E** The following matrix of parameters is read only for $milkprice = 5$:

- Multiplicative ($facSCC[i]$) and additive ($prSCC[i]$) adjustment factors for milk quality classes on the basis of SCC . Two parameters must be given for each milk quality class. The first one is used to multiply the milk price calculated before and the second parameter is added to the milk price. For more details see Section .

**Part F** These parameters are read only if there is cheese production ($pmilkch > 0$).

- Price per kg cheese ($prcheese$)

- Price per kg cheese whey ($prwhey$)

### 14.2.11.1 Example for Part A

Assume that the milk price does neither depend on the somatic cell count nor on the protein and/or the fat content. That means, the option for the calculation of the milk price ($milkprice$) is 1 in INPUTS11.TXT. Then besides of the variable $milkprice$ the only parameter read from the file is the basic milk price ($prmilkb$). That means, only the first part of the file is relevant:

```
/* This file is necessary ...  enclosed into quotation marks.*/
1
"Option for the calculation of the milk price
..."
" "
/* Part A: This part is read if the option for the calculation of the milk price takes
one of the following values:  1, 3 or 5 */
0.8
"Base price for milk"
"MU/kg"
```

The rest of the input file is ignored and it does not matter how it looks like.

### 14.2.11.2 Example 1 for Part B

This is an example for modelling the dependence of the milk price on the fat and/or protein content. It is relevant if the option for the calculation of the milk price[7] (variable *milkprice*) takes one of the following values: 3, 4 or 5.

Assume that there is a base milk price paid for milk carrier (milk without fat and protein). For each kg of milk fat, 2.1 MU[8] are paid, that means 0.021 MU per per cent fat ($=$ 10 g fat/kg milk). For each kg of milk protein, 4.2 MU are paid, that means 0.042 MU per per cent protein. Both for fat and protein content, the regression is over the whole range and there is no threshold value. The regression equation for fat content is:

$$y = 0 + 0.021(x - 0) = 0.021x \tag{14.4}$$

Therefore, $b_0 = 0$, $b_1 = 0.021$ and $x_r = 0$. For protein content we get

$$y = 0 + 0.042(x - 0) = 0.042x \tag{14.5}$$

so that $b_0 = 0$, $b_1 = 0.042$ and $x_r = 0$.

The appropriate part of the input file looks therefore as follows:

```
...
/* Part B: ...  For details see the manual.  */
0
"Parameter for the dependence of the milk price on the milk fat content.  ..."
" "
0
"Threshold values for milk fat (the number of values is given by the parameter above)."
"%"
0
"Parameter for the dependence of the milk price on the milk protein content ..."
" "
0
"Threshold values for milk protein (the number of values is given by the parameter above)."
"%"
0 0.021 0
"Constants (intercepts), regression coefficients and reference values for fat content in
individual classes"
"MU/% fat"
0 0.042 0
"Constants (intercepts), regression coefficients and reference values for protein content
in individual classes"
"MU/% protein"
0.47
"Standard deviation for milk fat content"
"%"
0.20
"Standard deviation for milk protein content"
"%"
```

### 14.2.11.3 Example 2 for Part B

This is a second example for modelling the dependence of the milk price on the fat and/or protein content. It is relevant if the option for the calculation of the milk price (variable *milkprice*) takes one of the following values: 3, 4 or 5.

There is a basic milk price paid for milk with given fat (7.5%) and protein (5.8%) content. For fat content greater than 7.5%, 0.021 MU is paid for each additional per cent, for fat content lower than 7.5%, the same value is subtracted from the

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[7]see Section 11.1 on page 109
[8]Monetary units

base price for each per cent. For protein content greater than 5.8%, 0.042 MU is paid for each additional per cent, for protein content lower than 5.8%, the same value is subtracted from the base price for each per cent. There is again only one class for regression. The regression equation for fat content is:

$$y = 0 + 0.021(x - 7.5) = 0.021(x - 7.5) \tag{14.6}$$

so that $b_0 = 0$, $b_1 = 0.021$ and $x_r = 7.5$. For protein content we get

$$y = 0 + 0.042(x - 5.8) = 0.042(x - 5.8) \tag{14.7}$$

that means $b_0 = 0$, $b_1 = 0.042$ and $x_r = 5.8$.
The relevant part of the input file looks therefore as follows:

```
...
/* Part B: This part ...  see the manual.  */
0
"Parameter for the dependence of the milk price on the milk fat content.  ...  "
" "
0
"Threshold values for milk fat (the number of values is given by the parameter above)."
"%"
0
"Parameter for the dependence of the milk price on the milk protein content ...  "
" "
0
"Threshold values for milk protein (the number of values is given by the parameter above)."
"%"
0 0.021 7.5
"Constants (intercepts), regression coefficients and reference values for fat content in
individual classes"
"MU/% fat"
0 0.042 5.8
"Constants (intercepts), regression coefficients and reference values for protein content
in individual classes"
"MU/% protein"
0.47
"Standard deviation for milk fat content"
"%"
0.20
"Standard deviation for milk protein content"
"%"
```

#### 14.2.11.4 Example 3 for Part B

This is the last example for modelling the dependence of the milk price on the fat and/or protein content. It is relevant if the option for the calculation of the milk price (variable *milkprice*) takes one of the following values: 3, 4 or 5.

In this example, there is a penalty of 0.021 MU per per cent of fat content below 7.5%. If fat content is between 7.5 and 8.0%, a bonus of 0.021 MU per percent of fat is paid. For fat content greater than 8.0% no bonus is paid (milk price with fat content above 8.0% is the same as the price for milk with 8.0% fat). This system may be described by one threshold value (8.0%). The payment below and above 7.5% fat (until 8.0% fat) can be described by the following equation:

$$y = 0 + 0.021(x - 7.5) = 0.021(x - 7.5) \tag{14.8}$$

so that $b_0 = 0$, $b_1 = 0.021$ and $x_r = 7.5$. From this equation we calculate for $x = 8.0$ a value of $y = 0.021(8.0 - 7.5) = 0.0105$. Therefore, for a fat content greater than the threshold value 8.0% we get the second regression equation as

$$y = 0.0105 + 0(x - 0) = 0.0105 \tag{14.9}$$

That means that $b_0 = 0.0105$, $b_1 = 0$ and $x_r = 0$.

For milk with a protein content of 5.8%, the base milk price[9] is paid. For each per cent of protein above this value, additional 0.042 MU are paid; for each per cent of protein below this value, the same penalty is subtracted. Therefore, for protein no threshold value is given and the regression is over the whole interval of protein content:

$$y = 0 + 0.042(x - 5.8) = 0.042(x - 5.8) \tag{14.10}$$

so that $b_0 = 0$, $b_1 = 0.042$ and $x_r = 5.8$.

The appropriate part of input file INPUTS11.TXT is then:

```
/* Part B: This part ...  see the manual.  */
1
"Parameter for the dependence of the milk price on the milk fat content.  ...  "
" "
8.0
"Threshold values for milk fat (the number of values is given by the parameter above)."
"%"
0
"Parameter for the dependence of the milk price on the milk protein content ...  "
" "
0
"Threshold values for milk protein (the number of values is given by the parameter above)."
"%"
0 0.021 7.5
0.0105 0 0
"Constants (intercepts), regression coefficients and reference values for fat content in
individual classes"
"MU/% fat"
0 0.042 5.8
"Constants (intercepts), regression coefficients and reference values for protein content
in individual classes"
"MU/% protein"
0.47
"Standard deviation for milk fat content"
"%"
0.20
"Standard deviation for milk protein content"
"%"
```

### 14.2.11.5 Example for part C

This part of the input file is read if the option for the calculation of the milk price[10] (variable *milkprice*) takes one of the following values: 2, 4 or 5. The text of the input file should be sufficiently self-explanatory. Just a short comment. If the number of classes for somatic cell count is 3 then there are 3-1=2 boundaries between the classes. Therefore, the upper limits are given only for classes 1 to 2. Part C of the input file has the form:

```
/* Part C: This part ...  the following values:  2, 4 or 5.  */
5.36
"Mean of somatic cell score in the dairy sheep flock"
" "
1.2
"Phenotypic standard deviation of somatic cell score in the dairy sheep flock"
" "
3
```

---

[9]Comment: The base milk price is an input parameter in Part A of INPUTS11.TXT (*milkprice* = 3 or 5) or is calculated from the prices of the individual milk quality classes (*milkprice* = 4).

[10]See Section 11.1 on page 109.

```
"Number of milk quality classes according to somatic cell content"
" "
300000 750000
"Upper limits for somatic cell count in the individual milk quality classes (the 1st class
being the best)"
"Number of somatic cells/ml milk"
```

#### 14.2.11.6   Example for part D

This part of the input file is read if the option for the calculation of the milk price (variable *milkprice*) is 2 or 4. The number of values given is identical to the number of classes for somatic cell count defined in Part C of the input file. For three classes, Part D looks like that:

```
/* Part D: The following ...  values:  2 or 4.  */
0.88 0.80 0.74
"Vector of base prices per kg milk in quality class i (i=0 to nSCC-1 where nSCC is the
number of milk quality classes according to somatic cell count)"
"MU/kg"
```

#### 14.2.11.7   Example for part E

This part of the input file is read if the option for the calculation of the milk price (variable *milkprice*) is 5. In the example, three milk quality classes on the basis of somatic cell count are assumed. The first class is always assumed to be the best. Assume that the basic milk price was read and corrected for fat and/or protein content. This value be 0.80 MU/kg. In the first class, it is assumed that 0.08 MU/kg were added to this price. That means, the multiplicative adjustment factor is 1 and the additive adjustment factor is 0.08. The milk price in this class is then: $1 \times 0.80 + 0.08 = 0.88$ MU/kg. In the second class, no correction is assumed, i.e. the multiplicative adjustment factor is 1 and the additive adjustment factor is 0. The final milk price is therefore calculated as $1 \times 0.80 + 0 = 0.80$ MU/kg. In the third class, 90% of the original price is payed. The multiplicative adjustment factor is therefore 0.9. The milk price in this class is $0.9 \times 0.80 + 0 = 0.72$ MU/kg. Part E of the input file looks then as follows:

```
/* Part E: The correction ...  manual.  */
1.0 0.08
1.0 0.00
0.9 0.00
"Multiplicative and additive adjustment factors for milk quality classes on the basis of
SCC"
"- MU/kg"
```

### 14.2.12   Input file INPUTS12.TXT

This file contains input parameters for calculating revenues from adult sheep (ewes, rams) and reared breeding lambs sorted out for culling. Data connected with cross-breeding are read only if there is cross-breeding in the system, otherwise they are ignored. The input parameters are:

- Variable indicating the pricing system for adult sheep (*priceS*; 1: according to live weight without taking into account conformation; 2: according to live weight taking into account conformation; 3: according to carcass weight not accounting for carcass quality; 4: according to EU evaluation system with quality classes for fleshiness and fat covering)

Fill in for pricing system 1:

- Price per kg live weight of pure-bred and cross-bred sheep older than 12 months ($prlwS[j]$)

Fill in for pricing system 2:

- Number of quality classes for adult sheep ($nclS$)

- Price per kg live weight of adult sheep in quality classes 1 to $nclS$ ($prclS[i]$)

- Relative frequencies of pure-bred ($j = 1$) or cross-bred ($j = 2$) adult sheep in quality classes 1 to $nclS$ ($pclS[j][i]$). The values must sum up to 1 for each $j$.

Fill in for pricing system 3:

- Price per kg carcass weight of pure-bred or cross-bred adult sheep ($prcwS[j]$)

Fill in for pricing system 4:

- Number of classes for fleshiness for adult sheep ($nclflS$)

- Number of classes for fat covering for adult sheep ($nclfcS$)

- Price per kg carcass weight for the reference class[11] for adult sheep ($prrefS$)

- $nclflS \times nclfcS$ matrix ($prclfcS[i][j]$) for price coefficients for each combination of classes for fleshiness (rows) and fat covering (columns) for adult sheep. The price for each combination of classes is given by multiplying these coefficients with the price for the reference class.

- $nclflS \times nclfcS$ matrix ($pclfcS[1][i][j]$) of relative frequencies of carcasses of pure-bred adult sheep in each combination of classes for fleshiness (rows) and fat covering (columns). The sum of the values must be 1.

- $nclflS \times nclfcS$ matrix ($pclfcS[2][i][j]$) of relative frequencies of carcasses of cross-bred adult sheep in each combination of classes for fleshiness (rows) and for fat covering (columns). The sum of the values must be 1.

Fill in for pricing systems 3 and 4:

- Dressing percentage of culled ewes ($dresE$)

- Dressing percentage of culled rams used for pure-breeding ($j = 1$) or cross-breeding ($j = 2$) in the flock ($dresR[j]$)

- Dressing percentage of pure-bred ($j = 1$) or cross-bred ($j = 2$) breeding lambs culled during rearing ($dresrL[j]$)

## 14.2.13   Input file INPUTS13.TXT

This file contains input parameters for calculating revenues from lambs slaughtered after weaning or artificial rearing (categories 7 and 32). Data connected with cross-breeding are read only if there is cross-breeding in the system, otherwise they are ignored. The input parameters are:

---

[11] The reference class will be mostly, but not necessarily, the best class. The prices for all other classes are then calculated by multiplying the price of the base class with a coefficient given in the following matrix.

- Variable indicating the pricing system for lambs slaughtered after weaning ($pricewL$, 1: according to live weight without taking into account conformation; 2: according to live weight taking into account conformation; 3: according to carcass weight not accounting for carcass quality; 4: according to the EU evaluation system with classes A, B, C for carcass weight and meat quality classes 1 and 2 within the classes for carcass weight for light lambs or according to the EU grading system for fleshiness and fat covering for heavy lambs)

Fill in for pricing system 1:

- Price per kg live weight of lambs slaughtered after weaning or artificial rearing ($prlwwL0$)

Fill in for pricing system 2:

- Number of quality classes for lambs slaughtered after weaning or artificial rearing ($nclwL$)

- Price per kg live weight of lambs slaughtered after weaning or artificial rearing in quality classes $i = 1$ to $nclwL$ ($prclwL[i]$)

- Relative frequencies of pure-bred ($j = 1$) or cross-bred ($j = 2$) lambs slaughtered after weaning or artificial rearing in quality classes $i = 1$ to $nclwL$ ($pclwL[j][i]$). The values must sum up to 1 for each $j$.

Fill in for pricing systems 3 and 4:

- Dressing percentage of pure-bred ($j = 1$) or cross-bred ($j = 2$) lambs slaughtered after weaning or artificial rearing ($dreswL[j]$)

Fill in for pricing system 3:

- Price per kg carcass weight of lambs slaughtered after weaning or after artificial rearing ($prcwwL$)

Fill in for pricing system 4:

- Coefficient of variation for weaning weight or weight at the end of artificial rearing ($vcwwL$)

- Price per kg carcass weight for classes A1, A2, B1, B2, C1 and C2 ($prclcwwL[r][s]$)

- Relative frequencies of pure-bred ($j = 1$) or cross-bred ($j = 2$) lambs in quality classes $s = 1$ and 2 within weight classes A to C ($r = 1, 2, 3$) ($pclcqwL[r][s][j]$)

Fill in for pricing system 4 (the following inputs are needed for lambs heavier than 13 kg which are sold on the basis of a grading system for fleshiness and fat covering):

- Number of classes for fleshiness ($nclflwL$)

- Number of classes for fat covering ($nclfcwL$)

- Price per kg carcass weight for the reference class[12] for lambs slaughtered after weaning or after artificial rearing ($prrefwL$)

---

[12]The reference class will be mostly, but not necessarily the best class. The prices for all other classes are then calculated by multiplying the price of the base class with a coefficient given in the following matrix.

- Matrix for price coefficients ($prclfcwL[i][j]$) for each combination of classes for fleshiness (rows) and fat covering (columns). The price for each combination of classes is given by multiplying these coefficients with the price for the reference class.

- Matrix of relative frequencies of carcasses ($pclfcwL[1][i][j]$) of pure-bred lambs in each combination of classes for fleshiness (rows) and fat covering (columns). The sum of the values must be 1.

- Matrix of relative frequencies of carcasses ($pclfcwL[2][i][j]$) of cross-bred lambs in each combination of classes for fleshiness (rows) and fat covering (columns). The sum of the values must be 1.

## 14.2.14   Input file INPUTS14.TXT

This file contains input parameters for calculating revenues from lambs in fattening (categories 8-12, 33-37 and 43-47). The file is only read if there is fattening in the system. Data connected with cross-breeding are read only if there is cross-breeding in the system, otherwise they are ignored. The input parameters are:

- Variable indicating the pricing system for fattened lambs ($pricefL$) The levels of this variable have the same meaning as the levels of the variable $priceS$, the first input parameter in file INPUTS12.TXT (see Subsection 14.2.12).

Fill in for pricing system 1:

- Price per kg live weight of pure-bred and cross-bred fattened lambs ($prlwfL[j]$)

Fill in for pricing system 2:

- Number of quality classes for fattened lambs ($nclfL$)

- Price per kg live weight of fattened lambs in quality classes 1 to $nclfL$ ($prclfL[i]$)

- Relative frequencies of pure-bred ($j = 1$) or cross-bred ($j = 2$) fattened lambs quality classes 1 to $nclfL$ ($pclfL[j][i]$). The values must sum up to 1 for each $j$.

Fill in for pricing systems 3 and 4:

- Dressing percentage of pure-bred ($j = 1$) and cross-bred ($j = 2$) lambs of sex $s$ ($s = 1$ : females, $s = 2$ : males, $s = 0$ : castrates) fattened to target $l$ ($dresfL[s][l][j]$) where $l = 1, \ldots lf[s]$

Fill in for pricing system 3:

- Price per kg carcass weight of fattened lambs ($prcwfL0$)

Fill in for pricing system 4:

- Number of classes for fleshiness for fattened lambs ($nclflfL$)

- Number of classes for fat covering for fattened lambs ($nclfcfL$)

- Price per kg carcass weight for the reference class[13] for fattened lambs ($prreffL$)

---

[13]The reference class will be mostly, but not necessarily, the best class. The prices for all other classes are then calculated by multiplying the price of the base class with a coefficient given in the following matrix.

- $nclflfL \times nclfcfL$ matrix ($prclfcfL[i][j]$) for price coefficients for each combination of classes for fleshiness (rows) and fat covering (columns) for fattened lambs. The price for each combination of classes is given by multiplying these coefficients with the price for the reference class.

- Two $nclflfL \times nclfcfL$ matrices ($pclfcfL[j][i][k]$) (for pure-bred and cross-bred animals, respectively) of relative frequencies of carcasses of fattened lambs in each combination of classes for fleshiness (rows) and fat covering (columns). The sum of the values must be 1 for each $j$.

## 14.3   TEXTS_OUT.TXT

This file contains texts which are used for printing the results. It contains headings of sections of the results files, comments and names of variables the values of which are printed in the results files. For editing the file read carefully the remarks at the beginning of Chapter .

# Chapter 15

# Program output

## 15.1 The results file

The name of the file the results are written to is determined by the user when starting the program. The first part of the file contains information on the version of the program, copyright and contact to the authors and the values of the system variables read from PARAS.TXT (see Section 14.1). The second part of the file copies more or less the data input files INPUTS*.TXT where '*' is to be replaced by the corresponding numbers. The information read from the input files is selected according to the parameters given in the parameter file. Therefore, the results file does not contain a simple copy of the input files, but only data from input files which will be needed for the given calculation.

The third part of the results file contains the results in the following order:

- Structure of the ewe flock

- Survival and reproduction characteristics of the ewe flock

- Structure of the ram population

- Characteristics of progeny

  - Structure of the progeny
  - Growth characteristics of lambs till weaning
  - Growth characteristics of lambs in artificial rearing
  - Growth characteristics of breeding lambs in rearing

- Weight and age of ewes at lambing

- Weight and age of rams when entering the flock

- Milk production

- Nutrition costs

  - Ewes
  - Rams
  - Lambs

- Non-feed and total costs

  - Ewes

  - Rams of the breed of the flock
  - Rams of the breed used for crossing in the flock
  - Cost per pure-bred lamb till weaning or till the end of artificial rearing
  - Cost per cross-bred lamb till weaning or till the end of artificial rearing
  - Cost per pure-bred female breeding lamb
  - Cost per cross-bred female breeding lamb
  - Cost per pure-bred male breeding lamb
  - Cost per cross-bred male breeding lamb
  - Cost per fattened lamb

- Meat prices and revenues

  - Meat prices
  - Revenues per ewe and reproductive cycle
  - Revenues per ram of the breed of the flock and reproductive cycle
  - Revenues per ram of the breed used for crossing in the flock and per reproductive cycle
  - Revenues per pure-bred lamb till weaning and till the end of artificial rearing
  - Revenues per cross-bred lamb till weaning and till the end of artificial rearing
  - Revenues per pure-bred female breeding lamb
  - Revenues per cross-bred female breeding lamb
  - Revenues per pure-bred male breeding lamb
  - Revenues per cross-bred male breeding lamb
  - Revenues per fattened lamb
  - Revenues per lamb died in fattening

- Summing-up of revenues and costs for some types of animals from birth till selling, till slaughter or till entering the flock

  - Total revenues and costs per replacement female or male
  - Total revenues and costs per sold female or male pure-bred lamb
  - Total revenues and costs per sold female or male cross-bred lamb
  - Final age and weight and total revenues and costs per fattened lamb
  - Total revenues from milk and cheese

- Miscellaneous

  - Mean classes for quality of life animals or for carcass quality for slaughter animals
  - Costs for purchasing replacement

- Profit

- Marginal economic values ($MEV_i$) for all traits $i$. Which value is printed as marginal economic value depends on the option *ewopt* :

$$MEV_i = \begin{cases} ev[i][1] & \text{if } ewopt = 0 \\ ev[i][2] & \text{if } ewopt = 1 \\ ev[i][1] + \frac{1}{2}ev[i][2] & \text{if } ewopt = 2 \end{cases}.$$

**Remark.** A dense network of conditions was used in the program to ensure printing out only the items relevant for the given production system. But it cannot fully be guaranteed that no variables not meaningful for the given calculation slipped through the meshes. In these cases don't worry, as the values of these variables are (hopefully) ignored in the calculation.

## 15.2 Files CHECKS and CHECKS1

The files CHECKS and CHECKS1 are mainly thought as a help in programming. The file CHECKS is printed after loop 1 of the program before the economic values are calculated. The file CHECKS1 is printed after the last loop of the program when all economic values have been calculated. Both files contain only the names and the values of all variables in alphabetic order without further explaining text. The names of all variables are given in Appendix B. Both files should be identical to a great part if the program works correctly. File CHECKS1 contains the economic values additionally to file CHECKS and differs in the number of the loop of the program ($zr$). Further differences should be observed only in temporary variables or should be rounding errors.

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# Appendix A

# Numbering of traits in the program

1. Birth weight

2. Weaning weight. The economic weight is calculated only if there is customary weaning.

3. Average daily gain from birth until weaning. The economic weight is calculated only if there is customary weaning.

4. Weight at the end of artificial rearing. The economic weight is calculated only if there is artificial rearing.

5. Average daily gain in artificial rearing. The economic weight is calculated only if there is artificial rearing.

6. Average daily gain of breeding animals during rearing

7. Average daily gain in fattening. The economic weight is calculated only if there is fattening.

8. Mature weight

9. Dressing percentage of lambs at weaning or at the end of artificial rearing. The economic weight is calculated only if there is a pricing system where dressing percentage is paid for ($pricewL = 3$ or 4).

10. Dressing percentage of fattened lambs. The economic weight is calculated only if there is fattening and if there is a pricing system where dressing percentage is paid for ($pricefL = 3$ or 4).

11. Dressing percentage of adult sheep. The economic weight is calculated only if there is a pricing system where dressing percentage is paid for ($priceS = 3$ or 4).

12. Average quality class for lambs at weaning or at the end of artificial rearing when paid for live weight. The economic weight is calculated only if animals are paid for live weight ($pricewL = 2$).

13. Average quality class for fattened lambs when paid for live weight. The economic weight is calculated only if animals are paid for live weight ($pricefL = 2$).

14. Average quality class for adult sheep when paid for live weight. The economic weight is calculated only if animals are paid for live weight ($priceS = 2$).

15. Average class for fleshiness for adult sheep. The economic weight is calculated only if animals are paid for carcass quality ($priceS = 4$).

16. Average class for fat covering for adult sheep. The economic weight is calculated only if animals are paid for carcass quality ($priceS = 4$).

17. Average class for fleshiness for fattened lambs and/or for heavy lambs (carcass weight > 13 kg) slaughtered after weaning or after artificial rearing. The economic weight is calculated only if animals are paid for carcass quality ($pricefL = 4$ and/or $pricewL = 4$). Lambs slaughtered after weaning are included only for non-dairy breeds ($typeb > 1$).

18. Average class for fat covering for fattened lambs and/or for heavy lambs (carcass weight > 13 kg) slaughtered after weaning or after artificial rearing. The economic weight is calculated only if animals are paid for carcass quality ($pricefL = 4$ and/or $pricewL = 4$). Lambs slaughtered after weaning are included only for non-dairy breeds ($typeb > 1$).

19. Average class for carcass quality for lambs slaughtered after weaning or artificial rearing. The economic weight is calculated only if animals are paid for carcass quality ($pricewL = 4$).

20. Conception rate of female lambs

21. Average conception rate of ewes

22. Average litter size for lambing ewes

23. Average survival rate of lambs at lambing

24. Average survival rate of lambs till weaning. The economic weight is calculated only if there is customary weaning ($typew = 1$).

25. Average survival rate of lambs till the end of artificial rearing. The economic weight is calculated only if there is artificial rearing ($typew = 2$).

26. Average productive lifetime of ewes in numbers of reproductive cycles

27. Average productive lifetime of ewes in years

28. Total milk yield in the standardized milking period

29. Average daily milk yield for the whole milking period

30. Fat content in milk

31. Milk fat yield in the standardized milking period

32. Protein content in milk

33. Milk protein yield in the standardized milking period

34. Somatic cell score

35. Fleece weight

# Appendix B

# List of variables and constants

This list contains all variables used in the program. Some additional variables which are used only in the manual as they are useful for a clear arrangement and which are explained there are not part of the list.

a      Used in the calculation of the stationary state of the ewe flock

a1      Convergence criterion used in the calculation of the stationary state of the ewe flock or the ram population

a2      Temporary variable

a3      Temporary variable

a4      Temporary variable

ach      Constant (intercept) in regression equation (6.16)

adg[i][j]      Temporary variable: Average daily gain for different periods for pure-bred ($j = 1$) or cross-bred ($j = 2$) female ($i = 1$) or male ($i = 2$) lambs

adgb[k][i][j]      Temporary variable: Average daily gain for different periods for pure-bred ($j = 1$) or cross-bred ($j = 2$) female ($k = 1$) or male ($k = 2$) lambs born in litter size $i$ ($i = 1, \ldots, clt$)

adgbwL[k][i][j]      Average daily gain from birth to weaning for pure-bred ($j = 1$) or cross-bred ($j = 2$) female ($k = 1$) or male ($k = 2$) lambs born in litter size $i$ ($i = 1, \ldots, clt$)

adgE      Average daily gain of ewes between first and second lambing

adgfE      Extra daily gain of ewes in the flushing period

adgfL      Extra daily gain of female breeding lambs in the flushing period

adgP[i][j]      Average daily gain of category $i$ ($i = 1, ..., PP$) of pure-bred ($j = 1$) or cross-bred ($j = 2$) progeny

adgR[i]      Average daily gain of rams of the breed of the flock ($i = 1$) or of rams of the breed used for crossing in the flock ($i = 2$) between the first and second breeding cycle

adgr[k][i][j] Average daily gain of pure-bred ($j = 1$) or cross-bred ($j = 2$) female ($k = 1$) or male ($k = 2$) breeding progeny from weaning to the first breeding season ($i = 1$) and from breeding season $i - 1$ to breeding season $i$ ($i = 2, \ldots, bs[k]$)

adgwarL[k][i][j] Average daily gain from weaning to the end of artificial rearing for pure-bred ($j = 1$) or cross-bred ($j = 2$) female ($k = 1$) or male ($k = 2$) lambs born in litter size $i$ ($i = 1, \ldots, clt$)

agearL Age of lambs at the end of artificial rearing

ageE[i] Age of ewe at lambing $i$ ($i = 1, \ldots, LL$)

agelFP[i] Age at lambing of female lambs conceived in breeding season $i$ ($i = 1, \ldots, bs[1]$)

agepurMP[j] Age of purchased male of breed $j$ ($j = 1$ : breed of the flock, $j = 2$: breed used in the flock for crossing)

ageR[i][j] Age of rams of the breed of the flock ($j = 1$) or of the breed used for crossing in the flock ($j = 2$) at the beginning of breeding cycle $i$ ($i = 1, \ldots, RR$)

ager[k][i] Age of female ($k = 1$) or male ($k = 2$) breeding lambs at the beginning of breeding season $i$ ($i = 1, \ldots, bs[k]$)

agetP[i][j] Age of category $i$ ($i = 1, \ldots, PP$) of pure-bred ($j = 1$) or cross-bred ($j = 2$) progeny at the end of the time interval these categories exist

agewL Age of lambs at weaning

AkharL Number of man-hours per lamb in the period of artificial rearing

AkhE Number of man-hours per ewe and year (including lambs till weaning, excluding milking and cheese production and shearing if done by external workers)

AkhfL Number of man-hours per male or female lamb or castrate in fattening per year

AkhR Number of man-hours per ram and year

AkhrL Number of man-hours per female or male breeding lamb in rearing per year

avclfL[j] Average quality class for pure-bred ($j = 1$) or cross-bred ($j = 2$) fattened lambs when animals are paid for live weight

avclS[j] Average quality class for pure-bred ($j = 1$) or cross-bred ($j = 2$) adult sheep when animals are paid for live weight

avclwL[j] Average quality class for pure-bred ($j = 1$) or cross-bred ($j = 2$) lambs at weaning or at the end of artificial rearing when animals are paid for live weight

avconrateE Average conception rate of ewes (averaged over reproductive cycles)

avcqwL[j] Average class for carcass quality in pure-bred ($j = 1$) or cross-bred ($j = 2$) lambs slaughtered after weaning or artificial rearing

avfcfL[j]    Average class for fat covering in pure-bred ($j = 1$) or cross-bred ($j = 2$) fattened lambs

avfcL[j]    Average class for fat covering in pure-bred ($j = 1$) or cross-bred ($j = 2$) fattened lambs and/or heavy lambs (carcass weight $> 13$ kg) slaughtered after weaning or artificial rearing.  The variable $avfcL[j]$ is calculated as the weighted mean of $avfcfL[j]$ and $avfcwL[j]$.

avfcS[j]    Average class for fat covering in pure-bred ($j = 1$) or cross-bred ($j = 2$) adult sheep

avfcwL[j]    Average class for fat covering in pure-bred ($j = 1$) or cross-bred ($j = 2$) heavy lambs (carcass weight $> 13$ kg) slaughtered after weaning or artificial rearing

avfleshfL[j]  Average class for fleshiness in pure-bred ($j = 1$) or cross-bred ($j = 2$) fattened lambs

avfleshL[j]  Average class for fleshiness in pure-bred ($j = 1$) or cross-bred ($j = 2$) fattened lambs and/or heavy lambs (carcass weight $> 13$ kg) slaughtered after weaning or artificial rearing.  The variable $avfleshL[j]$ is calculated as the weighted mean of $avfleshfL[j]$ and $avfleshwL[j]$.

avfleshS[j]  Average class for fleshiness in pure-bred ($j = 1$) or cross-bred ($j = 2$) adult sheep

avfleshwL[j] Average class for fleshiness in pure-bred ($j = 1$) or cross-bred ($j = 2$) heavy lambs (carcass weight $> 13$ kg) slaughtered after weaning or artificial rearing

avlifelE    Productive lifetime of ewes in number of reproductive cycles

avlifeyE    Productive lifetime of ewes in years

avlitlE    Average litter size per ewe lambing

avlitpE[i]   Average litter size per ewe lambing in reproductive cycle $i$ ($i = 1, \ldots, LL$)

avmilkd    Average daily milk production in the whole lactation (from lambing till drying off)

avsur24hL[j]  Average survival rate of pure-bred ($j = 1$) or cross-bred ($j = 2$) lambs at lambing (until 24 hours after birth)

avsurarL[j]  Average survival rate of pure-bred ($j = 1$) or cross-bred ($j = 2$) lambs from 24 hours after birth till the end of artificial rearing

avsurwL[j]  Average survival rate of pure-bred ($j = 1$) or cross-bred ($j = 2$) lambs from 24 hours after birth till weaning

avwar[i][j]   Average weight of pure-bred ($j = 1$) or cross-bred ($j = 2$) female ($i = 1$) or male ($i = 2$) lambs at the end of artificial rearing

avww[i][j]   Average weaning weight of pure-bred ($j = 1$) or cross-bred ($j = 2$) female ($i = 1$) or male ($i = 2$) lambs

awo     Parameter $a$ for lactation curve (6.1)

basemilkm Milk yield from weaning to the end of the milking period per ewe lambing calculated for the standard lactation curve (6.1)

basemilkw  Milk yield until weaning per ewe lambing calculated for the standard lactation curve (6.1)

basemilkws[i]  Milk yield until weaning per ewe lambing calculated for the standard lactation curve (6.1) in feeding season $i$ ($i = 1, \ldots, nfs$)

bch  Regression coefficient for fat content in equation (6.16)

BS  Maximal number of breeding seasons for female or male progeny $+ 1$ (set to 5, used for dimensioning arrays in the program)[1]

bs[i]  Number of breeding seasons for female ($i = 1$) or male ($i = 2$) progeny (fixed to 3 for female and to 2 for male progeny)

bwL[k][i][j]  Birth weight of female ($k = 1$) or male ($k = 2$) progeny within each litter size $i$ and breeding type $j$ ($i = 1, \ldots clt$, $j = 1, 2$; $j = 1$: pure-bred lambs, $j = 2$: cross-bred lambs)

bwo  Parameter $b$ for lactation curve (6.1)

C  Maximal number of ewe categories $+ 1$ (set to 100, used for dimensioning arrays in the program, see footnote on this page)

c1[i] to c3[i]  Constants in the equations for the calculation of net energy requirement for lambs; $i = 1$ : female lambs, $i = 2$ : male lambs, $i = 0$ : castrates.

c4[i] to c6[i]  Constants in the equations for the calculation of protein requirement for lambs; $i = 1$ : female lambs, $i = 2$ : male lambs, $i = 0$ : castrates.

casprot  Casein as fraction of protein in milk

CB  Differentiates between cross-breeding and pure-breeding (set to 3, used for dimensioning arrays in the program)

cch  Regression coefficient for protein content in equation (6.16)

cheesewhey  Amount of cheese whey per kg cheese

cheesey  Cheese yield in kg from 1 kg milk

clf[k][i]  This variable indicates if target $i$ ($i = 1, \ldots lf[k]$) in fattening of progeny ($k = 1$ : female progeny, $k = 2$ : male progeny, $k = 0$ : castrates) is applied only to pure-bred ($clf[k][i] = 1$) or cross-bred ($clf[k][i] = 2$) progeny or both to pure-bred and cross-bred progeny ($clf[k][i] = 0$).

CLT  Maximal number of classes for litter size $+ 1$ (e.g. singles, twins, triplets, set to 5, used for dimensioning arrays in the program, see footnote on the current page)

clt  Number of classes for litter size (e.g. singles, twins, triplets) for the given calculation (maximal value 4)

coninsE  Average conception rate of ewes after insemination

conrateE[i]  Conception rate of ewes in reproductive cycle $i$ ($i = 1, \ldots, LL - 1$)

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[1]Numbering of elements in arrays in the C language starts with 0. As in the program the first element of the array mostly is not used and only elements with numbers $1, 2, \ldots, n$ are occupied, the dimension of the array must be $n + 1$.

conrateFP[i][j]  Conception rate of pure-bred ($j = 1$) or cross-bred ($j = 2$) female progeny in the individual breeding seasons ($i = 1, \ldots, bs[1]$)

costAkh  Cost per man-hour (including insurance)

costbedE[i]  Cost for bedding per housed ewe of category $i$ ($i = 1, \ldots, TE$) including lambs till weaning and per reproductive cycle

costbedL[i][j]  Cost for bedding per housed pure-bred ($j = 1$) or crossbed ($j = 2$) lamb of category $i$ ($i = 1, \ldots, PP$)

costbedR[i][j]  Cost for bedding per housed ram of category $i$ ($i = 1, \ldots, TR$) and breed $j$ ($j = 1$ : breed of the flock, $j = 2$ : breed used for crossing in the flock) per breeding cycle

costbreedE[i]  Cost for breeding per ewe of category $i$ ($i = 1, \ldots, TE$) and per reproductive cycle

costbreedL[i][j]  Cost for breeding per pure-bred ($j = 1$) or cross-bred ($j = 2$) female lamb of category $i$

costcheese0E  Cost for processing 1 kg milk to cheese (facilities, labour, etc. without costs for milk)

costcheeseE[i]  Cost for producing cheese (facilities, labour, etc. without costs for milk) per ewe of category $i$ ($i = 1, \ldots, TE$)

costdead  Cost for removing and rendering a dead animal (per kg weight)

costdiedE[i]  Cost per died ewe of category $i$ ($i = 1, \ldots, TE$)

costdiedL[i][j]  Cost per died pure-bred ($j = 1$) or cross-bred ($j = 2$) lamb of category $i$ ($i = 1, \ldots, PP$)

costE[i]  Total costs per ewe of category $i$ ($i = 1, \ldots, TE$) per reproductive cycle

costfE[i]  Total feeding costs per ewe of category $i$ ($i = 1, \ldots, TE$) and per reproductive cycle

costfix0E  Fixed costs per stable place per day for ewes (including lambs till weaning)

costfix0R  Fixed costs per stable place per day for rams

costfixarL  Fixed costs per stable place per day for lambs in artificial rearing

costfixE[i]  Fixed costs per stable place per reproductive cycle for ewes (including lambs till weaning) of category $i$ ($i = 1, \ldots, TE$)

costfixfL  Fixed costs per stable place per day for lambs in fattening

costfixL[i][j]  Fixed costs per pure-bred ($j = 1$) or cross-bred ($j = 2$) lamb of category $i$ ($i = 1, \ldots, PP$)

costfixR[i][j]  Fixed costs per stable place per ram of category $i$ ($i = 1, \ldots, TR$) and breed $j$ ($j = 1$ : breed of the flock, $j = 2$ : breed used for crossing in the flock) and per breeding cycle

costfixrL  Fixed costs per stable place per day per female or male breeding lamb

costfL[i][j]  Total feeding costs per pure-bred ($j = 1$) or cross-bred ($j = 2$) lamb of category $i$ ($i = 1, \ldots, PP$)

costfR[i][j]  Total feeding costs per ram of category $i$ $(i = 1, \ldots, TR)$ of the breed of the flock $(j = 1)$ or of the breed used for crossing in the flock $(j = 2)$ and per breeding cycle

costins[j]  Cost per insemination (price for dose and labour) for pure-breeding $(j = 1)$ and cross-breeding $(j = 2)$

costL[i][j]  Total costs per pure-bred $(j = 1)$ or cross-bred $(j = 2)$ lamb of category $i$ $(i = 1, \ldots, PP)$

costlabE[i]  Total labour costs per ewe of category $i$ $(i = 1, \ldots, TE)$ and per reproductive cycle

costlabL[i][j]  Total labour costs per pure-bred $(j = 1)$ or cross-bred $(j = 2)$ lamb of category $i$ $(i = 1, \ldots, PP)$

costlabR[i][j]  Total labour costs per ram of category $i$ $(i = 1, \ldots, TR)$ and breed $j$ $(j = 1 :$ breed of the flock, $j = 2 :$ breed used for crossing in the flock) and per breeding cycle

costlamb  Costs (reduced by revenues) for ewes and rams which should be allotted to one weaned (or artificially reared) lamb

costmarkbR  Marketing costs (e.g. transport, advertising) per breeding ram

costmarkcul  Marketing costs (e.g. transport, advertising) per animal to be culled

costmarkE[i]  Marketing costs per ewe of category $i$ and per reproductive cycle

costmarkfL  Marketing costs (e.g. transport, advertising) per kg live weight of lambs sold after fattening

costmarkL[i][j]  Marketing costs per pure-bred $(j = 1)$ or cross-bred $(j = 2)$ lamb of category $i$ $(i = 1, \ldots, PP)$

costmarkR[i][j]  Marketing costs per ram of category $i$ $(i = 1, \ldots, TR)$ and breed $j$ $(j = 1 :$ breed of the flock, $j = 2 :$ breed used for crossing in the flock)

costmarkrL[i]  Marketing costs (e.g. transport, advertising) per female $(i = 1)$ or male $(i = 2)$ breeding lamb

costmarkwL  Marketing costs (e.g. transport, advertising) per kg live weight of lambs sold at weaning or at the end of artificial rearing

costmilk0E  Cost for milking per kg milk (variable costs, i.e. for energy for cooling, labour, etc.)

costmilkE[i]  Cost for milking (variable costs, i.e. for energy for cooling, labour, etc.) per ewe of category $i$ $(i = 1, \ldots, TE)$

costnfE[i]  Total non-feed costs per ewe of category $i$ $(i = 1, \ldots, TE)$ and per reproductive cycle

costnfL[i][j]  Total non-feed costs per pure-bred $(j = 1)$ or cross-bred $(j = 2)$ lamb of category $i$ $(i = 1, \ldots, PP)$

costoein  Cost for induction and oestrus synchronisation per ewe and reproductive cycle

costoeinFP  Cost for induction and oestrus synchronisation per female lamb per breeding season

costpurchFP  Cost for purchasing female breeding lambs per ewe per reproductive cycle

costpurchR[i][j]  Cost for purchasing rams per ram of category $i$ ($i = 1, \ldots, nstgR$) of the breed of the flock ($j = 1$) or of the breed used for crossing in the flock ($j = 2$)

costR[i][j]  Total costs per ram of category $i$ ($i = 1, \ldots, TR$) of the breed of the flock ($j = 1$) or of the breed used for crossing in the flock ($j = 2$)

costreins[j]  Costs per re-insemination for pure-breeding ($j = 1$) and cross-breeding ($j = 2$)

costshe0E  Cost per shearing a ewe

costshe0L  Costs per shearing a lamb

costshe0R  Cost per shearing a ram

costsheE[i]  Total shearing costs per ewe of category $i$ ($i = 1, \ldots, TE$) and per reproductive cycle

costsheL[i][j]  Total shearing costs per pure-bred ($j = 1$) or cross-bred ($j = 2$) lamb of category $i$ ($i = 1, \ldots, PP$)

costsheR[i][j]  Total shearing costs per ram of category $i$ ($i = 1, \ldots, TR$) and breed $j$ ($j = 1$ : breed of the flock, $j = 2$ : breed used for crossing in the flock) and per breeding cycle

costskE[i]  Costs for tanning skin per ewe of category $i$ ($i = 1, \ldots, TE$) and per reproductive cycle

costskL[i][j]  Costs for tanning skin per pure-bred ($j = 1$) or cross-bred ($j = 2$) lamb of category $i$ ($i = 1, \ldots, PP$)

costtan  Costs for tanning skin

costvetE[i]  Veterinary costs per ewe of category $i$ ($i = 1, \ldots, TE$) and per reproductive cycle

costvetL[i][j]  Veterinary costs per pure-bred ($j = 1$) or cross-bred ($j = 2$) lamb of category $i$ ($i = 1, \ldots, PP$)

costvetR[i][j]  Veterinary costs per ram of category $i$ ($i = 1, \ldots, TR$) and breed $j$ ($j = 1$ : breed of the flock, $j = 2$ : breed used for crossing in the flock) and per breeding cycle

costwatE[i]  Total costs for water per ewe of category $i$ ($i = 1, \ldots, TE$) and per reproductive cycle

costwatL[i][j]  Total costs for water per pure-bred ($j = 1$) or cross-bred ($j = 2$) lamb of category $i$ ($i = 1, \ldots, PP$)

costwatR[i][j]  Total costs for water per ram of category $i$ ($i = 1, \ldots, TR$) of the breed of the flock ($j = 1$) or of the breed used for crossing in the flock ($j = 2$) and per breeding cycle

CR  Maximal number of categories for rams $+ 1$ (set to 30, used for dimensioning arrays in the program, see footnote on page 177)

crossing        Type of progeny (1: only pure-bred progeny, 2: pure-bred and cross-bred progeny)

CSP             Maximal number of groups of surplus progeny + 1 (set to 10, used for dimensioning arrays in the program, see footnote on page 177)

csp[i]          Number of groups of surplus female ($i = 1$) or male ($i = 2$) progeny or castrates ($i = 0$). In the given version of the program is $csp[0] \leq 5$, $csp[1] \leq 7$ and $csp[2] \leq 8$.

cullbsMP[i][j]  Culling rate of male progeny from weaning (for $i = 1$) or from breeding season $i - 1$ (for $i > 1$) to breeding season $i$ ($i = 1, \ldots, bs[2]$); $bs[2]$ is fixed to 2 in the given version of the program.

cwo             Parameter $c$ for lactation curve (6.1)

cy              Indicator variable which takes value 1 if regression equation (6.16) is used for the calculation of the milk amount needed for 1 kg cheese and which takes value 2 if van Slyke's formula (6.17) to (6.19) is used

datbbs          Date of the beginning of the breeding season[2]

datconFP[i]     Date of conceiving of female progeny in breeding season $i$ ($i = 1, \ldots, bs[1]$)

datdry          Date of drying off of dairy ewes

datchfs[i]      Date of a change in the feeding season ($i = 1, \ldots, nchfs$)

datebs          End date of the breeding season

datlamb         Date of lambing (start date of the reproductive cycle)

datwL           Date of weaning lambs

dcE[i]          Length of the time period in the reproductive cycle of the occurrence of non-feed costs for ewes of category $i$ ($i = 1, \ldots, TE$)

dcL[i][j]       Length of the time period of the occurrence of non-feed costs for pure-bred ($j = 1$) or cross-bred ($j = 2$) lambs of category $i$ ($i = 1, \ldots, PP$)

dcR[i]          Length of the time period in the breeding cycle of the occurrence of non-feed costs for rams of category $i$ ($i = 1, \ldots, TR$)

dmilkst         Length of the standardized milking period in days

dnpregcE        Interval between the end of the appropriate breeding season and time of culling ewes for failure to conceive

dnpregcFP       Interval between the end of the appropriate breeding season and time of culling female lambs for failure to conceive

dpregsFP        Days of pregnancy when pregnant female lambs are sold

dresE           Dressing percentage of culled ewes

dresfL[s][l][j] Dressing percentage of pure-bred ($j = 1$) and cross-bred ($j = 2$) lambs of sex $s$ ($s = 1$ : females, $s = 2$ : males, $s = 0$ : castrates) fattened to target $l = 1, \ldots, lf[s]$

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[2]All variables referring to dates are expressed in days from January 1st of year zero in the program. Input of dates (compare Subsection 14.2.1) must be in the format "year month day" where year is relative and the time scale starts with year zero always.

dresR[j]    Dressing percentage of culled rams used for pure-breeding ($j = 1$) or cross-breeding ($j = 2$) in the flock

dresrL[j]   Dressing percentage of pure-bred ($j = 1$) or cross-bred ($j = 2$) breeding lambs culled during rearing

dreswL[j]   Dressing percentage of pure-bred ($j = 1$) and cross-bred ($j = 2$) lambs slaughtered after weaning or after artificial rearing

drymE[i][j]  Dry matter content in fresh matter for seasonal variant $j$ ($j = 1, \ldots, nfs$) of feeding ration $i$ ($i = 1, \ldots, fE$) for ewes

drymL[i][j]  Dry matter content in fresh matter for seasonal variant $j$ ($j = 1, \ldots, nfs$) of feeding ration $i$ ($i = 1, \ldots, fL$) for lambs

drymR[i][j]  Dry matter content in fresh matter for seasonal variant $j$ ($j = 1, \ldots, nfs$) of feeding ration $i$ ($i = 1, \ldots, fR$) for rams

dselR       Time interval from the end of the breeding season to selling of breeding rams

dshpE       Length of the period of high pregnancy where a special feeding ration is applied to ewes

dwatE[k][l]  Daily amount of water (in litres) per ewe fed with seasonal variant $l$ ($l = 1, \ldots, nfs$) of feeding ration $k$ ($k = 1, \ldots, fE$)

dwatL[k][l]  Daily amount of water (in litres) per lamb fed with seasonal variant $l$ ($l = 1, \ldots, nfs$) of feeding ration $k$ ($k = 1, \ldots, fL$)

dwatR[k][l]  Daily amount of water (in litres) per ram fed with seasonal variant $l$ ($l = 1, \ldots, nfs$) of feeding ration $k$ ($k = 1, \ldots, fR$)

dwoolptE    Daily wool production of ewes

dwoolptR[j]  Daily wool production of rams of the breed of the flock ($j = 1$) or of the breed used for crossing in the flock ($j = 2$)

dwoolptrL[i][j]  Daily wool production of a female ($i = 1$) or male ($i = 2$) pure-bred ($j = 1$) or cross-bred ($j = 2$) lamb in the rearing period or in fattening

dwoolptwL   Daily wool production of lambs until weaning

dwoolptarL  Daily wool production per lamb in artificial rearing

ev[i][j]    Marginal economic weight of trait $i$ expressed in pure-bred ($j = 1$) or cross-bred ($j = 2$) animals calculated for changing the trait mean by $\pm 0.5\%$. For numbering of traits see Appendix A.

ev0[i][j]   Marginal economic weight of trait $i$ expressed in pure-bred ($j = 1$) or cross-bred ($j = 2$) animals calculated for changing the trait mean by $\pm 1\%$.

evdiff[i][j]  Difference between the marginal economic weight calculated for changing the trait mean by $\pm 0.5\%$ and the marginal economic weight calculated for changing the trait mean by $\pm 1\%$, expressed in %:

$$evdiff[i][j] = 100 \times \frac{ev[i][j] - ev0[i][j]}{ev[i][j]}$$

evp[i][j]    Marginal economic weight of trait $i$ expressed in pure-bred ($j = 1$) or cross-bred ($j = 2$) animals with units used for printing the results

ewopt    Option for calculating economic weights (for details see Section 14.1)

facSCC[i]    Multiplicative adjustment factors for milk quality classes on the basis of SCC quality class $i$ ($i = 1, ..., NSCC$)

fat    Fat content in milk

fatcb    Variable that indicates the presence ($fatcb = 1$) or the absence ($fatcb = 0$) of fattening of cross-bred animals

fatch    Fat content in cheese in %

fatpb    Variable that indicates the presence ($fatpb = 1$) or the absence ($fatpb = 0$) of fattening of pure-bred animals

fatymst    Fat yield in the standardized milking period in kg

favfL[j]    Weighting factor for pure-bred ($j = 1$) or cross-bred ($j = 2$) fattened lambs in the calculation of the average class for fleshiness ($avfleshL$) and fat covering ($avfcL$), $0 \leq favfL[j] \leq 1$

favwL[j]    Weighting factor for pure-bred ($j = 1$) or cross-bred ($j = 2$) heavy lambs (carcass weight $>$ 13 kg) slaughtered after weaning or after artificial rearing in the calculation of the average class for fleshiness ($avfleshL$) and fat covering ($avfcL$), $0 \leq favwL[j] \leq 1$

fdm    Fat in dry matter of cheese in %

FE    Maximal number of different feed rations for ewes + 1 (set to 6, used for dimensioning arrays in the program, see footnote on page 177)

fE    Number of different feed rations for ewes ($fE = 5$ in the given version of the program)

feE[i][k][l]    Fresh feed requirement (without considering wasting of feed) calculated from the net energy content in feed per ewe of category $i$ ($i = 1, \ldots, TE$) fed with seasonal variant $l$ ($l = 1, \ldots, nfs$) of feeding ration $k$ ($k = 1, \ldots, fE$)

feedcost    Option for calculating feed costs (1: Feed costs are calculated from the net energy and protein requirements, 2: Feed costs are calculated only from the net energy requirements)

feL[i][j][k][l]    Fresh feed requirement (without considering wasting of feed) calculated from the net energy content in feed per pure-bred ($j = 1$) or cross-bred ($j = 2$) lamb of category $i$ ($i = 1, \ldots, PP$) fed with seasonal variant $l$ ($l = 1, \ldots, nfs$) of feeding ration $k$ ($k = 1, \ldots, fL$)

femrep    Option for female replacement (1: Own replacement females are reared, 2: A part of replacement females are purchased)

feR[i][j][k][l]    Fresh feed requirement (without considering wasting of feed) calculated from net energy content in feed per ram of category $i$ ($i = 1, \ldots, TR$) of the breed of the flock ($j = 1$) or of the breed used for crossing in the flock ($j = 2$) fed with seasonal variant $l$ ($l = 1, \ldots, nfs$) of feeding ration $k$ ($k = 1, \ldots, fR$)

ffE[i][k][l] Fresh feed requirement (including wasting of feed) per ewe of category $i$ ($i = 1, \ldots, TE$) fed with seasonal variant $l$ ($l = 1, \ldots, nfs$) of feeding ration $k$ ($k = 1, \ldots, fE$)

ffL[i][j][k][l] Fresh feed requirement (including wasting of feed) per pure-bred ($j = 1$) or cross-bred ($j = 2$) lamb of category $i$ ($i = 1, \ldots, PP$) fed with seasonal variant $l$ ($l = 1, \ldots, nfs$) of feeding ration $k$ ($k = 1, \ldots, fL$)

ffR[i][j][k][l] Fresh feed requirement (including wasting of feed) per ram of category $i$ ($i = 1, \ldots, TR$) of the breed of the flock ($j = 1$) or of the breed used for crossing in the flock ($j = 2$) fed with seasonal variant $l$ ($l = 1, \ldots, nfs$) of feeding ration $k$ ($k = 1, \ldots, fR$)

FL Maximal number of different feed rations for lambs $+ 1$ (set to 21, used for dimensioning arrays in the program, see footnote on page 177)

fL Number of different feed rations for lambs. In the given version of the program $fL = 20$. That means that 20 different feeding rations are defined but normally not all defined feeding rations are used.

flushabE Length of the flushing period for ewes after the start of the breeding season

flushabL Length of the flushing period for female breeding lambs after the start of the breeding season

flushbbE Length of the flushing period for ewes before the start of the breeding season

flushbbL Length of the flushing period for female breeding lambs before the start of the breeding season

flushbbR Length of the flushing period for males before the start of the breeding season

fpdiE[i][k][l] Fresh feed requirement (without considering wasting of feed) calculated from the protein content in feed per ewe of category $i$ ($i = 1, \ldots, TE$) fed with seasonal variant $l$ ($l = 1, \ldots, nfs$) of feeding ration $k$ ($k = 1, \ldots, fE$)

fpdiL[i][j][k][l] Fresh feed requirement (without considering wasting of feed) calculated from the protein content in feed per pure-bred ($j = 1$) or cross-bred ($j = 2$) lamb of category $i$ ($i = 1, \ldots, PP$) fed with seasonal variant $l$ ($l = 1, \ldots, nfs$) of feeding ration $k$ ($k = 1, \ldots, fL$)

fpdiR[i][j][k][l] Fresh feed requirement (without considering wasting of feed) calculated from the protein content in feed per ram of category $i$ ($i = 1, \ldots, TR$) of the breed of the flock ($j = 1$) or of the breed used for crossing in the flock ($j = 2$) fed with seasonal variant $l$ ($l = 1, \ldots, nfs$) of feeding ration $k$ ($k = 1, \ldots, fR$)

FR Maximal number of different feed rations for rams $+ 1$ (set to 3, used for dimensioning arrays in the program, see footnote on page 177)

fR Number of different feed rations for rams ($fR = 2$ in the given version of the program)

hetmw Heterotic effect for mature weight

| | |
|---|---|
| HS | Maximal number of sheep husbandry systems + 1 (set to 4, used for dimensioning arrays in the program, see footnote on page 177) |
| hs | Number of sheep husbandry systems (set to 3) |
| i | Index variable |
| i1 | Index variable |
| i2 | Index variable |
| i3 | Index variable |
| icb | Index for the category of cross-bred animals in fattening which is used as reference value in the calculation of economic weights |
| ilcb | Index for the target of fattening of cross-bred animals which is used as reference value in the calculation of economic weights |
| ilpb | Index for the target of fattening of pure-bred animals which is used as reference value in the calculation of economic weights |
| intml | Interval between mating and lambing in days |
| intlm | Interval between lambing and mating in days |
| ipb | Index for the category of pure-bred animals in fattening which is used as reference value in the calculation of economic weights |
| iscb | Index for sex of cross-bred animals which is used as reference value in the calculation of economic weights of fattening traits |
| ispb | Index for sex of pure-bred animals which is used as reference value in the calculation of economic weights of fattening traits |
| j | Index variable |
| j1 | Index variable |
| ja | Index variable |
| jb | Index variable |
| k | Index variable |
| k0[i][j] | Number of the first class for fattening progeny ($i = 1$ : female progeny, $i = 2$ : male progeny, $i = 0$ : castrates, $j = 1$ : pure-bred progeny, $j = 2$ : cross-bred progeny). $k0[i][j]$ is an integer in the range from 1 to $lf[i]$. Mathematically expressed, $k0[i][1]$ is the minimal value of $k$ for which holds that $clf[i][k] = 1$ or $clf[i][k] = 0$ and $k0[i][2]$ is the minimal value of $k$ for which holds that $clf[i][k] = 2$ or $clf[i][k] = 0$. |
| k1 | index variable |
| k2 | index variable |
| k3 | index variable |
| k4 | index variable |
| k5 | index variable |
| k6 | index variable |

k7 index variable

kadgbw[k][i][j] Ratio of daily gain from birth to weaning of female ($k = 1$) or male ($k = 2$) progeny within litter size $i$ ($i = 1, \ldots clt$) and breeding type $j$ ($j = 1$: pure-bred lambs, $j = 2$: cross-bred lambs) and daily gain from birth to weaning of female progeny born as singles ($i = 1$) within breeding type $j$

kadgfat[k][i][j] Ratio of the average daily gain in fattening of progeny ($k = 1$ : female progeny, $k = 2$ : male progeny, $k = 0$ : castrates) of breeding type $j$ ($j = 1$: pure-bred lambs, $j = 2$: cross-bred lambs) to target $i$ ($i = 1, \ldots, lf[k]$) and the average daily gain of a reference animal of the given breeding type. For female progeny the reference trait is $adgP[7 + l][j]$ with $l = k0[1][j]$. For male progeny the reference trait is also $adgP[7 + l][j]$ with $l = k0[1][j]$ if female progeny is fattened. Otherwise the reference trait is $adgP[32 + l][j]$ with $l = k0[2][j]$. For castrates the reference trait is $adgP[7 + l][j]$ with $l = k0[1][j]$ if female progeny is fattened. If there is no fattening of female progeny, but fattening of male progeny exists, the reference trait is $adgP[32 + l][j]$ with $l = k0[2][j]$. If there is only fattening of castrates, the reference trait is $adgP[42 + l][j]$ with $l = k0[0][j]$.

kadgr[k][i][j] Ratio (within breeding type $j$ with $j = 1$ : pure-bred progeny and $j = 2$ : cross-bred progeny) of average daily gain in rearing of female ($k = 1$) or male ($k = 2$) progeny from weaning to breeding season 1 or from breeding season $i - 1$ to $i$ ($i = 2, \ldots, bs[k]$) and average daily gain in rearing of female progeny from weaning to breeding season 1. In cross-bred animals it can happen that there are only male animals but no females. Then average daily gain of cross-bred male progeny from weaning to the first breeding season is used as reference trait for cross-bred animals. For details see eq. (5.10) and (5.11).

kadgwar[k][i][j] Ratio of daily gain in artificial rearing of female ($k = 1$) or male ($k = 2$) progeny within litter size $i$ ($i = 1, \ldots clt$) and breeding type $j$ ($j = 1$: pure-bred lambs, $j = 2$: cross-bred lambs) and daily gain in artificial rearing of female progeny born as singles ($i = 1$) within breeding type $j$

kbw[k][i][j] Ratio of birth weight of female ($k = 1$) or male ($k = 2$) progeny within litter size $i$ ($i = 1, \ldots clt$) and breeding type $j$ ($j = 1$: pure-bred lambs, $j = 2$: cross-bred lambs) and birth weight of female progeny born as singles ($i = 1$) within breeding type $j$

kconrateFP[i][j] Ratio of the conception rate of pure-bred ($j = 1$) or cross-bred ($j = 2$) female progeny in breeding season $i$ ($i = 1, \ldots, bs[1]$) and the conception rate in breeding season 1:

$$kconrateFP[i][j] = \frac{conrateFP[i][j]}{conrateFP[1][j]}$$

kdif Price coefficient for purchasing replacement. The coefficient expresses the relative price of purchased replacement compared to the costs of own replacement.

kdresER Ratio $dresR[1]/dresE$

kdresEL Ratio $dresrL[1]/dresE$

kdresfL[k][i][j]  Ratio of dressing percentage of fattened animals of progeny $k$ ($k = 1$ : female progeny, $k = 2$ : male progeny, $k = 0$ : castrates) of breeding type $j$ ($j = 1$: pure-bred lambs, $j = 2$: cross-bred lambs) to target $i$ ($i = 1, \ldots, lf[k]$) and dressing percentage of a reference animal of the given breeding type. For details see variable $kadgfat[k][i][j]$.

kdresRL  Ratio $dresrL[2]/dresR[2]$

kE  Number of iterations in the calculation of the stationary state of the structure of the ewe flock

kmilkcE  Coefficient expressing the decrease of the milk yield in ewes culled for health problems or died during the reproductive cycle in relation to ewes with complete normal lactations

kmwRE[j]  Ratio of mature weight of rams to mature weight of ewes ($j = 1$ : breed of the flock, $j = 2$ : breed used for crossing in the flock)

kR  Number of iterations in the calculation of the stationary state of the structure of the population of rams in the flock

ktE[i]  Coefficient for activity allowance for housed ewes ($i = 1$), for lowland ewes out-of-door ($i = 2$) or for ewes on hill grazing ($i = 3$)

ktL[i]  Coefficient for activity allowance for housed lambs ($i = 1$), for lowland lambs out-of-door ($i = 2$) or for lambs on hill grazing ($i = 3$)

ktlp[i]  Adjustment factors for the lactation curve for each parity $i$ ($i = 1, \ldots, LL$)

ktlsl[i]  Adjustment factors for the lactation curve for the number of suckled lambs $i$ ($i = 0, \ldots, clt$)

kwarL[i][j]  Ratio of fleece weight of pure-bred ($j = 1$) or cross-bred ($j = 2$) female ($i = 1$) or male ($i = 2$) lambs at the end of artificial rearing to fleece weight of rams

kwE  Ratio of fleece weight of ewes to fleece weight of rams

kwfL[i][j]  Ratio of fleece weight of pure-bred ($j = 1$) or cross-bred ($j = 2$) female ($i = 1$) or male ($i = 2$) fattened lambs to fleece weight of rams

kwrL[i][j]  Ratio of fleece weight of pure-bred ($j = 1$) or cross-bred ($j = 2$) female ($i = 1$) or male ($i = 2$) breeding lambs to fleece weight of rams

kwwL[i][j]  Ratio of fleece weight of pure-bred ($j = 1$) or cross-bred ($j = 2$) female ($i = 1$) or male ($i = 2$) weaned lambs to fleece weight of rams

L  Maximal number of reproductive cycles $+ 1$ (set to 16, used for dimensioning arrays in the program, see footnote on page 177)

l1_0[i]  Needed for the calculation of $l1E[i]$ in the iteration process

l1aR[i][j]  Probability that in the stationary state of the whole production system, a ram of the breed of flock ($j = 1$) or of the breed used for crossing in the flock ($j = 2$) belongs to category $i$ ($i = 1, ..., TR$)

l1E[i]  Probability that in the stationary state of the whole production system a ewe belongs to category $i$ ($i = 1, ..., TE$)

l1L[i][j][k]   Frequency of progeny per ewe and reproductive cycle in category $i$ ($i = 1, ..., PP$), for the type of breeding $j$ ($j = 0, 1, 2$; $j = 1$ : pure-bred animals, $i = 2$: cross-bred animals, $i = 0$: sum of pure-bred and cross-bred animals) and for litter size $k$ ($k = 1, \ldots, clt$); the frequency was derived from the stationary state of the ewe flock

l1R[i]   Probability that in the stationary state of the whole production system, a ram belongs to category $i$ ($i = 1, ..., TR$)

l1skL[i][j]   Frequency of progeny per ewe and reproductive cycle in category $i$ ($i = 1, ..., PP$) and for the type of breeding $j$ ($j = 0, 1, 2$; $j = 1$ : pure-bred animals, $i = 2$: cross-bred animals, $i = 0$: sum of pure-bred and cross-bred animals); the frequency was derived from the stationary state of the ewe flock; $l1skL[i][j]$ is calculated from $l1L[i][j][k]$ by summing over $k = 1, \ldots, clt$.

l3E[i]   Ewes lambing in reproductive cycle $i$ ($i = 1, ..., LL$) expressed as proportion of ewes entering any reproductive cycle ( $\sum_{i=1}^{LL} l3E[i] \leq 1$)

l4E[i]   Ewes entering reproductive cycle $i$ ($i = 1, ..., LL$) expressed as proportion of ewes entering any reproductive cycle ( $\sum_{i=1}^{LL} l4E[i] = 1$)

l4R[i]   Rams entering breeding cycle $i$ ($i = 1, ..., RR$) expressed as proportion of rams entering any breeding cycle ( $\sum_{i=1}^{RR} l4R[i] = 1$)

l5R[i][j]   Rams of the breed of the flock ($j = 1$) or of the breed used for crossing in the flock ($j = 2$) entering breeding cycle $i$ ($i = 1, ..., RR$) expressed as proportion of rams entering any breeding cycle ( $\sum_{i=1}^{RR} \sum_{j=1}^{crossing} l5R[i] = 1$)

lengthmp   Length of the milking period after weaning

lengthrc   Length of reproductive cycle in days

LF   Maximal number of targets for fattening $+ 1$ (set to 6, used for dimensioning arrays in the program, see footnote on page 177)

lf[i]   Number of targets for fattening for female ($i = 1$) or male ($i = 2$) progeny or castrates ($i = 0$), read from the parameter file PARAS.TXT. It must hold that $0 \leq lf[i] \leq 5$.

LL   Number of reproductive cycles for the given calculation

lossfE[i][j]   Feed losses through wasting for seasonal variant $j$ ($j = 1, \ldots, nfs$) of feeding ration $i$ ($i = 1, \ldots, fE$) for ewes

lossfL[i][j]   Feed losses through wasting for seasonal variant $j$ ($j = 1, \ldots, nfs$) of feeding ration $i$ ($i = 1, \ldots, fL$) for lambs

lossfR[i][j]   Feed losses through wasting for seasonal variant $j$ ($j = 1, \ldots, nfs$) of feeding ration $i$ ($i = 1, \ldots, fR$) for rams

lpreg   Length of pregnancy

manarL   Amount of manure per lamb per day in artificial rearing

manbL   Amount of manure per male or female breeding lamb in rearing per day if the animals are housed

manE      Amount of manure per ewe (including lambs till weaning) per day if the ewes are housed

manfL      Amount of of manure per female or male lamb or castrate in fattening per day if the animals are housed

manR      Amount of manure per ram per day

mcwwL[i][j]   Mean carcass weight for pure-bred ($j = 1$) or cross-bred ($j = 2$) female ($i = 1$) and male ($i = 2$) lambs slaughtered after weaning or artificial rearing (categories 7 and 32)

milkch      Amount of milk needed per kg cheese

milkmpar[j]   Milk yield from weaning to the end of the milking period per ewe lambing in parity $j$ ($j = 1, \ldots, LL$) (weighted average over milk yield for all possible numbers of suckled lambs)

milkmrel[i][j]   Milk yield from weaning to the end of the milking period per ewe lambing with $i$ ($i = 0, \ldots, clt$) suckled lambs in lactation $j$ ($j = 1, \ldots, LL$)

milkprice      Option for the calculation of the milk price (for details see Section 14.2.11)

milksw[i]      Amount of milk milked for sale until weaning in lactation $i$ ($i = 1, \ldots, LL$)

milkw0L[j]   Amount of milk from ewes without lambs available from birth to weaning per lamb from ewes with two or more suckled lambs in feeding season $j$ ($j = 1, \ldots, nfs$)

milkwL[i][j]   Total milk amount available from birth to weaning for a lamb from a litter with litter size $i$ ($i = 1, \ldots, clt$) in feeding season $j$ ($j = 1, \ldots, nfs$). In this variable, litter size is to be understood as the number of suckled lambs.

milkwrel[i][j]   Milk yield until weaning per ewe lambing with $i$ ($i = 0, \ldots, clt$) suckled lambs in lactation $j$ ($j = 1, \ldots, LL$)

milkws[i][j][k]   Milk yield until weaning per ewe lambing in the flock per reproductive cycle for ewes with $i$ ($i = 0, \ldots, clt$) suckled lambs in lactation $j$ ($j = 1, \ldots, LL$) in feeding season $k$ ($k = 1, \ldots, nfs$)

milkwsrel[i][j][k]   Milk yield until weaning per ewe lambing with $i$ ($i = 0, \ldots, clt$) suckled lambs in lactation $j$ ($j = 1, \ldots, LL$) in feeding season $k$ ($k = 1, \ldots, nfs$)

minw[i][j]   Minimal weight of pure-bred ($j = 1$) or cross-bred ($j = 2$) female ($i = 1$) or male ($j = 1$) breeding lambs required for first mating

moich      Moisture of cheese in %

mSCS      Mean of somatic cell score in the sheep flock

mwE[j]      Mature weight of pure-bred ($j = 1$) or crossbreed ($j = 2$) ewes

mwE2      Mature weight of ewes from the breed used in the flock for crossing

mwMP[j]      Mature weight of pure-bred ($j = 1$) or crossbreed ($j = 2$) male progeny ($mwMP[1] = mwR[1]$)

mwR[j]        Mature weight of rams of the breed of the flock ($j = 1$) or of the breed used for crossing in the flock ($j = 2$)

Na24hL[i]     Number of lambs alive at 24 hours after birth per ewe per reproductive cycle summed over litter size for the type of breeding ($i = 0, 1, 2$; $i = 1$ : pure-bred lambs, $i = 2$: cross-bred lambs, $i = 0$: sum of pure-bred and cross-bred lambs)

na24hL[i][j]  Number of lambs alive at 24 hours after birth per ewe per reproductive cycle for the type of breeding ($i = 0, 1, 2$; $i = 1$ : pure-bred lambs, $i = 2$: cross-bred lambs, $i = 0$: sum of pure-bred and cross-bred lambs) and for each litter size ($j = 1, \ldots, clt$)

NarL[i]       Number of lambs per ewe and reproductive cycle at the end of artificial rearing for type of breeding $i$ ($i = 0, 1, 2$; $i = 1$ : pure-bred lambs, $i = 2$: cross-bred lambs, $i = 0$: sum of pure-bred and cross-bred lambs) summed over litter size

narL[i][j]    Number of lambs per ewe and reproductive cycle at the end of artificial rearing for type of breeding $i$ ($i = 0, 1, 2$; $i = 1$ : pure-bred lambs, $i = 2$: cross-bred lambs, $i = 0$: sum of pure-bred and cross-bred lambs) and for each litter size ($j = 1, \ldots, clt$)

NbtL[i]       Number of lambs born per ewe per reproductive cycle summed over litter size for the type of breeding ($i = 0, 1, 2$; $i = 1$ : pure-bred lambs, $i = 2$: cross-bred lambs, $i = 0$: sum of pure-bred and cross-bred lambs)

nbtL[i][j]    Number of lambs born per ewe per reproductive cycle for the type of breeding ($i = 0, 1, 2$; $i = 1$ : pure-bred lambs, $i = 2$: cross-bred lambs, $i = 0$: sum of pure-bred and cross-bred lambs) and for each litter size ($j = 1, \ldots, clt$)

NCHFS         Maximal number of changes of the feeding period for the whole time period from the beginning of the reproductive cycle to the time the last animals of the progeny enter the flock + 1 (set to 30, used for dimensioning arrays in the program, see footnote on page 177)

nchfs         Number of changes of the feeding period during the year

nchfst        Total number of changes of the feeding period for the whole time period from the beginning of the reproductive cycle to the time the last animals of the progeny enter the flock

NCL           Maximal number of quality classes + 1 (value set to 6)

NCLCQ         Maximal number of quality classes + 1 for lambs slaughtered after weaning or after artificial rearing (value set to 4)

nclcqwL       Number of quality classes for lambs slaughtered after weaning or after artificial rearing (value set to 2)

NCLCW         Maximal number of classes for carcass weight for lambs + 1 (value set to 5)

nclcwwL       Number of classes for carcass weight for lambs slaughtered after weaning or after artificial rearing (value set to 3)

NCLFC         Maximal number classes for fat covering + 1 (value set to 8)

nclfcfL      Number of classes for fat covering for fattened lambs

nclfcS       Number of classes for fat covering for adult sheep

nclfcwL      Number of classes for fat covering for lambs slaughtered after weaning or after artificial rearing

NCLFL        Maximal number classes for fleshiness + 1 (value set to 8)

nclfL        Number of quality classes for fattened lambs

nclflfL      Number of classes for fleshiness for fattened lambs

nclflS       Number of classes for fleshiness for adult sheep

nclflwL      Number of classes for fleshiness for lambs slaughtered after weaning or after artificial rearing

nclS         Number of quality classes for adult sheep

nclwL        Number of quality classes for lambs slaughtered after weaning

ndiedfat[k][i][j] Number of pure-bred ($j = 1$) or cross-bred ($j = 2$) female ($k = 1$) or male ($k = 2$) progeny or castrates ($k = 0$) died in fattening to target $i$ ($i = 1, \ldots, lf[k]$)

nd[i]        Number of days in feeding season $i$ ($i = 1, \ldots, nfs$)

nebL[b][i][j][k][l] Total net energy requirement for a pure-bred ($j = 1$) or cross-bred ($j = 2$) lamb of category $i$ ($i = 1, \ldots, PP$) from a litter with size $b$ ($b = 1, \ldots clt$) fed with feeding ration $k$ ($k = 1, \ldots, fL$) in feeding season $l$ ($l = 1, \ldots, nfs$)

nectoparL    Number of treatments against ecto-parasites per lamb from early weaning till the end of artificial rearing

nectopclFP   Number of treatments against ecto-parasites per female breeding lamb from conceiving to lambing

nectopE      Number of treatments against ecto-parasites per ewe per reproductive cycle

nectopf[i][j] Number of treatments against ecto-parasites per female lamb ($i = 1$), male lamb ($i = 2$) or castrate ($i = 0$) in fattening to target $j$ ($j = 1, \ldots, lf[i]$)

nectopR      Number of treatments against ecto-parasites per ram per breeding cycle

nectoprL[i]  Number of treatments against ecto-parasites per female or male breeding lamb from weaning or the end of artificial rearing till the 1st breeding season ($i = 1$) or from the 1st to 2nd (or from the 2nd to 3rd) breeding season ($i = 2$)

nectopwL     Number of treatments against ecto-parasites per lamb till weaning

nedE[i][j]   Net energy content in dry matter for seasonal variant $j$ ($j = 1, \ldots, nfs$) of feeding ration $i$ ($i = 1, \ldots, fE$) for ewes

nedL[i][j]   Net energy content in dry matter for seasonal variant $j$ ($j = 1, \ldots, nfs$) of feeding ration $i$ ($i = 1, \ldots, fL$) for lambs

nedR[i][j]  Net energy content in dry matter for seasonal variant $j$ ($j = 1, \ldots, nfs$) of feeding ration $i$ ($i = 1, \ldots, fR$) for rams

neE[i][k][l]  Total net energy requirement for lactation per ewe of category $i$ ($i = 1, \ldots, TE$) which will be fed with feeding ration $k$ ($k = 1, \ldots, fE$) in feeding season $l$ ($l = 1, \ldots, nfs$)

nefE[i][k][l]  Net energy requirement for flushing per ewe of category $i$ ($i = 1, \ldots, TE$) fed with feeding ration $k$ ($k = 3$) in feeding season $l$ ($l = 1, \ldots, nfs$)

nefL[i][j][k][l]  Net energy requirement for flushing per pure-bred ($j = 1$) or cross-bred ($j = 2$) lamb of category $i$ ($i = 1, \ldots, PP$) fed with feeding ration $k$ ($k = 3$) in feeding season $l$ ($l = 1, \ldots, nfs$)

negbL[b][i][j][k][l]  Net energy requirement for growth for a pure-bred ($j = 1$) or cross-bred ($j = 2$) lamb of category $i$ ($i = 1, \ldots, PP$) from a litter with size $b$ ($b = 1, \ldots clt$) which will be fed with feeding ration $k$ ($k = 1, \ldots, fL$) in feeding season $l$ ($l = 1, \ldots, nfs$)

negL[i][j][k][l]  Net energy requirement for growth for a pure-bred ($j = 1$) or cross-bred ($j = 2$) lamb of category $i$ ($i = 1, \ldots, PP$) which will be fed with feeding ration $k$ ($k = 1, \ldots, fL$) in feeding season $l$ ($l = 1, \ldots, nfs$)

negL14m[j][l]  Net energy requirement for growth for a pure-bred ($j = 1$) or cross-bred ($j = 2$) lamb of category 14 to be mated which will be fed with feeding ration 4 in feeding season $l$ ($l = 1, \ldots, nfs$)

negL14nm[j][l]  Net energy requirement for growth for a pure-bred ($j = 1$) or cross-bred ($j = 2$) lamb of category 14 not to be mated which will be fed with feeding ration 4 in feeding season $l$ ($l = 1, \ldots, nfs$)

neglE[i][k][l]  Net energy requirement for growth for a lambing ewe of category $i$ ($i = 1, \ldots, TE$); the ewe is fed with feeding ration $k$ ($k = 1, \ldots fE$) in feeding season $l$ ($l = 1, \ldots, nfs$)

negnlE[i][k][l]  Net energy requirement for growth for a barren ewe of category $i$ ($i = 1, \ldots, TE$); the ewe is fed with feeding ration $k$ ($k = 1, \ldots fE$) in feeding season $l$ ($l = 1, \ldots, nfs$)

negR[i][j][k][l]  Net energy requirement for growth for a ram of category $i$ ($i = 1, \ldots, TR$) of the breed of the flock ($j = 1$) or the breed used for crossing in the flock ($j = 2$) ; the ram is fed with feeding ration $k$ ($k = 1, \ldots fR$) in feeding season $l$ ($l = 1, \ldots, nfs$)

neL[i][j][k][l]  Net energy requirement for a pure-bred ($j = 1$) or cross-bred ($j = 2$) lamb of category $i$ ($i = 1, \ldots, PP$) fed with feeding ration $k$ ($k = 1, \ldots, fL$) in feeding season $l$ ($l = 1, \ldots, nfs$)

nelbE[b][i][k][l]  Net energy requirement for lactation per ewe lambing of category $i$ ($i = (j - 1) \times nstgE + i1$ where $i1 = 3, \ldots, nstgE$ for $j = 1, \ldots, LL - 1$ and $i1 = 3$ for $j = LL$, $j$ is the number of the reproductive cycle) with litter size $b$ ($b = 1, \ldots clt$) which will be fed with feeding ration $k$ ($k = 1, 2$) in feeding season $l$ ($l = 1, \ldots, nfs$)

nelE[i][k][l]  Net energy requirement for lactation per ewe lambing of category $i$ ($i = (j - 1) \times nstgE + i1$ where $i1 = 3, \ldots, nstgE$ for $j = 1, \ldots, LL - 1$ and $i1 = 3$ for $j = LL$, $j$ is the number of the reproductive cycle) which will be fed with feeding ration $k$ ($k = 1, 2$) in feeding season $l$ ($l = 1, \ldots, nfs$), averaged over litter size

nelwL[i][j]  Net energy available from milk per lamb from a litter with litter size[3] $i$ ($i = 1, \ldots, clt$) in feeding season $j$ ($j = 1, \ldots, nfs$)

nembL[b][i][j][k][l]  Net energy requirement for maintenance for a pure-bred ($j = 1$) or cross-bred ($j = 2$) lamb of category $i$ ($i = 1, \ldots, PP$) from a litter with size $b$ ($b = 1, \ldots clt$) which will be fed with feeding ration $k$ ($k = 1, \ldots, fL$) in feeding season $l$ ($l = 1, \ldots, nfs$)

nemilk  Net energy content of milk (nutrition value for lambs)

nemL[i][j][k][l]  Net energy requirement for maintenance for a pure-bred ($j = 1$) or cross-bred ($j = 2$) lamb of category $i$ ($i = 1, \ldots, PP$) which will be fed with feeding ration $k$ ($k = 1, \ldots, fL$) in feeding season $l$ ($l = 1, \ldots, nfs$) averaged over litter size

nemL14m[j][l]  Net energy requirement for maintenance for a pure-bred ($j = 1$) or cross-bred ($j = 2$) lamb of category 14 to be mated which will be fed with feeding ration 4 in feeding season $l$ ($l = 1, \ldots, nfs$)

nemL14nm[j][l]  Net energy requirement for maintenance for a pure-bred ($j = 1$) or cross-bred ($j = 2$) lamb of category 14 not to be mated which will be fed with feeding ration 4 in feeding season $l$ ($l = 1, \ldots, nfs$)

nemlE[i][k][l]  Net energy requirement for maintenance for a ewe lambing of category $i$ ($i = 1, \ldots, TE$); the ewe is fed with feeding ration $k$ ($k = 1, \ldots fE$) in feeding season $l$ ($l = 1, \ldots, nfs$)

nemnlE[i][k][l]  Net energy requirement for maintenance for a barren ewe of category $i$ ($i = 1, \ldots, TE$); the ewe is fed with feeding ration $k$ ($k = 1, \ldots fE$) in feeding season $l$ ($l = 1, \ldots, nfs$)

nemR[i][j][k][l]  Net energy requirement for maintenance for a ram of category $i$ ($i = 1, \ldots, TR$) of the breed of the flock ($j = 1$) or the breed used for crossing in the flock ($j = 2$) ; the ram is fed with feeding ration $k$ ($k = 1, \ldots fR$) in feeding season $l$ ($l = 1, \ldots, nfs$)

nendoparL  Number of drenchings against worm (endo-parasites) from early weaning till the end of artificial rearing

nendopclFP  Number of drenchings against worm (endo-parasites) per female breeding lamb from conceiving to lambing

nendopE  Number of drenchings against worm (endo-parasites) per ewe per reproductive cycle

nendopf[i][j]  Number of drenchings against worm (endo-parasites) per female lamb ($i = 1$), male lamb ($i = 2$) or castrate ($i = 0$) in fattening to target $j$ ($j = 1, \ldots, lf[i]$)

nendopR  Number of drenchings against worm (endo-parasites) per ram per breeding cycle

nendoprL[i]  Number of drenchings against worm (endo-parasites) per female or male breeding lamb from weaning or the end of artificial rearing till the 1st breeding season ($i = 1$) or from the 1st to 2nd (or from the 2nd to 3rd) breeding season ($i = 2$)

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[3]For this variable, litter size is to be understood as the number of suckled lambs and not as the number of lambs born.

nendopwL  Number of drenchings against worm (endo-parasites) per lamb till weaning

nepbE[b][i][k][l]  Net energy requirement for pregnancy for a ewe of category $i$ ($i = nstgE, 2 \times nstgE, \ldots, (LL - 1) \times nstgE$) with expected litter size $b$ ($b = 1, \ldots clt$) which will be fed with feeding ration $k$ ($k = 4, 5$) in feeding season $l$ ($l = 1, \ldots, nfs$)

nepE[i][k][l]  Net energy requirement for pregnancy for a ewe of category $i$ ($i = nstgE, 2 \times nstgE, \ldots, (LL - 1) \times nstgE$) which will be fed with feeding ration $k$ ($k = 4, 5$) in feeding season $l$ ($l = 1, \ldots, nfs$), averaged over expected litter size

nepbL[b][i][j][k][l]  Net energy requirement for pregnancy for a pure-bred ($j = 1$) or cross-bred ($j = 2$) female of category $i$ ($i = 15, 16, 19, 20, 23, 24$) with expected litter size $b$ ($b = 1, \ldots clt$) which will be fed with feeding ration $k$ ($k = 4, 5$) in feeding season $l$ ($l = 1, \ldots, nfs$)

nepL[i][j][k][l]  Net energy requirement for pregnancy for a pure-bred ($j = 1$) or cross-bred ($j = 2$) female of category $i$ ($i = 15, 16, 19, 20, 23, 24$) which will be fed with feeding ration $k$ ($k = 4, 5$) in feeding season $l$ ($l = 1, \ldots, nfs$), averaged over expected litter size

neR[i][j][k][l]  Total net energy requirement for a ram of category $i$ ($i = 1, \ldots, TR$) of the breed of the flock ($j = 1$) or the breed used for crossing in the flock ($j = 2$) ; the ram is fed with feeding ration $k$ ($k = 1, \ldots fR$) in feeding season $l$ ($l = 1, \ldots, nfs$)

neweR[i]  Number of rams needed per ewe per reproductive cycle. The rams are either of the same breed as the breed of the ewes ($i = 1$) or of a breed different from the breed of the ewes ($i = 2$). In the first case pure-bred progeny is produced and the second case will result in cross-bred progeny.

newbL[b][i][j][k][l]  Net energy requirement for wool for a pure-bred ($j = 1$) or cross-bred ($j = 2$) lamb of category $i$ ($i = 1, \ldots, PP$) from a litter with size $b$ ($b = 1, \ldots clt$) which will be fed with feeding ration $k$ ($k = 1, \ldots, fL$) in feeding season $l$ ($l = 1, \ldots, nfs$)

newL[i][j][k][l]  Net energy requirement for wool for a pure-bred ($j = 1$) or cross-bred ($j = 2$) lamb of category $i$ ($i = 1, \ldots, PP$) which will be fed with feeding ration $k$ ($k = 1, \ldots, fL$) in feeding season $l$ ($l = 1, \ldots, nfs$)

newL14m[j][l]  Net energy requirement for wool for a pure-bred ($j = 1$) or cross-bred ($j = 2$) lamb of category 14 to be mated which will be fed with feeding ration 4 in feeding season $l$ ($l = 1, \ldots, nfs$)

newL14nm[j][l]  Net energy requirement for wool for a pure-bred ($j = 1$) or cross-bred ($j = 2$) lamb of category 14 not to be mated which will be fed with feeding ration 4 in feeding season $l$ ($l = 1, \ldots, nfs$)

newlE[i][k][l]  Net energy requirement for growth of wool for a ewe lambing of category $i$ ($i = 1, \ldots, TE$); the ewe is fed with feeding ration $k$ ($k = 1, \ldots fE$) in feeding season $l$ ($l = 1, \ldots, nfs$)

newnlE[i][k][l]  Net energy requirement for growth of wool for a barren ewe of category $i$ ($i = 1, \ldots, TE$); the ewe is fed with feeding ration $k$ ($k = 1, \ldots fE$) in feeding season $l$ ($l = 1, \ldots, nfs$)

newR[i][j][k][l] Net energy requirement for growth of wool for a ram of category $i$ ($i = 1, \ldots, TR$) of the breed of the flock ($j = 1$) or the breed used for crossing in the flock ($j = 2$); the ram is fed with feeding ration $k$ ($k = 1, \ldots fR$) in feeding season $l$ ($l = 1, \ldots, nfs$)

NFAT  Maximal number of threshold values for milk fat content in the milk pricing system

nfat  Number of thresholds for milk fat content in the milk pricing system

nfattar[k][i][j] Number of pure-bred ($j = 1$) or cross-bred ($j = 2$) female ($k = 1$) or male ($k = 2$) progeny or castrates ($k = 0$) reaching the appropriate target $i$ ($i = 1, \ldots, lf[k]$) in fattening, per ewe per reproductive cycle

NFS  Maximal number of different feeding seasons during the year $+ 1$ (set to 5, used for dimensioning arrays in the program, see footnote on page 177)

nfs  Number of different feeding seasons during the year (e.g. summer and winter feeding periods, dry and wet feeding periods). The maximal value of $nfs$ is 4.

nherd[i]  Number of weaned female ($i = 1$) or male ($i = 2$) lambs per ewe per reproductive cycle that must be reared for own flock replacement

Nlamb  Number of lambings in the flock per ewe and reproductive cycle

nmatFP[i][j] Number of reared surplus breeding pure-bred ($j = 1$) or cross-bred ($j = 2$) female lambs mated in breeding season $i$ ($i = 1, \ldots, bs[1]$) per ewe and reproductive cycle

NPROT  Maximal number of threshold values for milk protein content in the milk pricing system

nprot  Number of thresholds for milk protein content in the milk pricing system

npurchFP  Number of female replacement per ewe and reproductive cycle purchased from outside the flock

npurchMP[i] Number of rams per ewe and reproductive cycle purchased from outside the flock. The rams are either of the same breed as the breed of the ewes ($i = 1$) or of a breed different from the breed of the ewes ($i = 2$).

nramMP[i] Number of weaned male lambs that must enter the flock per ewe per reproductive cycle ($i = 0, 1, 2$; $i = 1$ : males of the breed of the flock, $i = 2$: males of the breed which is used for crossing in the flock, $i = 0$: sum of males of both breeds)

nrcull[k][i][j] Number of pure-bred ($j = 1$) or cross-bred ($j = 2$) female ($k = 1$) progeny determined for replacement and culled after breeding season $i$ ($i = 1, \ldots, bs[1]$) or number of pure-bred ($j = 1$) or cross-bred ($j = 2$) male lambs ($k = 2$) determined for replacement and culled from weaning to breeding season 1 ($i = 1$) or from breeding season $i - 1$ to breeding season $i$ ($i = 1, \ldots, bs[2]$)

nrdied[k][i][j] Number of pure-bred ($j = 1$) or cross-bred ($j = 2$) female progeny ($k = 1$) determined for replacement and died from weaning (for $i = 1$) or from breeding season $i - 1$ (for $i > 1$) to breeding season $i$ ($i = 1, \ldots, bs[1]$) or number of pure-bred ($j = 1$) or cross-bred ($j = 2$) male progeny ($k = 2$) determined for replacement and died from weaning (for $i = 1$) or from breeding season $i - 1$ (for $i > 1$) to breeding season $i$ ($i = 1, \ldots, bs[2]$)

nrdiedmlFP[i]  Number of pure-bred ($i = 1$) or cross-bred ($i = 2$) female lambs for replacement died from mating (conceiving) till lambing

nreins  Number of re-inseminations per oestrus

nrmatFP[i]  Number of female progeny for replacement mated in breeding season $i$ ($i = 1, \ldots, bs[1]$)

NSCC  Maximal number of milk quality classes according to somatic cell content in the sheep flock

nSCC  Number of milk quality classes according to somatic cell content in the sheep flock

nshearL  Number of shearings per lambs from birth until the end of artificial rearing

nsheE  Number of shearings per ewe per reproductive cycle

nshefL[i][j]  Number of shearings per female lamb ($i = 1$), male lamb ($i = 2$) or castrate ($i = 0$) in fattening to target $j$ ($j = 1, \ldots, lf[i]$)

nsheFP  Number of shearings per female breeding lamb from conceiving to lambing

nsheR[j]  Number of shearings per ram of the breed of the flock ($j = 1$) or of the breed used for crossing in the flock ($j = 2$) per breeding cycle

nsherL[i]  Number of shearings per female (or male) breeding lamb in rearing from weaning or the end of artificial rearing till breeding season $i = 1$ and from breeding season $i - 1$ to breeding season $i$ ($i = 1, \ldots, bs[1]$)

nshewL  Number of shearings per lambs from birth until weaning

nsl  Number of suckled lambs for which the lactation curve was defined

nsold[k][i][j]  Number of pure-bred ($j = 1$) or cross-bred ($j = 2$) surplus female progeny ($k = 1$) sold as breeding females before mating ($i = 0$) or as pregnant animals after breeding season $i$ ($i = 1, \ldots, bs[1]$) and number of pure-bred ($j = 1$) or cross-bred ($j = 2$) surplus male progeny ($k = 2$) sold as breeding males before breeding season $i$ ($i = 1, \ldots, bs[2]$)

nsp[k][i][j]  Number of pure-bred ($j = 1$) or cross-bred ($j = 2$) weaned surplus female ($k = 1$) or male ($k = 2$) progeny or castrates ($k = 0$) sold in different categories $i$ ($i = 1, \ldots, csp[k]$). Female and male progeny: $i = 1$ : sold at weaning for slaughter, $i = 2$: sold as breeding animals. Male progeny: $i = 3$ : castrated animals. Female progeny: $i = 3, \ldots, 7$ : fattened to target 1 to 5, respectively. Male progeny: $i = 4, \ldots, 8$ : fattened to target 1 to 5, respectively. Castrates: $i = 1, \ldots, 5$ : fattened to target 1 to 5, respectively.

nspcull[k][i][j]  Number of pure-bred ($j = 1$) or cross-bred ($j = 2$) surplus female ($k = 1$) or male ($k = 2$) progeny originally determined for selling as breeding animals that were culled after breeding season $i$ ($i = 1, \ldots, bs[1]$) because of failure to conceive (female progeny) or that were culled before breeding season $i$ ($i = 1, \ldots, bs[2]$, male progeny)

nspdied[k][i][j]  Number of pure-bred ($j = 1$) or cross-bred ($j = 2$) surplus female progeny ($k = 1$) originally determined for selling as breeding animals that died from weaning till the first breeding season ($i = 1$) or from breeding season $i - 1$ to breeding season $i$ for $i = 2, \ldots, bs[1]$ or number of surplus male progeny ($k = 2$) originally determined for selling as breeding animals that died from weaning till the first breeding season ($i = 1$) or from breeding season $i - 1$ to breeding season $i$ for $i = 2, \ldots, bs[2]$.

nstg1E  Number of stages for ewes which occur in all reproductive cycles (=3)

nstg1R  Number of stages for rams which occur in all reproductive cycles (=3)

nstg2E  Number of stages for ewes which do not occur in the last reproductive cycle (=2)

nstg2R  Number of stages for rams which do not occur in the last reproductive cycle (=1)

nstgE  Maximal number of stages for ewes within a reproductive cycle ($nstgE = nstg1E + nstg2E = 5$)

nstgR  Maximal number of stages for rams within a breeding cycle ($nstgR = nstg1R + nstg2R = 4$)

NT  Number of traits $+ 1$

NwL[i]  Number of lambs weaned per ewe per reproductive cycle summed over litter size for type $i$ of breeding ($i = 1$ : pure-bred lambs, $i = 2$: cross-bred lambs, $i = 0$: sum of pure-bred and cross-bred lambs)

nwL[i][j]  Number of lambs weaned per ewe per reproductive cycle for type $i$ of breeding ($i = 1$ : pure-bred lambs, $i = 2$: cross-bred lambs, $i = 0$: sum of pure-bred and cross-bred lambs) and for litter size $j$ ($j = 1, \ldots, clt$)

nwsp[i][j]  Number of surplus pure-bred ($j = 1$) or cross-bred ($j = 2$) female ($i = 1$) or male ($i = 2$) progeny per ewe per reproductive cycle

opsbL  Option for the price for breeding lambs (1: lambs are paid per animal, 2: lambs are paid per kg live weight)

P  Maximal number of categories for progeny $+ 1$ (set to 52, used for dimensioning arrays in the program, see footnote on page 177)

parL[i][j]  Proportion of pure-bred ($j = 1$) or cross-bred ($j = 2$) lambs at the end of artificial rearing in litter size $i$ ($i = 1, \ldots, clt$)

pbarrE[i]  Fraction of barren ewes in reproductive cycle $i$ ($i = 1, \ldots, LL - 1$) kept to the next breeding season

pbarrFP[i][j]  Fraction of barren pure-bred ($j = 1$) or cross-bred ($j = 2$) female progeny after breeding season $i$ kept to the next breeding season ($i = 1, \ldots, bs[1] - 1$)

pbtba[i][j]  Probability that the number of suckled lambs is $j$ for a ewe who has born $i$ ($i \geq j$) lambs

pcastMP  Castrates in fattening as proportion of the sum of male lambs and castrates in fattening

pcl0[i]   Temporary variable in the calculation of economic weights saving original values of $pclS[j][i]$, $pclfL[j][i]$ and $pclwL[j][i]$ for $j = 1$ or 2

pcl00[i][k]   Temporary variable in the calculation of economic weights saving original values of $pclfcfL[j][i][k]$ or $pclfcS[j][i][k]$ for $j = 1$ or 2

pcl11[i][k]   Temporary variable in the calculation of economic weights saving original values of $pclfcwL[j][i][k]$ for $j = 1$ or 2

pclcqwL[r][s][j]   Relative frequencies of pure-bred ($j = 1$) or cross-bred ($j = 2$) lambs slaughtered after weaning or artificial rearing (categories 7 and 32) in quality classes $s = 1$ or 2 within weight class $r$ ($r = 1, \ldots, 3$)

pclcwL[i][r][s][j]   Relative frequencies for the combinations of weight classes A to C ($r = 1, \ldots, 3$) and quality classes 1 and 2 ($s = 1, 2$) for pure-bred ($j = 1$) or cross-bred ($j = 2$) female ($i = 1$) and male ($i = 2$) lambs slaughtered after weaning or artificial rearing (categories 7 and 32)

pclcwwL[i][r][j]   Relative frequencies in carcass weight classes A to C ($r = 1, \ldots, 3$) or in the class for heavy lambs ($r = 4$) for pure-bred ($j = 1$) or cross-bred ($j = 2$) female ($i = 1$) or male ($i = 2$) lambs slaughtered after weaning or artificial rearing (categories 7 and 32)

pclfcfL[j][i][k]   $nclflfL \times nclfcfL$ matrices specific for breeding type ($j = 1$ for pure-bred and $j = 2$ for cross-bred animals) of relative frequencies of carcasses of fattened lambs in each combination of classes for fleshiness (rows) and for fat covering (columns). The sum of the values must be 1 for each $j$.

pclfcS[k][i][j]   $nclflS \times nclfcS$ matrix of relative frequencies of carcasses of pure-bred ($k = 1$) or cross-bred ($k = 2$) adult sheep in each combination of classes for fleshiness (rows) and for fat covering (columns). The sum of the values must be 1 for each $k$.

pclfcwL[j][i][k]   $nclflwL \times nclfcwL$ matrices specific for breeding type ($j = 1$ for pure-bred and $j = 2$ for cross-bred animals) of relative frequencies of carcasses of "heavy" lambs ($>13$ kg) slaughtered after weaning or after artificial rearing in each combination of classes for fleshiness (rows) and for fat covering (columns). The sum of the values must be 1 for each $j$.

pclfL[j][i]   Relative frequencies of fattened pure-bred ($j = 1$) or cross-bred ($j = 2$) lambs in quality classes $i = 1$ to $nclfL$. The values must sum up to 1 for each $j$.

pclS[j][i]   Relative frequencies of pure-bred ($j = 1$) or cross-bred ($j = 2$) adult sheep in quality classes $i = 1$ to $nclS$. The values must sum up to 1 for each $j$.

pclwL[j][i]   Relative frequencies of pure-bred ($j = 1$) or cross-bred ($j = 2$) lambs slaughtered after weaning in quality classes $i = 1$ to $nclwL$. The values must sum up to 1 for each $j$.

pclwLql[i]   Temporary variable in the calculation of economic weights: abscissa of the upper border of the $i^{th}$ quality class in the shifted standardized normal distribution

pclwLqm[i]   Temporary variable in the calculation of economic weights: abscissa of the upper border of the $i^{th}$ quality class in the standardized normal distribution

pconE[i]     Pregnant ewes in reproductive cycle $i$ ($i = 1, \ldots, LL - 1$) as proportion of ewes mated in this cycle

pconstayE[i]  Probability that a ewe entering reproductive cycle $i$ ($i = 1, \ldots, LL - 1$) will become pregnant in the cycle and stay to the next cycle

pcrossE[i]   Fraction of ewes crossed with other breeds in reproductive cycle $i$ ($i = 1, \ldots, LL - 1$). $pcrossE[0]$ is the fraction of female lambs crossed with other breeds.

pcrosst      Ewes mated with rams of a different breed as proportion of all mated ewes

pctE[i]      Fraction of ewes naturally mated in pure-breeding ($i = 1$) or in cross-breeding ($i = 2$). The sum $pctE[1] + pctE[2]$ is smaller than 1 if there is also artificial insemination.

pcullE[i]    Fraction of ewes entering reproductive cycle $i$ ($i = 1, \ldots, LL$) that were involuntarily culled for reasons other than infertility

pcullfcE0    Relative frequency of ewes involuntarily culled for failure to conceive averaged over all reproductive cycles

pcullfcEp    Ewes involuntarily culled for failure to conceive as percentage of ewes replaced per reproductive cycle

pcullhE[i]   Fraction of ewes entering reproductive cycle $i$ ($i = 1, \ldots, LL$) that were involuntarily culled for health problems other than failure to conceive

pcullhE0     Relative frequency of ewes involuntarily culled for health problems other than failure to conceive averaged over all reproductive cycles

pcullhEp     Ewes involuntarily culled for health problems other than failure to conceive as percentage of ewes replaced per reproductive cycle

pcullmE[i]   Fraction of ewes entering reproductive cycle $i$ ($i = 1, \ldots, LL$) that were voluntarily culled for low milk production

pcullmE0     Relative frequency of ewes voluntarily culled for low milk production averaged over all reproductive cycles

pcullmEp     Ewes voluntarily culled for low milk production as percentage of ewes replaced per reproductive cycle

pcullR[i]    Fraction of rams entering breeding cycle $i$ ($i = 1, \ldots, RR$) that were culled for health or for age

pdibL[b][i][j][k][l]  Total protein requirement for a pure-bred ($j = 1$) or cross-bred ($j = 2$) lamb of category $i$ ($i = 1, \ldots, PP$) from a litter with size $b$ ($b = 1, \ldots clt$) fed with feeding ration $k$ ($k = 1, \ldots, fL$) in feeding season $l$ ($l = 1, \ldots, nfs$)

pdidE[i][j]  Protein content in dry matter for seasonal variant $j$ ($j = 1, \ldots, nfs$) of feeding ration $i$ ($i = 1, \ldots, fE$) for ewes

pdidL[i][j]  Protein content in dry matter for seasonal variant $j$ ($j = 1, \ldots, nfs$) of feeding ration $i$ ($i = 1, \ldots, fL$) for lambs

pdidR[i][j]  Protein content in dry matter for seasonal variant $j$ ($j = 1, \ldots, nfs$) of feeding ration $i$ ($i = 1, \ldots, fR$) for rams

pdiE[i][k][l]  Total protein requirement per ewe of category $i$ $(i = 1, \ldots, TE)$ which will be fed with feeding ration $k$ $(k = 1, \ldots, fE)$ in feeding season $l$ $(l = 1, \ldots, nfs)$

pdiedarL[i][j]  Pure-bred $(j = 1)$ or cross-bred $(j = 2)$ lambs died from early weaning till the end of artificial rearing with milk replacer as proportion of lambs alive at early weaning for litter size $i$ $(i = 1, \ldots, clt)$

pdiedbL[i][j]  Fraction of pure-bred $(j = 1)$ or cross-bred $(j = 2)$ lambs stillborn or died until 24 hours for the individual classes for litter size $(i = 1, \ldots, clt)$

pdiedbtL[i][j]  Fraction of lambs stillborn or died until 24 hours for the individual classes for number of dead lambs $j$ within each litter size $i$ $(i = 1, \ldots, clt; \; j = 1, \ldots, i)$. It must be $\sum_{j=1}^{i} pdiedbtL[i][j] = pdiedbL[i][1]$.

pdiedE[i]  Fraction of ewes died after entering reproductive cycle $i$ $(i = 1, \ldots, LL)$

pdiedE0  Dead rate of ewes averaged over all reproductive cycles

pdiedEp  Ewes died as percentage of ewes replaced per reproductive cycle

pdiedR[i]  Fraction of rams that died in breeding cycle $i$ $(i = 1, \ldots, RR)$

pdiedwL[i][j]  Pure-bred $(j = 1)$ or cross-bred $(j = 2)$ lambs died till weaning as proportion of lambs born alive (lambs alive at 24 hours after birth) for all classes of litter size $(i = 1, \ldots, clt)$

pdifE[i][k][l]  Protein requirement for flushing per ewe of category $i$ $(i = 1, \ldots, TE)$ fed with feeding ration $k$ $(k = 3)$ in feeding season $l$ $(l = 1, \ldots, nfs)$

pdifL[i][j][k][l]  Protein requirement for flushing per pure-bred $(j = 1)$ or cross-bred $(j = 2)$ lamb of category $i$ $(i = 1, \ldots, PP)$ fed with feeding ration $k$ $(k = 3)$ in feeding season $l$ $(l = 1, \ldots, nfs)$

pdigbL[b][i][j][k][l]  Protein requirement for growth for a pure-bred $(j = 1)$ or cross-bred $(j = 2)$ lamb of category $i$ $(i = 1, \ldots, PP)$ from a litter with size $b$ $(b = 1, \ldots clt)$ which will be fed with feeding ration $k$ $(k = 1, \ldots, fL)$ in feeding season $l$ $(l = 1, \ldots, nfs)$

pdigL[i][j][k][l]  Protein requirement for growth for a pure-bred $(j = 1)$ or cross-bred $(j = 2)$ lamb of category $i$ $(i = 1, \ldots, PP)$ which will be fed with feeding ration $k$ $(k = 1, \ldots, fL)$ in feeding season $l$ $(l = 1, \ldots, nfs)$

pdigL14m[j][l]  Protein requirement for growth for a pure-bred $(j = 1)$ or cross-bred $(j = 2)$ lamb of category 14 to be mated which will be fed with feeding ration 4 in feeding season $l$ $(l = 1, \ldots, nfs)$

pdigL14nm[j][l]  Protein requirement for growth for a pure-bred $(j = 1)$ or cross-bred $(j = 2)$ lamb of category 14 not to be mated which will be fed with feeding ration 4 in feeding season $l$ $(l = 1, \ldots, nfs)$

pdiglE[i][k][l]  Protein requirement for growth for a lambing ewe of category $i$ $(i = 1, \ldots, TE)$ fed with feeding ration $k$ $(k = 1, \ldots fE)$ in feeding season $l$ $(l = 1, \ldots, nfs)$

pdignlE[i][k][l]  Protein requirement for growth for a barren ewe of category $i$ $(i = 1, \ldots, TE)$ fed with feeding ration $k$ $(k = 1, \ldots fE)$ in feeding season $l$ $(l = 1, \ldots, nfs)$

pdigR[i][j][k][l]  Protein requirement for growth for a ram of category $i$ ($i = 1, \ldots, TR$) of the breed of the flock ($j = 1$) or the breed used for crossing in the flock ($j = 2$) ; the ram is fed with feeding ration $k$ ($k = 1, \ldots fR$) in feeding season $l$ ($l = 1, \ldots, nfs$)

pdiL[i][j][k][l]  Protein requirement for a pure-bred ($j = 1$) or cross-bred ($j = 2$) lamb of category $i$ ($i = 1, \ldots, PP$) fed with feeding ration $k$ ($k = 1, \ldots, fL$) in feeding season $l$ ($l = 1, \ldots, nfs$)

pdilbE[b][i][k][l]  Protein requirement for lactation per ewe lambing of category $i$ ($i = (j-1) \times nstgE + i1$ where $i1 = 3, \ldots, nstgE$ for $j = 1, \ldots, LL - 1$ and $i1 = 3$ for $j = LL$, $j$ is the number of the reproductive cycle) with litter size[4] $b$ ($b = 1, \ldots clt$) which will be fed with feeding ration $k$ ($k = 1, 2$) in feeding season $l$ ($l = 1, \ldots, nfs$)

pdilE[i][k][l]  Protein requirement for lactation per ewe lambing of category $i$ ($i = (j-1) \times nstgE + i1$ where $i1 = 3, \ldots, nstgE$ for $j = 1, \ldots, LL - 1$ and $i1 = 3$ for $j = LL$, $j$ is the number of the reproductive cycle) which will be fed with feeding ration $k$ ($k = 1, 2$) in feeding season $l$ ($l = 1, \ldots, nfs$), averaged over litter size

pdilwL[i][j]  Digestible protein (PDI) available from milk per lamb from a litter with litter size $i$ ($i = 1, \ldots, clt$) in feeding season $j$ ($j = 1, \ldots, nfs$)

pdimbL[b][i][j][k][l]  Protein requirement for maintenance for a pure-bred ($j = 1$) or cross-bred ($j = 2$) lamb of category $i$ ($i = 1, \ldots, PP$) from a litter with size $b$ ($b = 1, \ldots clt$) which will be fed with feeding ration $k$ ($k = 1, \ldots, fL$) in feeding season $l$ ($l = 1, \ldots, nfs$)

pdimilk  Protein content (PDI) in milk (nutrition value for lambs)

pdimL[i][j][k][l]  Protein requirement for maintenance for a pure-bred ($j = 1$) or cross-bred ($j = 2$) lamb of category $i$ ($i = 1, \ldots, PP$) which will be fed with feeding ration $k$ ($k = 1, \ldots, fL$) in feeding season $l$ ($l = 1, \ldots, nfs$)

pdimL14m[j][l]  Protein requirement for maintenance for a pure-bred ($j = 1$) or cross-bred ($j = 2$) lamb of category 14 to be mated which will be fed with feeding ration 4 in feeding season $l$ ($l = 1, \ldots, nfs$)

pdimL14nm[j][l]  Protein requirement for maintenance for a pure-bred ($j = 1$) or cross-bred ($j = 2$) lamb of category 14 not to be mated which will be fed with feeding ration 4 in feeding season $l$ ($l = 1, \ldots, nfs$)

pdimlE[i][k][l]  Protein requirement for maintenance for a lambing ewe of category $i$ ($i = 1, \ldots, TE$) fed with feeding ration $k$ ($k = 1, \ldots fE$) in feeding season $l$ ($l = 1, \ldots, nfs$)

pdimnlE[i][k][l]  Protein requirement for maintenance for a barren ewe of category $i$ ($i = 1, \ldots, TE$) fed with feeding ration $k$ ($k = 1, \ldots fE$) in feeding season $l$ ($l = 1, \ldots, nfs$)

pdimR[i][j][k][l]  Protein requirement for maintenance for a ram of category $i$ ($i = 1, \ldots, TR$) of the breed of the flock ($j = 1$) or the breed used for crossing in the flock ($j = 2$) ; the ram is fed with feeding ration $k$ ($k = 1, \ldots fR$) in feeding season $l$ ($l = 1, \ldots, nfs$)

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[4]For this variable, litter size is to be understood as the number of suckled lambs and not as the number of lambs born.

pdipbE[b][i][k][l] Protein requirement for pregnancy for a ewe of category $i$ ($i = nstgE, 2 \times nstgE, \ldots, (LL - 1) \times nstgE$) with expected litter size $b$ ($b = 1, \ldots clt$) which will be fed with feeding ration $k$ ($k = 4, 5$) in feeding season $l$ ($l = 1, \ldots, nfs$)

pdipE[i][k][l] Protein requirement for pregnancy for a ewe of category $i$ ($i = nstgE, 2 \times nstgE, \ldots, (LL-1) \times nstgE$) fed with feeding ration $k$ ($k = 4, 5$) in feeding season $l$ ($l = 1, \ldots, nfs$), averaged over expected litter size

pdipbL[b][i][j][k][l] Protein requirement for pregnancy for a pure-bred ($j = 1$) or cross-bred ($j = 2$) female of category $i$ ($i = 15, 16, 19, 20, 23, 24$) with expected litter size $b$ ($b = 1, \ldots clt$) which will be fed with feeding ration $k$ ($k = 4, 5$) in feeding season $l$ ($l = 1, \ldots, nfs$)

pdipL[i][j][k][l] Protein requirement for pregnancy for a pure-bred ($j = 1$) or cross-bred ($j = 2$) female of category $i$ ($i = 15, 16, 19, 20, 23, 24$) which will be fed with feeding ration $k$ ($k = 4, 5$) in feeding season $l$ ($l = 1, \ldots, nfs$), averaged over expected litter size

pdiR[i][j][k][l] Total protein requirement for a ram of category $i$ ($i = 1, \ldots, TR$) of the breed of the flock ($j = 1$) or the breed used for crossing in the flock ($j = 2$) ; the ram is fed with feeding ration $k$ ($k = 1, \ldots fR$) in feeding season $l$ ($l = 1, \ldots, nfs$)

pdiwbL[b][i][j][k][l] Protein requirement for wool for a pure-bred ($j = 1$) or cross-bred ($j = 2$) lamb of category $i$ ($i = 1, \ldots, PP$) from a litter with size $b$ ($b = 1, \ldots clt$) which will be fed with feeding ration $k$ ($k = 1, \ldots, fL$) in feeding season $l$ ($l = 1, \ldots, nfs$)

pdiwL[i][j][k][l] Protein requirement for wool for a pure-bred ($j = 1$) or cross-bred ($j = 2$) lamb of category $i$ ($i = 1, \ldots, PP$) fed with feeding ration $k$ ($k = 1, \ldots, fL$) in feeding season $l$ ($l = 1, \ldots, nfs$)

pdiwL14m[j][l] Protein requirement for wool for a pure-bred ($j = 1$) or cross-bred ($j = 2$) lamb of category 14 to be mated and fed with feeding ration 4 in feeding season $l$ ($l = 1, \ldots, nfs$)

pdiwL14nm[j][l] Protein requirement for wool for a pure-bred ($j = 1$) or cross-bred ($j = 2$) lamb of category 14 not to be mated and fed with feeding ration 4 in feeding season $l$ ($l = 1, \ldots, nfs$)

pdiwlE[i][k][l] Protein requirement for growth of wool for a lambing ewe of category $i$ ($i = 1, \ldots, TE$) fed with feeding ration $k$ ($k = 1, \ldots fE$) in feeding season $l$ ($l = 1, \ldots, nfs$)

pdiwnlE[i][k][l] Protein requirement for growth of wool for a barren ewe of category $i$ ($i = 1, \ldots, TE$) fed with feeding ration $k$ ($k = 1, \ldots fE$) in feeding season $l$ ($l = 1, \ldots, nfs$)

pdiwR[i][j][k][l] Protein requirement for growth of wool for a ram of category $i$ ($i = 1, \ldots, TR$) of the breed of the flock ($j = 1$) or the breed used for crossing in the flock ($j = 2$) ; the ram is fed with feeding ration $k$ ($k = 1, \ldots fR$) in feeding season $l$ ($l = 1, \ldots, nfs$)

pf[i] Temporary variable in the calculation of economic weights containing the changed marginal frequencies of a matrix

pf0[i] Temporary variable in the calculation of economic weights saving the original marginal frequencies of a matrix

pf1[i]     Temporary variable in the calculation of economic weights saving the original marginal frequencies of a matrix

Pherd[i]   Fraction of pure-bred weaned female lambs conceived ($i = 1$) or of pure-bred weaned male lambs ($i = 2$) that entered the flock summed over all breeding seasons

pherd[i][j]  Fraction of pure-bred weaned female ($i = 1$) lambs conceived in breeding season $j$ ($j = 1, \ldots, bs[1]$) and entered the flock or fraction of pure-bred weaned male ($i = 2$) lambs that entered the flock in breeding season $j$ ($j = 1, \ldots, bs[2]$)

pherdyMP   Pure-bred young rams (rams used in the first breeding season following their weaning) that entered the flock as proportion of the total number of pure-bred rams that entered the flock

Phicwl[r]  Temporary variable necessary for calculating the relative frequencies ($pclcwwL[i][r][j]$) in carcass weight classes A to C ($r = 1, \ldots, 3$)

Phiscc[i]  Cumulative frequency up to the $i$th class of milk quality due to somatic cell count ($i = 0, \ldots, nSCC - 2$)

pinsE[j]   Proportion of insemination in ewes intended for pure-breeding ($j = 1$) and for cross-breeding ($j = 2$)

pinsFP[j]  Proportion of insemination in pure-bred ($j = 1$) or cross-bred ($j = 2$) female progeny

placE      Parity for which the lactation curve was defined

plambE[i]  Proportion of lambing ewes in category $i$ ($i = 1, \ldots, TE$)

Pltype[i][j]  Fraction of lambings in individual classes for litter size ($i = 1, \ldots, clt$) for all reproductive cycles ($j = 1, \ldots, LL$)

pmatE[i]   Fraction of ewes entering reproductive cycle $i$ ($i = 1, \ldots, LL - 1$) that will be mated in this cycle

pmat[k][i][j]  Fraction of reared breeding pure-bred ($j = 1$) or cross-bred ($j = 2$) female lambs ($k = 1$) mated in breeding season $i$ ($i = 1, \ldots, bs[1]$) or fraction of reared breeding male lambs ($k = 2$) that can be first used for breeding in breeding season $i$ ($i = 1, \ldots, bs[2]$) following their weaning

pmilkch    Proportion of milk produced in the flock for cheese production

pmilkwm    Proportion of milk for sale produced by ewes from lambing till weaning

pnconE[i]  Fraction of ewes entering reproductive cycle $i$ ($i = 1, \ldots, LL - 1$) that will not conceive in this cycle

pnconculE[i]  Probability that a ewe entering reproductive cycle $i$ ($i = 1, \ldots, LL - 1$) will not conceive in this cycle and will be culled

pnconstayE[i]  Probability that a ewe entering reproductive cycle $i$ ($i = 1, \ldots, LL - 1$) will not conceive in this cycle and will stay to the next cycle

pnlambE[i]  Proportion of not lambing ewes in category $i$ ($i = 1, \ldots, TE$)

PP         Number of categories for progeny, set to 48 in the given version of the program. For numbering of the categories see Section .

ppurchFP  Fraction of replacement females purchased from outside the flock

ppurchMP  Fraction of replacement males purchased from outside the flock

prbR[j]  Price per breeding ram purchased for pure-breeding ($j = 1$) or cross-breeding ($j = 2$)

prcheese  Price per kg cheese

prclcwwL[r][s]  Price per kg carcass weight in the combinations of weight classes A to C ($r = 1, \ldots, 3$) and quality classes 1 and 2 ($s = 1, 2$) for lambs slaughtered after weaning or artificial rearing (categories 7 and 32)

prclfcfL[i][j]  $nclflfL \times nclfcfL$ matrix for price coefficients for each combination of classes for fleshiness (rows) and for fat covering (columns) for fattened lambs. The price for each combination of classes is given by multiplying these coefficients with the price for the reference class $prreffL$.

prclfcS[i][j]  $nclflS \times nclfcS$ matrix for price coefficients for each combination of classes for fleshiness (rows) and fat covering (columns) for adult sheep. The price for each combination of classes is given by multiplying these coefficients with the price for the reference class $prrefS$.

prclfcwL[i][j]  $nclflwL \times nclfcwL$ matrix for price coefficients for each combination of classes for fleshiness (rows) and fat covering (columns) for "heavy" lambs ($>$13 kg) slaughtered after weaning or artificial rearing. The price for each combination of classes is given by multiplying these coefficients with the price for the reference class $prrefwL$.

prclfL[i]  Price per kg live weight of fattened lambs in quality class $i$ ($i = 1, \ldots, nclfL$).

prclS[i]  Price per kg live weight of adult sheep in quality classes $i = 1$ to $nclS$

prclwL[i]  Price per kg live weight of lambs slaughtered after weaning in quality class $i$ ($i = 1, \ldots, nclwL$).

prconFP[i][j]  Fraction of pure-bred ($j = 1$) or cross-bred ($j = 2$) weaned female lambs conceived in breeding season $i$ ($i = 1, \ldots, bs[1]$)

prcwawL[i][j]  Average price per kg carcass weight for pure-bred ($j = 1$) or cross-bred ($j = 2$) female ($i = 1$) or male ($i = 2$) light lambs (carcass weight $\leq$ 13 kg) slaughtered after weaning or artificial rearing (categories 7 and 32)

prcwbwL[j]  Average price per kg carcass weight for pure-bred ($j = 1$) or cross-bred ($j = 2$) heavy lambs (carcass weight $>$ 13 kg) slaughtered after weaning or artificial rearing (categories 7 and 32)

prcwcwL[i][j]  Average price per kg carcass weight for pure-bred ($j = 1$) or cross-bred ($j = 2$) female ($i = 1$) or male ($i = 2$) lambs slaughtered after weaning or artificial rearing (categories 7 and 32)

prcwfL0  Price per kg carcass weight of fattened lambs

prcwfL[j]  Average price per kg carcass weight for pure-bred ($j = 1$) or cross-bred ($j = 2$) fattened lambs

prcwS[j]  Average price per kg carcass weight of pure-bred ($j = 1$) or cross-bred ($j = 2$) adult sheep

prcwwL[j]  Price per kg carcass weight of pure-bred ($j = 1$) or cross-bred ($j = 2$) weaned lambs or lambs after artificial weaning

prectop  Costs for drugs per treatment against ecto-parasites and per animal

prendop  Costs for drugs per kg life weight and per drenching against worm (endo-parasites)

prfE[i][j]  Price per kg fresh feed for seasonal variant $j$ ($j = 1, \dots, nfs$) of feeding ration $i$ ($i = 1, \dots, fE$) for ewes

prfL[i][j]  Price per kg fresh matter for seasonal variant $j$ ($j = 1, \dots, nfs$) of feeding ration $i$ ($i = 1, \dots, fL$) for lambs

prfR[i][j]  Price per kg fresh feed for seasonal variant $j$ ($j = 1, \dots, nfs$) of feeding ration $i$ ($i = 1, \dots, fR$) for rams

pricefL  Variable indicating the pricing system for lambs slaughtered after fattening (till 12 months of age). Takes the same values as *priceS*.

priceS  Variable indicating the pricing system for adult sheep (1: according to live weight without taking into account conformation; 2: according to live weight taking into account conformation; 3: according to carcass weight not accounting for carcass quality; 4: according to EU evaluation system with quality classes for fleshiness and fat covering)

pricewL  Variable indicating the pricing system for lambs slaughtered after weaning (1: according to live weight without taking into account conformation; 2: according to live weight taking into account conformation; 3: according to carcass weight not accounting for carcass quality; 4: according to the EU evaluation system with classes A, B, C for carcass weight and meat quality classes 1 and 2 within the classes for carcass weight for light lambs or according to the EU grading system for fleshiness and fat covering for heavy lambs)

prlwfL[j]  Average price per kg live weight of a pure-bred ($j = 1$) or cross-bred ($j = 2$) fattened lamb

prlwS[j]  Average price per kg live weight of pure-bred ($j = 1$) or cross-bred ($j = 2$) adult sheep

prlwwL[j]  Average price per kg live weight of a pure-bred ($j = 1$) or cross-bred ($j = 2$) lamb at weaning or at the end of artificial rearing

prman  Price per kg manure

prmilk  Price per kg milk of given fat and protein content and given somatic cell count

prmilkb  Base milk price per kg milk, input parameter

prmilkf[i]  Bonus or penalty for fat content per kg milk in the $i$th class of fat content ($i = 0, \dots, nfat$)

prmilkfp  Milk price corrected for fat and protein content and not yet corrected for milk quality classes (per kg milk)

prmilkp[i]  Bonus or penalty for protein content per kg milk in the $i$th class of protein content ($i = 0, \dots, nprot$)

| | |
|---|---|
| profnsub | Profitability of the production system excluding subsidies |
| profsub | Profitability of the production system including subsidies |
| prot | Protein content in milk |
| protymst | Protein yield in the standardized milking period in kg |
| prreffL | Price per kg carcass weight for the reference class for fattened lambs |
| prrefS | Price per kg carcass weight for the reference class for adult sheep |
| prrefwL | Price per kg carcass weight for the reference class for lambs slaughtered after weaning or after artificial rearing |
| prsbL[i][j] | Price for sold breeding lambs of category $i$ ($i = 13, 15, 19, 23, 26, 38$ or $40$) and breeding type $j$ ($j = 1$ : pure-bred lambs, $j = 2$ : cross-breed lambs) per kg live weight |
| prsbR[j] | Price per sold breeding ram of breed $j$ |
| prSCC[i] | Vector of base prices per kg milk in quality class $i$ ($i = 1, ..., NSCC$) for options 2 and 4 for the calculation of the milk price (see Section 11.1 on page 109); vector of additive adjustment factors for the milk price per kg milk in quality class $i$ for option 5 for the calculation of the milk price |
| prscc | Temporary variable for calculating the milk price |
| prskrE | Price per raw skin of ewes |
| prskrL[j] | Price per raw skin from pure-bred ($j = 1$) and cross-bred ($j = 2$) lambs |
| prskrR[j] | Price per raw skin from rams of breed $j$ ($j = 1$ : rams for pure-breeding, $j = 2$: rams for cross-breeding) |
| prsktE | Price per tanned skin of ewes |
| prsktL[j] | Price per tanned skin from pure-bred ($j = 1$) or cross-bred ($j = 2$) lambs |
| prsktR[j] | Price per tanned skin from rams of breed $j$ ($j = 1$ : rams for pure-breeding, $j = 2$ : rams for cross-breeding) |
| prstraw | Price of material for bedding |
| prwat | Price per litre water |
| prwhey | Price per kg cheese whey |
| prwoolE | Price per kg wool of ewes |
| prwoolL[j] | Price per kg wool of pure-bred ($j = 1$) and cross-bred ($j = 2$) lambs |
| prwoolR[j] | Price per kg wool of rams of breeding type $j$ ($j = 1$: rams for pure-breeding, $j = 2$: rams for cross-breeding) |
| ps13[j] | Fraction of not mated pure-bred ($j = 1$) or cross-bred ($j = 2$) weaned surplus female progeny sold before the first breeding season |
| pSCC[i] | Vector of proportions of sold milk in quality class $i$ ($i = 0, ..., nSCC - 1$) |
| pskarL | Proportion of lambs after artificial rearing that give skin to the shepherd |

pskE        Proportion of culled ewes that give skin to the shepherd

pskfL       Proportion of lambs slaughtered after fattening that give skin to the
            shepherd

pskR        Proportion of culled rams that give skin to the shepherd

pskrL       Proportion of slaughtered breeding lambs that give skin to the shepherd

pskwL       Proportion of lambs after weaning that give skin to the shepherd

psold[k][i][j] Fraction of reared pure-bred ($j = 1$) or cross-bred ($j = 2$) female
            progeny ($k = 1$) intended for selling as breeding animals before mating
            ($i = 0$) or as pregnant animals after breeding season $i$ ($i = 1, \ldots, bs[1]$) or
            fraction of reared male progeny ($k = 2$) intended for selling as breeding
            animals before breeding season $i$ ($i = 1, \ldots, bs[2]$)

psoldR[i]   Fraction of rams sold as breeding animals in breeding cycle $i$ ($i = 1, \ldots, RR$)

psp[k][i][j] Fraction of pure-bred ($j = 1$) or cross-bred ($j = 2$) weaned surplus
            female ($k = 1$) or male ($k = 2$) progeny or castrates ($k = 0$) sold
            in different categories $i$ ($i = 1, \ldots, csp[k]$). The categories for female
            progeny are: $i = 1$: sold at weaning for slaughter, $i = 2$: sold as breed-
            ing animals, $i = 3, \ldots, 7$: fattened to target 1 to 5, respectively. The
            categories for male progeny are: $i = 1$: sold at weaning for slaughter,
            $i = 2$: sold as breeding animals, $i = 3$ : castrated, $i = 4, \ldots 8$: fat-
            tened to target 1 to 5, respectively. The categories for castrates are:
            $i = 1, \ldots, 5$: fattened to target 1 to 5, respectively. Generally it must
            be $\sum_{i=1}^{csp[k]} psp[k][i][j] = 1$ for all $j$ and $k$ for the input values. In the
            program the values for castrates (first index 0) are converted so that
            they are expressed as fraction of the weaned surplus male progeny so
            that holds $\sum_{i=1}^{lf[0]} psp[0][i][j] = psp[2][3][j]$ for $j = 1, 2$.

pstayR[i]   Probability that a ram entering breeding cycle $i$ ($i = 1, \ldots, RR-1$) will
            stay to the next cycle

PsuckE[i][j] Number of ewes with $i$ suckled lambs ($i = 0, \ldots, clt$) in lactation $j$
            ($j = 1, \ldots, LL$) expressed as proportion of all ewes in the flock

pt[i]       Temporary variable in the calculation of economics the values of which
            represent threshold values of the standardized normal distribution

ptskarL     Proportion of skins from lambs after artificial rearing which are sold as
            tanned skin

ptskE       Proportion of skins of ewes which are sold as tanned skin

ptskfL      Proportion of skins of lambs slaughtered after fattening sold as tanned
            skin

ptskR       Proportion of skins of rams which are sold as tanned skin

ptskrL      Proportion of skins of slaughtered breeding lambs sold as tanned skin

ptskwL      Proportion of skins from lambs after weaning which are sold as tanned
            skin

pwL[i][j]   Proportion of weaned pure-bred ($j = 1$) or cross-bred ($j = 2$) lambs in
            each litter size $i$ ($i = 1, \ldots, clt$)

pwrepFP[i]  Proportion of mature weight at which pure-bred ($i = 1$) or cross-bred ($i = 2$) female progeny can be mated for the first time

pwrepMP  Proportion of mature weight at which pure-bred males can be used for breeding

pyoungMP[i]  Proportion of young pure-bred ($i = 1$) or cross-bred ($i = 2$) rams in the flock

qaveE[i]  Discounting coefficients for revenues or costs that occur continuously over the whole time period the ewes of category $i$ ($i = 1, ..., TE$) are kept or at any (unknown) time (e.g. feed costs, revenues from wool)

qaveR[i][j]  Discounting coefficients for revenues or costs that occur continuously over the whole time period the rams of category $i$ ($i = 1, ...TR$) and breed $j$ ($j = 1$: rams for pure-breeding, $j = 2$: rams for cross-breeding) are kept or at any (unknown) time

qaveL[i][j]  Discounting coefficients for revenues or costs that occur continuously over the whole time period the lambs of category $i$ ($i = 1, ...PP$) and breeding type $j$ ($j = 1$ : pure-bred lambs, $j = 2$ : cross-breed lambs) are kept or at any (unknown) time

qbreedE[i]  Discounting coefficients for breeding costs for ewes of category $i$ ($i = 1, ..., TE$)

qbreedL[i]  Discounting coefficients for breeding costs for female breeding lambs of category $i$

qcl0[i]  Temporary variable in the calculation of economic weights saving original values of vectors and returning them later on to the main program

qendE[i]  Discounting coefficients for revenues or costs that occur at the end of the keeping period for ewes of category $i$ ($i = 1, ..., TE$) (e.g. marketing costs, revenues from culled animals)

qendR[i][j]  Discounting coefficients for revenues or costs that occur at the end of the keeping period for rams of category $i$ ($i = 1, ...TR$) and breed $j$ ($j = 1$: rams for pure-breeding, $j = 2$: rams for cross-breeding)

qendL[i][j]  Discounting coefficients for revenues or costs that occur at the end of the keeping period for lambs of category $i$ ($i = 1, ...PP$) and breeding type $j$ ($j = 1$ : pure-bred lambs, $j = 2$ : cross-breed lambs)

qmilkE[i]  Discounting coefficients for revenues from milk and/or cheese and for costs connected with milking sheep of category $i$ ($i = 1, \ldots, TE$)

qpurchR  Discounting coefficient for costs to purchase breeding rams

R  Maximal number of breeding cycles for rams + 1 (set to 8, used for dimensioning arrays in the program, see footnote on page 177)

ratiooldR  Ewes to old ram ratio in the breeding season

ratioR  Average ewes to ram ratio in the breeding season

ratioyoungR  Ewes to young ram ratio in the breeding season

rcas  Casein recovered in cheese as fraction

revcE[i]       Revenues per culled ewe of category $i$ ($i = 1, ..., TE$) and per reproductive cycle

revcheeseE[i]  Revenues from cheese per ewe of category $i$ ($i = 1, ..., TE$) and per reproductive cycle

revcL[i][j]    Revenues per culled lamb of category $i$ ($i = 1, ..., PP$) and breeding type $j$ ($j = 1$ : pure-bred lambs, $j = 2$ : cross-breed lambs)

revcR[i][j]    Revenues per culled ram of category $i$ ($i = 1, ..., TR$) and breed $j$ ($j = 1$ : rams for pure-breeding, $j = 2$ : rams for cross-breeding)

revE[i]        Total revenues per ewe of category $i$ ($i = 1, ..., TE$)

revL[i]        Total revenues per lamb of category $i$ ($i = 1, ..., PP$)

revmanE[i]     Revenues from manure per ewe of category $i$ ($i = 1, ..., TE$) and per reproductive cycle

revmanL[i][j]  Revenues from manure per lamb of category $i$ ($i = 1, ..., PP$) and breeding type $j$ ($j = 1$ : pure-bred lambs, $j = 2$ : cross-bred lambs)

revmanR[i][j]  Revenues from manure per ram of category $i$ ($i = 1, ...TR$) and breed $j$ ($j = 1$ : rams for pure-breeding, $j = 2$ : rams for cross-breeding)

revmilkE[i]    Revenues from milk per ewe of category i ($i = 1, ..., TE$) and per reproductive cycle

revR[i]        Total revenues per ram of category $i$ ($i = 1, ..., TR$)

revsbL[i][j]   Revenues per sold breeding lamb of category $i$ ($i = 13, 15, 19, 23, 26, 38$ or $40$) and breeding type $j$ ($j = 1$ : pure-bred lambs, $j = 2$ : cross-breed lambs)

revskrE[i]     Revenues from raw skin per ewe of category $i$ ($i = 1, ..., TE$) and per reproductive cycle

revskrL[i][j]  Revenues from raw skin per lamb of category $i$ ($i = 1, ..., PP$) and breeding type $j$ ($j = 1$ : pure-bred lambs, $j = 2$ : cross-bred lambs)

revskrR[i][j]  Revenues from raw skin per ram of category i ($i = 1, ..., TR$) and breed $j$ ($j = 1$ : rams for pure-breeding, $j = 2$ : rams for cross-breeding)

revsktE[i]     Revenues from tanned skin per ewe of category i ($i = 1, ..., TE$) and per reproductive cycle

revsktL[i][j]  Revenues from tanned skin per lamb of category $i$ ($i = 1, ..., PP$) and breeding type $j$ ($j = 1$ : pure-bred lambs, $j = 2$ : cross-bred lambs)

revsktR[i][j]  Revenues from tanned skin per ram of category i ($i = 1, ..., TR$) and breed $j$ ($j = 1$ : rams for pure-breeding, $j = 2$ : rams for cross-breeding)

revsoldR[i][j] Revenues per sold ram of category $i$ ($i = 1, ...TR$) and breed $j$ ($j = 1$ : rams for pure-breeding, $j = 2$ : rams for cross-breeding)

revwE[i]       Revenues from wool per ewe of category $i$ ($i = 1, ..., TE$) and per reproductive cycle

revwL[i][j]    Revenues from wool per lamb of category $i$ ($i = 1, ...PP$) and breeding type $j$ ($j = 1$ : pure-bred lambs, $j = 2$ : cross-breed lambs)

revwR[i][j]  Revenues from wool per ram of category $i$ ($i = 1, ...TR$) and breed $j$ ($j = 1$: rams for pure-breeding, $j = 2$: rams for cross-breeding)

rf[i][j]  Coefficients for the regression of the milk price on milk fat content. $i = 0$: intercept, $i = 1$ : linear regression coefficient, $i = 2$ : reference value for fat content; $j$ ($j = 0, ..., nfat$) refers to the class for fat content.

rfat  Fat recovered in cheese as fraction

rp[i][j]  Coefficients for the regression of the milk price on the milk protein content. $i = 0$: intercept, $i = 1$ : linear regression coefficient, $i = 2$ : reference value for protein content; $j$ ($j = 0, ..., nprot$) refers to the class for protein content.

RR  Number of breeding cycles for rams for the given calculation (input parameter)

rs  Coefficient in van Slyke's formula (6.17) to (6.19) representing other milk solids and added salt recovered in cheese

sl1E  Sum of elements of vector **l1E** ($sl1E = \sum_{i=1}^{TE} l1E[i]$); this sum must be 1 if the calculation is correct

sl1R  Sum of elements of vector **l1R** ($sl1R = \sum_{i=1}^{TR} l1R[i]$); this sum must be 1 if the calculation is correct

sexrbf  Parameter related to the sex ratio of born animals: proportion of females; set to 0.5

sexrbm  Parameter related to the sex ratio of born animals: proportion of males; set to 0.5

sigmacwwL[i][j]  Standard deviation of carcass weight for pure-bred ($j = 1$) or cross-bred ($j = 2$) female ($i = 1$) and male ($i = 2$) lambs slaughtered after weaning or artificial rearing (categories 7 and 32)

sigmafat  Phenotypic standard deviation for milk fat content

sigmaprot  Phenotypic standard deviation for milk protein content

sigmaSCS  Phenotypic standard deviation of somatic cell score in the ewe flock

sigmawr[i][j]  Standard deviation of the weight of female ($i = 1$) or male ($i = 2$) breeding lambs at the first breeding season after weaning for breeding type $j$ ($j = 1$ : pure-bred progeny, $j = 2$ : cross-bred progeny)

SP  Number of genders in progeny (set to 3, used for dimensioning arrays in the program, see footnote on page 177)

strawarL  Amount of material for bedding per lamb per day in artificial rearing

strawE  Amount of material for bedding per housed ewe (including lambs till weaning) per day

strawfL  Amount of material for bedding per female or male lamb or castrate in fattening per day if lambs are housed

strawR  Amount of material for bedding per ram per day

strawrL  Amount of material for bedding per male or female breeding lamb in rearing per day if lambs are housed

subE       Governmental subsidy per ewe and year

subR       Governmental subsidy per sold breeding ram

surbs[k][i][j] Survival rate of pure-bred ($j = 1$) or cross-bred ($j = 2$) female ($k = 1$) or male ($k = 2$) progeny from weaning (for $i = 1$) or from breeding season $i - 1$ (for $i > 1$) to breeding season $i$ ($i = 1, \ldots, bs[k]$)

surfat[k][i][j] Survival rate of pure-bred ($j = 1$) or cross-bred ($j = 2$) female ($k = 1$) or male ($k = 2$) progeny or castrates ($k = 0$) in fattening to target $i$ ($i = 1, \ldots, lf[k]$)

surmlFP[i] Survival rate of pure-bred ($i = 1$) or cross-bred ($i = 2$) female progeny from mating to lambing

sw[i][j]     Temporary variable: Start weight for different periods of growth for pure-bred ($j = 1$) or cross-bred ($j = 2$) female ($i = 1$) or male ($i = 2$) lambs

swb[k][i][j] Temporary variable: Start weight for different periods of growth for pure-bred ($j = 1$) or cross-bred ($j = 2$) female ($k = 1$) or male ($k = 2$) lambs born in litter size $i$ ($i = 1, \ldots, clt$)

tave[i][j]   Age of pure-bred ($j = 1$) or cross-bred ($j = 2$) lambs of category $i$ ($i = 1, \ldots, PP$) in the middle of the time period of the existence of the category

Tcosts     Total costs in the whole production system per ewe and year

TcostsE    Total costs for ewes per ewe and reproductive cycle

TcostsR    Total costs for rams per ewe and reproductive cycle

TE         Dimension of the transmission matrix for the ewe flock in the given calculation (= Number of ewe categories)

te[i][j]      Elements of the transmission matrix for the calculation of the structure of the ewe flock ($i, j = 1, ..., TE$)

techbL[i]   Sheep husbandry system for breeding lambs in feeding season $i$ ($i = 1, \ldots, nfs$). *techbL*[i] can take only three values: 1 for housed lambs, 2 for lowland lambs out-of-doors or 3 for lambs on hill grazing. The numbering of seasons starts on 1 January, i.e. the value of *techbL*[1] is the value which is valid on 1 January.

techE[i]    Sheep husbandry system for ewes in feeding season $i$ ($i = 1, \ldots, nfs$). *techE*[i] can take only three values: 1 for housed ewes, 2 for lowland ewes out-of-doors or 3 for ewes on hill grazing. The numbering of seasons starts on 1 January, i.e. the value of *techE*[1] is the value which is valid on 1 January.

techfatL[i] Sheep husbandry system for fattened lambs in feeding season $i$ ($i = 1, \ldots, nfs$). *techfatL*[i] can take only three values: 1 for housed lambs, 2 for lowland lambs out-of-doors or 3 for lambs on hill grazing. The numbering of seasons starts on 1 January, i.e. the value of *techfatL*[1] is the value which is valid on 1 January.

tend[i][j]   Age of pure-bred ($j = 1$) or cross-bred ($j = 2$) lambs of category $i$ ($i = 1, \ldots, PP$) at the end of the time period of the existence of the category

thfat[i]     Threshold values for milk fat content in the milk pricing system ($i = 0, ..., nfat - 1$)

thprot[i]    Threshold values for milk protein content in the milk pricing system ($i = 0, ..., nprot - 1$)

tmilkm       Total milk yield from weaning to the end of the milking period per ewe in the flock per reproductive cycle

tmilkmst     Milk yield in the standardized milking period in kg

tmilkw       Total milk yield until weaning per ewe in the flock per reproductive cycle

tmilkw0[i]   Total amount of milk from ewes without lambs available from birth to weaning for lambs (per ewe in the flock) in feeding season $i$ ($i = 1, \ldots, nfs$)

tp[i]        Average temperature during feeding season $i$ ($i = 1, \ldots, nfs$)

Tprof        Total profit per ewe and year

Tprofh       In the calculation of economic weights: Value of $Tprof$ for the increased value of the trait

Tprofl       In the calculation of economic weights: Value of $Tprof$ for the decreased value of the trait

Tprofm       In the calculation of economic weights: Value of $Tprof$ for the average value of the trait

TR           Dimension of the transmission matrix for the ram population in the given calculation (Number of ram categories)

tr[i][j]     Elements of the transmission matrix for the calculation of the structure of the ram population ($i, j = 1, ..., TR$)

Trev         Total revenues from all animal categories of the given breed per ewe and year

TrevE        Total revenues from ewes per ewe and reproductive cycle

TrevR        Total revenues from rams per ewe and reproductive cycle

tSCC[i]      Upper limits for somatic cell count in milk quality class $i$ ($i = 0, ..., nSCC - 2$) the 1st class being the best one

tSCS[i]      Upper limits for somatic cell score in milk quality class $i$ ($i = 0, ..., nSCC - 2$) (the 1st class being the best one)

Tsub         Total subsidies per ewe and year

tv2h         In the calculation of economic weights: increased value of a 2nd trait

tv2l         In the calculation of economic weights: decreased value of a 2nd trait

tv2m         In the calculation of economic weights: average value of 2nd trait

tvh          In the calculation of economic weights: increased value of the trait

tvl          In the calculation of economic weights: decreased value of the trait

tvm      In the calculation of economic weights: average value of the trait

twL[i][j]      Total litter weight at birth when $i$ ($i = 1, \ldots, clt$) lambs are born in reproductive cycle $j$ ($j = 1, \ldots, LL$)

typeb      Type of sheep breed (1: dairy sheep, 2: meat sheep)

typew      Type of weaning (1: customary weaning, 2: early weaning followed by artificial rearing with milk replacer)

u      Annual discount rate

ulf[k][i]      Indicator for the unit for target $i$ ($i = 1, \ldots, lf[k]$) of fattening of female ($k = 1$) or male ($k = 2$) progeny or castrates ($k = 0$). Two values are allowed: 1 for kg and 2 for days.

valfs[i]      Code (or value) of feeding season from January 1st ($i = 0$) or after the $i^{th}$ change of the feeding season ($i = 1, \ldots, nchfs$). The values of $valfs[i]$ must be integers in the range from 1 to $nfs$.

vcwr[i][j]      Coefficient of variation of the weight of female ($i = 1$) or male ($i = 2$) breeding lambs at the first breeding season after weaning for breeding type $j$ ($j = 1$ : pure-bred progeny, $j = 2$ : cross-bred progeny)

vcwwL      Coefficient of variation for weaning weight or weight at the end of artificial rearing

vetarL      Average costs for veterinary service and drugs (except of parasite treatment) per lamb in artificial rearing

vetclFP      Average costs for veterinary service and drugs (except of parasite treatment) per female breeding lamb from conceiving to lambing

vetE      Average costs for veterinary service and drugs (except for parasite treatment) per ewe per reproductive cycle

vetf[i][j]      Average costs for veterinary service and drugs (except of parasite treatment) per female lamb ($i = 1$), male lamb ($i = 2$) or castrate ($i = 0$) in fattening to target $j$ ($j = 1, \ldots, lf[i]$)

vetR      Average costs for veterinary service and drugs (except of parasite treatment) per ram and breeding cycle

vetrL[i]      Average costs for veterinary service and drugs (except of parasite treatment) per female or male breeding lamb from weaning (or the end of artificial rearing) till the 1st breeding season ($i = 1$) or from the 1st to the 2nd (or from the 2nd to the 3rd) breeding season ($i = 2$)

vetwL      Average costs for veterinary service and drugs (except of parasite treatment) per lamb till weaning

vlf[k][i]      Value (age or weight) of target $i$ ($i = 1, \ldots, lf[k]$) of fattening of female ($k = 1$) or male ($k = 2$) progeny or castrates ($k = 0$). Be careful to insert the right number, have in mind that unit $ulf[k][i]$ belongs to this value.

warL[k][i][j]      Weight of female ($k = 1$) or male ($k = 2$) progeny within litter size $i$ and breeding type $j$ ($i = 1, \ldots clt$, $j = 1, 2$; $j = 1$: pure-bred lambs, $j = 2$: cross-bred lambs) at the end of artificial rearing

watE[i][k][l]  Water requirement per ewe of category $i$ ($i = 1, \ldots, TE$) fed with feeding ration $k$ ($k = 1, \ldots fE$) in feeding season $l$ ($l = 1, \ldots, nfs$)

watL[i][j][k][l]  Water requirement per pure-bred ($j = 1$) or cross-bred ($j = 2$) lamb of category $i$ ($i = 1, \ldots, PP$) fed with feeding ration $k$ ($k = 1, \ldots fL$) in feeding season $l$ ($l = 1, \ldots, nfs$)

watL14m[j][l]  Water requirement for a pure-bred ($j = 1$) or cross-bred ($j = 2$) lamb of category 14 to be mated which will be fed with feeding ration 4 in feeding season $l$ ($l = 1, \ldots, nfs$)

watL14nm[j][l]  Water requirement for a pure-bred ($j = 1$) or cross-bred ($j = 2$) lamb of category 14 not to be mated which will be fed with feeding ration 4 in feeding season $l$ ($l = 1, \ldots, nfs$)

watlE[i][k][l]  Water requirement per ewe lambing of category $i$ ($i = 1, \ldots, TE$) fed with feeding ration $k$ ($k = 1, \ldots fE$) in feeding season $l$ ($l = 1, \ldots, nfs$)

watnlE[i][k][l]  Water requirement per barren ewe of category $i$ ($i = 1, \ldots, TE$) fed with feeding ration $k$ ($k = 1, \ldots fE$) in feeding season $l$ ($l = 1, \ldots, nfs$)

watR[i][j][k][l]  Water requirement per ram of category $i$ ($i = 1, \ldots, TR$) of the breed of the flock ($j = 1$) or the breed used for crossing in the flock ($j = 2$); the ram is fed with feeding ration $k$ ($k = 1, \ldots fR$) in feeding season $l$ ($l = 1, \ldots, nfs$).

wbR[i][j]  Weight of rams of the breed of the flock ($j = 1$) or of the breed used for crossing in the flock ($j = 2$) at the beginning of breeding cycle $i$ ($i = 1, \ldots, RR$)

wgfE  Live weight gain during flushing of ewes

wgfL  Live weight gain during flushing of female breeding lambs

wlE[i]  Weight of ewes at lambing $i$ ($i = 1, \ldots, LL$)

wlFP[i]  Weight at first lambing of female lambs conceived in breeding season $i$ ($i = 1, \ldots, bs[1]$)

wmat[i][j]  Average weight of pure-bred ($j = 1$) or cross-bred ($j = 2$) female ($i = 1$) or male ($i = 2$) lambs mated in the first breeding season following their weaning

wnmat[i][j]  Average weight of pure-bred ($j = 1$) or cross-bred ($j = 2$) female ($i = 1$) or male ($i = 2$) lambs not mated in the first breeding season following their weaning

woolptE  Wool production per ewe and reproductive cycle

woolptR[j]  Wool production per ram of the breed of the flock ($j = 1$) or of the breed used for crossing in the flock ($j = 2$) and per breeding cycle

wP[i][j]  Weight of pure-bred ($j = 1$) or cross-bred ($j = 2$) progeny of category $i$ ($i = 1, \ldots, PP$) at the end of the time period defined for the given category. For numbering the categories of progeny see Section 4.2 on page 23.

wpurMP[j]  Weight of purchased male of breeding type $j$ ($j = 1$: pure-bred male, $j = 2$: male for cross-breeding)

wrL[k][i][j]  Average weight of pure-bred ($j = 1$) or cross-bred ($j = 2$) female ($k = 1$) or male ($k = 2$) breeding lambs at the beginning of breeding season $i$ ($i = 1, \ldots, bs[k]$) following their weaning

wshearL[s][j]  Amount of wool gained per shearing per pure-bred ($j = 1$) or cross-bred ($j = 2$) female ($s = 1$) or male ($s = 2$) lamb in artificial rearing

wsheE  Amount of wool gained per shearing per ewe

wshefL[s][j]  Amount of wool gained per shearing per pure-bred ($j = 1$) or cross-bred ($j = 2$) female ($s = 1$) or male ($s = 2$) lamb or castrate ($s = 0$) in fattening

wsherL[s][j]  Amount of wool gained per shearing per reared pure-bred ($j = 1$) or cross-bred ($j = 2$) breeding female ($s = 1$) or male ($s = 2$) lamb

wsheR[j]  Amount of wool gained per shearing per ram of breeding type $j$ ($j = 1$ : rams for pure-breeding, $j = 2$ : rams for cross-breeding)

wshewL[s][j]  Amount of wool gained per shearing per pure-bred ($j = 1$) or cross-bred ($j = 2$) female ($s = 1$) or male ($s = 2$) lamb from birth to weaning

wwL[k][i][j]  Weaning weight of female ($k = 1$) or male ($k = 2$) progeny born in litter size $i$ and breeding type $j$ ($i = 1, \ldots clt$, $j = 1, 2$; $j = 1$ : pure-bred lambs, $j = 2$ : cross-bred lambs)

z1  Variable used for numbering the headlines in the results file

z2  Variable used for numbering the headlines in the results file

zr  Number of the loop of the program

# Appendix C

# Changes in program EWSH1 since version 1.0.1

## C.1   Changes in May to June 2008 (Version 1.0.2)

The aim of the changes was to extend the applicableness of the program also to meat sheep and other non-dairy sheep. The following changes were carried out:

- The options for the type of breed ($typeb$) in the parameter file PARAS.TXT were extended. The original option 2 (meat sheep) was replaced by 2 (non-dairy sheep with known lactation curve) and 3 (non-dairy sheep with unknown lactation curve).

- Input file INPUTS07.TXT was added. This file is used instead of INPUTS06.TXT if the lactation curve is not known.

- Chapter 6 on page 51 (Milk production) in the Manual and the corresponding parts of the program were revised to allow including production systems with unknown lactation curve.

- Six variables ($nshewL$, $nshearL$, $pskwL$, $pskarL$, $ptskwL$ and $ptskarL$) connected with the calculation of shearing costs for progeny categories 5, 6, 30 and 31 were added to input file INPUTS09.TXT.

- Equations for the calculation of shearing costs for progeny categories 5, 6, 30 and 31 were added to the program and to the Manual.

- Equations for the calculation of costs for tanning skin for progeny categories 7 and 32 were added to the program and to the Manual.

- Eight inputs were added to file INPUTS10.TXT: Amount of wool per shearing per lamb until weaning ($wshewL[s][j]$) and amount of wool per shearing per lamb in artificial rearing ($wshearL[s][j]$), both for female and male ($s = 1$ or $s = 2$) pure-bred ($j = 1$) and cross-bred ($j = 2$) lambs.

- Equations for revenues from wool for progeny categories 5, 6, 30 and 31 were added in the program and the Manual.

- Equation for revenues from raw and tanned skin for progeny categories 7 and 32 were added in the program and the Manual.

- Six inputs ($nclflwL$, $nclfcwL$, $prrefwL$, $prclfcwL[i][j]$, $pclfcwL[1][i][j]$ and $pclfcwL[2][i][j]$) were added to file INPUTS13.TXT.

- Subsection 11.4.2.2 was partly rewritten to include heavy lambs (lambs with a carcass weight $> 13$ kg) slaughtered after weaning or artificial rearing.

- Traits 17 and 18 were redefined to include heavy lambs slaughtered after weaning or artificial rearing in addition to fattened lambs (see Subsection 12.2.2, Table 12.2 and Appendix A).

In version 1.0.1, the water costs were not considered in the calculation of the total costs. This error was corrected in the program and in the Manual in section 10.4 on page 108.

## C.2 Changes in July 2008 (Version 1.0.3)

The definition of growth traits of lambs from birth till weaning and from weaning till the end of artificial rearing was changed causing changes in the algorithm for the calculation of their economic values.

In the previous version of the program, the traits were primarily defined as weight at weaning or weight at the end of artificial rearing. Changing the weight at birth keeping the weaning weight constant caused an decrease in daily gain of lambs till weaning. This seems to be unnatural. More likely it is expected that progeny having higher embryonic growth (high birth weight) continues to have a higher growth rate also post partum.

Therefore, average daily gain from birth till weaning and from weaning till the end of artificial rearing were defined as primary growth characteristics post partum in version 1.0.3. of the program. Now when changing the birth weight and keeping the daily gain constant, the weight at weaning will change too. The alternative economic values for weight at weaning or weight at the end of artificial rearing are then only a recalculation from the economic values for the corresponding daily gain. Changes carried out in the program will have impact on the economic values of growth traits till weaning or till the end of artificial rearing.

## C.3 Changes in August and September 2008 (Version 1.1.1)

There were two basic changes carried out in the program:

- All costs and revenues are now discounted to the birth date of the animal. In the Manual, Chapter 8 was added where the discounting coefficients are calculated. The formulae for costs and revenues in Chapters 9 to 11 were modified. The discount rate $u$ was added in input file INPUTS01.TXT. The following new variables were introduced (see Appendix B for details): $qaveE[i]$, $qaveR[i][j]$, $qaveL[i][j]$, $qendE[i]$, $qendR[i][j]$, $qendL[i][j]$, $qbreedE[i]$, $qbreedL[i]$, $qpurchR[i][j]$, $qmilkE[i]$, $taveL[i][j]$ and $tendL[i][j]$.

- The economic weight for fleece weight as a new trait is calculated. For this purpose, the Chapter 7 was added and information was updated in Chapter 12. The following new variables were added: $kwarL[i][j]$, $kwE$, $kwfL[i][j]$, $kwrL[i][j]$ and $kwwL[i][j]$. They are explained in Appendix B.

Slight changes were carried out in the input file TEXTS_OUT.TXT.

## C.4 Changes in December 2008 (Version 1.1.2)

A linear equation was added to calculate the amount of milk needed for 1 kg cheese as function of protein and fat content in milk (see Section 6.3). The variable *pmilkch* was shifted from INPUTS09.TXT to INPUTS06.TXT. The variables *milkch* and *cheesewhey* were dropped from INPUTS09.TXT or INPUTS11.TXT, respectively, as they will be calculated from input parameters added to INPUTS06.TXT. The meaning of the variable *costcheese*$0E$ was changed; the cost originally referred to 1 kg cheese and now to 1 kg milk processed to cheese (change in equation (10.12)).

## C.5 Changes in May 2009 (Version 1.1.3)

Van Slyke's formula was added as a second option to calculate the amount of milk needed for 1 kg cheese. For details see Section 6.3. Several input parameters were added in the last part of input file INPUT06.TXT.

The formulae for the calculation of the economic values for traits 23 to 25 (average survival rate of lambs at lambing, till weaning and till the end of artificial rearing, respectively) were corrected. Originally the values were underestimated by a factor of 100.

An error in equation (10.58) was corrected.

## C.6 Changes in June and July 2009 (Version 1.1.4)

Two typing errors in Table 12.1 were corrected. Equation (9.24) was not correctly programmed; the error was corrected.

In input file INPUTS03.TXT, the fraction of lambs (of both sexes) stillborn or died until 24 hours for the individual classes for litter size ($pdiedbL[i][1]$, $i = 1, \ldots, clt$) were omitted as input parameters as these numbers can be easily calculated from the fraction of lambs stillborn or died until 24 hours for the individual classes for number of dead lambs $j$ within each litter size $i$ ($i = 1, \ldots, clt$; $j = 1, \ldots, i$). The fraction of lambs stillborn or died until 24 hours of age was added to the output in the results file.

In input file INPUTS09.TXT, the variables *costdeadm* and *costdeadL* were replaced by the variable *costdead*, costs for removing and rendering a dead animal (MU/kg) which are the same for all categories. That means, dead animals are no longer assumed to be paid per head. Changes were necessary in equations (10.11), (10.24) and (10.100).

In input file INPUTS10.TXT, the two variables "price per sold ram of the breed of the flock" ($prsbR[1]$) and "Price per sold ram of the breed used for crossing in the flock" ($prsbR[2]$) were added which allows for different prices for purchased and sold rams. The equation for the revenues from sold rams (11.22) was changed.

A new option for paying breeding lambs was introduced. Until recently breeding lambs could be paid per animal only. Now it is possible to calculate with the option that breeding lambs are paid per live weight. For this purpose, nine new inputs were added in input file INPUTS10.TXT. The new variables *opsbL* and $prsbL[i][j]$ were introduced. The text in subsection 11.4.5 was modified. The variables $revsbL[i][j]$ and wP[i][j] which had been read or calculated for also for some non-existing categories were set to zero for these categories. This latter change was only a cosmetic one as these values did have no influence on the calculations.

The order of the input files was changed. INPUTS05.TXT is now read before INPUTS04.TXT as parameters from INPUTS05.TXT are needed for deciding which input parameters are read from INPUTS04.TXT. There order was also changed in the manual. For reading input parameters from input file INPUTS04.TXT and

INPUTS10.TXT further conditions were added ensuring that parameters are read only if they are relevant for the given production system. Changes were made in subsections 5.2 and 5.3 concerning the definition of the reference trait for average daily gain of breeding animals in the rearing period. These changes resulted also in a slight modification of the algorithm for the calculation of the economic weight of this trait.

The calculation of $pcrosst$ (equation 3.19) was changed. The equation (4.74) for the calculation of $npurchMP[2]$ was added. The definition of $nramMP[i]$ was corrected in the list of variables. In equations (4.2) and (9.4), the index for $pcrossE[*]$ was changed from $k$ to $k-1$. Equation (4.4) was simplified. Equations (4.64) and (4.72) were modified. In equation (10.7), the upper limit for $i$ was changed from $TE$ to $TE - nstg1E$.

A new variable (average conception rate of ewes after insemination, $coninsE$) was added to input file INPUTS09.TXT. Equations (3.20) and (3.21) were changed to account for artificial insemination when the proportion of ewes for natural mating is calculated.

Chapter 2 was added to the manual. A paragraph in the manual in section 4.1 was deleted, as this text was moved to Chapter 2. The meaning of the variable $femrep$ in the parameter file PARAS.TXT was changed. It is not longer allowed to purchase all female replacement, but only a part of female replacement may be purchased. The new variable $ppurchFP$ was introduced in input file INPUTS04.TXT for this part. This change had consequences for equations (4.38) and (4.39).

The new variable $l1aR[i][j]$ was introduced (see subsection 3.2.4 for details). In the program output, printing of costs and revenues of non-existing ram categories was suppressed. Subsection 12.3.3 was added to the manual.

## C.7 Changes from October 2009 to May 2010 (Version 1.1.6)

- A bug in the calculation of the economic value for daily gain of breeding lambs in rearing was corrected. In the results file, the printed value for the relative frequency of cross-bred lambings in the flock was corrected.

- The restriction that revenues from heavy lambs slaughtered after weaning or after artificial rearing are calculated only for non-dairy sheep was omitted.

- Equation (11.48) was not correctly presented in the manual though correctly calculated in the program. The mistake in the manual was corrected.

- As the values $pcrossE[i]$ are of no importance in systems without crossing, the are not read from INPUTS01.TXT if there is no crossing.

- The variables $qmilkE[i]$ were in some cases incorrectly calculated. The error in the program was corrected.

- An error in printing (printing marginal economic values for fleshiness and fat covering was supressed in some cases) was corrected.

- A bug in the program where division by zero might occur was corrected.

- The number of maximal breeding cycles for rams was increased from 5 to 7.

- The equations for $dcL[15][j]$, $dcL[19][j]$ and $dcL[23][j]$ in (8.14) were not fully correct and were corrected therefore.

- The first equation in (8.30) was corrected.

- The second dimension was omitted in two variables ($nherd[i][j]$ was changed to $nherd[i]$ and $nrmatFP[i][j]$ was changed to $nrmatFP[i]$) as this dimension was not needed.

- The array $pherdyMP[i]$ was changed to the simple variable $pherdyMP$ as only one value was needed.

- Changes were carried out in equations (4.80) to (4.83).

- The equations for $pctE[1]$ and $pctE[2]$ were moved to Subsection 3.1.4. They were also moved in the program after the calculation of $pcrosst$.

- The formulae for $l1aR[i][j]$ and $l5R[i][j]$ were slightly modified and moved from subsection 3.2.4 to subsection 4.4.3 in manual.

- Redundant inputs for wool production ($woolptE$ and $woolptR[j]$ in INPUTS08.TXT) were omitted. The equations for their calculation are given in Section 7.1.

- The input parameters $prlwS0$ and $prcwS0$ in INPUTS12.TXT, $prlwwL0$ and $prcwwL$in INPUTS13.TXT and $prlwfL0$ and $prcwfL0$ in INPUTS14.TXT were replaced by $prlwS[j]$, $prcwS[j]$, $prlwwL[j]$, $prcwwL[j]$, $prlwfL[j]$ and $prcwfL[j]$, respectively, which allows for a differentiation between pure-bred and cross-bred animals.

- An incorrectness in the calculation of average lifetime of ewes in years was corrected (equation 12.26).

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