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An Excel Based Stochastic LP Model for a Dairy and Meat Farm

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Preface

The work with the model started during a research stay at Texas A & M University in 2003–04 and was based on a deterministic model for dairy and meat farms. Professor James Richardson suggested making the model stochastic in order to better utilize the information in the farm account statistics in risk analysis. The original model was based on average farm accounts while this is based on accounts from individual farms. The model has since been developed further and is also made more general in order to advance its applicability in farm analysis. The stochastic part has been worked out in cooperation with Prof James Richardson at Texas A & M University.

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Leif Jarle Asheim

Copies of this discussion paper are available at
http://www.nilf.no/Publikasjoner/DP/En/2008/DP-2008-03.pdf

Outline

Summary

This paper describes a stochastic linear programming model for farms with a milk and cattle meat production system. This model documentation is worked out using the farm account records for three family farms in Northern Norway. The model is built in Excel using the add-in Simetar to analyze risks. The LP model maximizes farm gross margins but the fixed costs of each farm are subtracted in order to compute farm profit and risk in farm profit. Data for the 15 years from 1991–2005 from the farms and from the annual editions of the Handbook of farm planning (NILF, 2000) have been used as a basis for developing the stochastic variables. The following variables have been made stochastic: area and yield of green fodder, yields of leys and pastures, yield of milk per cow, meat price, milk price, fuel costs and costs of concentrate feed. The rate of interest is also made stochastic. In the model the rate of interest is affecting the risk in farm profit through the fixed costs.

Emphasize has been given to build a flexible model allowing for examining effects of changes in several ways e.g. length of grazing period, calving time, or harvesting method for grass. The milk production is restricted by a farm specific milk quota, but otherwise the farming intensity is varied as farmers may choose selling e.g. small calves or up to two years old castrates with extensive use of pasture. Updating the model with data for another year is facilitated by defining prices for one year at a time and by cell referencing all variables. The records may be replaced with records for family farms with similar production systems in other areas in the country. The production is based on grass and pasture roughage. Dairy farms in more central areas also produce cereals, grain and oilseeds and the model has to be developed further for such farms.

The model will be used to carry out different farm economics analysis for Norwegian family farms combining milk and cattle meat production in production systems involving extensive use of pasture.

1 Introduction

The linear programming (LP) model is worked out in Excel using Simetar (www.Simetar.com) an Excel add-in to handle stochasticity. The model may be run in either a deterministic or a stochastic mode using the on or off switch of the ExpectedValue icon in Simetar. In the deterministic mode all the parameters in the matrix, objective function and Right Hand Side (RHS) variables of the LP model will have their expected values and the LP model comes up with an optimum solution. In the stochastic mode i.e. when the ExpectedValue icon is turned off, the model will run with stochastic values for the parameters which are determined after different procedures as outlined in the paper.

The LP maximize farm Gross Margins, defined as the difference between the enterprise output or gross income and the variable costs (See e.g. Ministry of Agriculture, Fishery and Food, 1977). The variable costs includes farm machinery repair and fuel and oil which are variable depending upon the size of the operation, but are sometimes treated as fixed costs. Labour costs are also treated as variable, this is much relief work and some seasonal labour on shorter term contracts and there is no regular paid labour on such farms. The fixed costs encompass depreciations of machinery and buildings and some land costs (e.g. drainage) and all costs for farm cars, administration, accounting, electricity and phone costs and other fixed costs. Premiums are sometimes considered as a fixed income and subtracted from the costs, but most premiums are paid out on acreage or per head basis or as a price subsidy.

The recorded fixed costs and interest costs are subtracted from the gross margins to arrive at farm profit. This is done in a separate process in the LP, but might as well be done after solving the LP. The risk is thus measured in the farm profit and not in the gross margins. This is important because the ability or willingness to bear the risks on family farms depend upon the fixed costs. There are also risks involved in the fixed costs, of particular importance the risk due to changing interest costs on capital. We have accounted for risk in interest on all capital, both own and borrowed.

A basis for the LP model is Norwegian family farm account records from dairy and meat farms i.e. farms where the cows are kept for both milk and for producing calves to be raised on the farm. Another requirement is that there shall be a substantial share of pasture in the feed ration. Most Norwegian dairy cow farmers raise the calves and the most common breed (Norwegian Red Cattle) is bred for both milk and meat yields. Generally farmers are working full time on such farms, however, the farmer or the spouse may be part-time farmers or have a smaller off-farm or farm business. The farm accounting data used in the model has been obtained from the account statistics of Norwegian Agricultural Economics Research Institute (NILF). The account data for a given year are usually available in the last part of the following year and are on a standardized form that can be pasted into the Excel worksheet where the names of the accounting items have been translated into English.

The three farms used in this documentation come from the counties Nordland, Troms and Finnmark in Northern Norway, and data from these farms can thus be used to examine risk problems associated with dairy and meat farming in sub-arctic areas. The model as such is quite general and will be adapted to dairy and meat farms in different areas and applied for examining different farm problems. The standardized form of the farm accounts facilitates use of account result for any farm with this farming system in the statistics. However, in other areas other farming opportunities has to be modelled, e.g. dairy farmers in Southern Norway generally (unless in mountainous areas) have a longer growing season and may produce other crops such as cereals and oilseeds for sale.

The construction of the model in Excel follows the general principle that each variable or parameter is entered only once in a cell and each time this value is used, there is a reference to the cell. Numbers are never written into a formula. This makes updating of the model easier as each value is changed only in one place. Some basic farm information or assumptions such as farm number and year are coloured dark green. Model values that can be changed or updated due to change of farm or year are coloured yellow, while the formulas or values that are generally not adjusted are uncoloured.

In order to study effects of calving time and length of the grazing period the date format in Excel has been used. The Excel date format operates with a specific date (Jan. 1 1900) as the first day and in order to calculate day number in the year the last day in the year before has to be subtracted so that when calving time or the first and last day of grazing are defined for the year 2000 the day number for the last day in 1999 is subtracted.

The energy content in yields and feed and energy requirements for animals are based on the Norwegian unit FEm (short for Feeding Energy-units milk). One FEm equals 6.9 Mega Joule (MJ) and is the approximate energy content of one kg of barley. For protein we use the AAT (Amino Acid absorbed in Intestine) that is measured in grams or kilograms. The maximum or minimum amounts of dry matter allowed in the feed ration of cattle or the content of dry matter in roughage are measured in kg.

Farmland area is measured in hectares in general, however due to the size of Norwegian farmland we use the unit decare, 1 decare of land equals 1000 square m or 1/10 of a hectare.

2 Farm data

The three records are placed on separate sheets entitled FarmA1991–05, FarmB1991–05 and FarmC1991–05. Each sheet contains the records of one farm for 15 years placed in columns. A few sums not defined in the records are calculated in the lower end of each sheet. The chosen numbers are entering the LP Model sheet in the columns F, G and H. The model also uses specific price data from the annual editions of Handbook of Farm Planning (NILF, 2000). These data are reproduced in time series on the sheet PriceIndicies and are generally on a per kg basis and linked to the same year as the farm data.

The active farm is determined by changing number in the cell “Farm to simulate” in D3 of the LP Model sheet below. By changing farm number, a different set of recorded data will appear in column D and the model can thus be run for another farm. If a scenario instruction is typed in that cell (e.g. =scenario(J3:L3) and with 1, 2 and 3 typed in the cells J3–L3) the model will run all three farms). It is also possible to run the model for another year by typing the year in cell H3 and the recorded data for that year will appear in column D.

The recorded area of cultivated and uncultivated farmland in the lines 6 and 7 are transferred unadjusted to the RHS for constraint 1 and 2 of the LP model. These are the numbers recorded each year. The green fodder area in line 8 was recorded until 2001 and the recorded distribution for those years has been extended to the whole period by bootstrapping the values for the years afterwards. Dairy and meat farmers in this part of the country use their land for meadow and pasture and buy all the concentrate feed. Farmers may also buy hay and bales of silage if needed. The recorded average farm roughage yield is displayed in the cell D9. Information about the first and last day on pasture appears in the lines 10–11 and thus the number of days indoor and on pasture can be calculated.

The recorded hours of labour input by the farm family and by hired work are calculated as total labour input in agriculture (The items M810 or M811 in the farm accounts from 2002 and onwards) minus hired labour M39 and M45 (M9 and M65 after 2002)[1]. Farmers on family farms quite often hire family members on an hourly basis, mostly for relief work, but in the model it is not distinguish between the categories of hired labour. The numbers are displayed in the lines 14–15 and in line 16 the model calculates the number of h available during the pasture time in accordance with length of the grazing season on each farm. Normally farm families take much of their holydays during the summer but on the other hand a disproportionate share of labour may be hired during the summer. The recorded number of h worked by the family is assumed to be the available labour force and the numbers for the selected farm in column D are transferred to the right hand side of the model for the constraints 10 and 11.

The recorded price per h for hired labour in line 17 is used unadjusted in the objective function of process 29 of the model and the default maximum amount of hired labour in the model is determined in line 18 as the maximum for the 15 accounting years period. Hired labour is considered as a variable cost, this is much relief work and some seasonal labour, on shorter term contracts. The farmer may hire somewhat more or less help for the same price, however a substantial increase in temporary hiring would not be possible and the payment would usually be higher for workers in more permanent hiring.

[1] Part of the data in M39 and M45 were recorded in M9 and M65 from 2002.

	A	B	C	D	E	F	G	H
2	**Part A. Data used for the individual farms**							
3		Farm TO Simulate		1	THE FARM SURVEY RESULTS FOR			2000
4		Last day in the year before		31.12.1999				
5						Farm A	Farm B	Farm C
6		Cultivated area, decare		241,0	1	241	252	198
7		Pasture area, decare		25,0	2	25	-	-
8		Green Fodder area, decare		25,0	3	25	30	33
9		Recorded yield, FEm/decare		194,0	4	194	221	165
10		First day grazing		01.07.2000	5	1. jul.	18. jun.	25. jul.
11		Last day grazing		15.09.2000	6	15. sep.	14. sep.	1. sep.
12		Grazing period, days		76,0	7	76	88	38
13					8			
14		Labor Input, family, h		2500	9	2 500	2 405	3 000
15		Hired labor, h		633	10	633	1 476	447
16		Summer Labor, family, h		521	11	521	580	312
17		Average wage hired labour in agr. NOK/h		107,7	12	108	121	112
18		Limit on hired labour		1870	13	1870	1599	717
19					14			
20		Fixed Costs, NOK		146775,0	15	146 775	227 259	193 932
21		Interest Rate		0,07	16	0,07	0,07	0,07
22		Interest Costs, NOK		53213,0	17	53 213	85 250	99 285
23		Farm profit		140435	18	140435	-13125	301191
24					19			
25		Milk Quota, l		89333	20	89 333	87 578	101 436
26		Milk yield per cow, l		6790	21	6 790	6 496	5 868
27		Date of calving (seasonal)		10.1.2000	22	10. jan.	20. sep.	1. okt.
28		Local Milk Price NOK/l		3,8	23	3,80	3,81	4,37
29		Local Meat Price Cows, NOK/kg		32,6	24	32,64	27,48	22,31
30		Local Price Bull 18-24 Months, NOK/kg		24,5	25	24,53	33,52	32,59
31		Local Price Castrate 24 months NOK/kg		24,5	26	24,53	33,52	32,59
32		Local Price Intermediate Calves NOK/kg		38,5	27	38,5	38,5	39,4
33		Cows, animal years		13,3	28	13,30	12,90	18,50
34		Slaughtered (discarded) cows, NOK per cow		3623	29	3 623	2 558	2 522
35		Other items of use per dairy cows, NOK/cow		1259	30	1 259	965	787
36		Different expences for animals NOK/dairy cow		2021	31	2 021	1 360	579
37					32			
38		Basic support for milk production, NOK/farm		66000	33	66 000	66 000	66 501
39		Extra support for relief for the first 8 cows		17224	34	17224	17224	17224
40		Bottum deduction of premiums, NOK/Farm		7000	35	7000	7000	7000
41					36			
42		Farm milk zone		7	37	7	7	9
43		Farm meat zone		4	38	4	4	5
44		Area & landscape support NOK/decare (0-200)		440	39	440	440	470
45		Area & landscape support NOK/decare (2-400)		220	40	220	220	220

The recorded fixed costs of the farms are shown in line 20. The fixed costs consist of costs for maintenance and depreciation of farm buildings and other farm constructions, all costs for farm cars, administration, accounting, electricity and phone costs and other fixed costs. Regarding farm tractors and farm machinery only depreciation has been added as the maintenance is calculated as a variable cost together with costs of fuel elsewhere in the model.

The values of the farm assets are recorded as beginning and end values in the balance and the average number is multiplied with the rate of interest (reproduced in line 21) to arrive at annual interest costs in line 22. The rate of interest is the same for all farms in a given year and the standard rate in the account statistics has been used. Generally there are no ownership charges other than interest on capital in the country. In line 23 is reproduced the actual farm profit. The data for farm profit is used when calibrating the model in part H (see later) but otherwise does not enter the calculations.

The farm milk quota is displayed in line 25 and transferred to the RHS coefficient for constraint 28 of the LP tableau. The recorded milk yield in D26 goes to the matrix for constraint 28 to determine number of cows within the quota. In line 27 is displayed the time of calving based on additional information from each farm. The information is used for computing the seasonal distribution of milk production in part C.2 and also to calculate seasonal distribution of cow and cattle feed requirements in section F, based on a standardized lactation curve.

The recorded milk price in D28 is, together with the milk yield in D26, used to calculate receipts from milk production (Part G). In this calculation the recorded receipts from cow meat in D34 and the cost for veterinary treatment and medicine and other variable items of use in animal husbandry in D35 and D36 are also considered. The recorded meat prices for bulls or castrates (D30–31) are used to calculate receipts from these activities to be used in their objective function. The price for intermediate calves is not recorded but cell D32 displays the price from the PriceIndices sheet.

Structural premiums and some local premiums or environmental support can sometimes be considered as a fixed income. In the lines 38–40 is displayed the basic support for milk production in the areas, the extra support for the first 8 cows and a bottom deduction of subsidies for the farms. The basic support and the extra relief payments are subtracted from the fixed costs of the model as it is assumed that the farmers will always have more than 8 cows. The bottom deduction amounted to NOK 7000 for 2000. These positive or negative amounts have to be added to the fixed costs, before arriving at the net fixed costs that are transferred to the objective function of process 30 of the LP tableau.

In line 42 is shown the milk zone of each of the farms. The milk zone is decisive for computing the premiums for area and cultural landscape in the lines 44 and 45. The area and cultural landscape support premiums are paid out on an acreage basis and the figures in the cells D44–45 goes directly to the processes 12 and 13. There are seven zones for area and landscape premiums in the country, each with a higher premium for the first 200 decares of farmland. Farm A and B get the rate for zone 7 and farm C the rate for zone 9. The rates are pr decare for farmland and are lowered by 30 percent for permanent pasture (infield) and the LP matrix coefficient is thus 0.7 for permanent pasture.

Norwegian farmers also obtain a supplementary payment per kg of meat produced, depending on region. There are five zones for rural meat production payments. The rate for the three farms is displayed in line 43. One of the farms is situated in zone number 5 and the other two in zone 4. The supplementary payment is added to the ordinary price of meat for intermediate calves above, other meat prices are recorded with the governmental payment included.

3 Prices, quantities and input data

The price, quantity, premium and other input data used in the model are shown on the next page. The repurchasing values for tractors and farm equipment in the cells D51–D66 in part B.1 are prices for the year 2000. The prices are multiplied with a farm machinery price index (NILF, 2008) in cell D49 in order to automatically update the calculations in accordance with the year selected in cell H3. The machinery prices are followed by prices for diesel (in D69) and different artificial fertilizers and lime (D72–D77), variable costs of electricity for barn drying when haymaking and preserving agents (formic acid) for silage in D80–D82. The energy content in one cubic m of silage in traditional silos is assumed to be 140 Fem. The costs for seed and herbicides are displayed in the cells D86–93. The data are taken from Handbook of farm planning (NILF, 2000). All these costs are multiplied with price indexes that are calculated using data from NILF (2008). The value of the price indexes is 1 for 2000. The price indexes are placed on a separate sheet entitled PriceIndices and the LP model input is updated by changing the year.

Baling of silage is normally conducted on a contractual basis on family farms, but the farmer himself may cut the grass and rake it because it is important that the grass is enough pre-dried before it is baled. This strategy will increase flexibility which is particularly important when the weather is changing fast during harvesting. Farmers also transport the bales from the field to the barn. The energy content of one bale of silage is assumed to be 135 Fem (D96). Bales of silage are normally stored outdoor so extra costs of storage need not be considered. In general the bailing alternative will involve increased machinery costs while farmers work during harvesting is reduced compared with traditional silage harvesting. Work with feeding is assumed to be the same for bales as for silage on an energy basis.

Some farmers continue with a traditional harvesting of silage, others are gradually shifting to bales. The data used to calculate the costs for bailing in column D94–D97 are based on the Handbook of Farm Planning (NILF, 2000) and brought in from the PriceIndices sheet. The costs and labour input for bailing and traditional harvesting are weighted together with a different share based on information collected from each farm before entering the objective function of the LP Model. It is possible to assume that all the silage on the farm is bailed (Part H).

	A	B	C	D	E	F	G	H	I
48	**Part B. These are the price, quantity and standard labour input data in**				**2000**				
49		Farm machinery price index value (2000=1)		**1,000**					
50		**B.1. PURCHACHING PRICES FOR TRACTORS AND EQUIPMENT**				**B.2. RELATIVE YIELD OF CROP PROCESSES**			
51		Tractor 92 Ehp with loading equipment		**406050**	NOK	Gross yield 1 cut,		**242**	FEm
52		Tractor 52 Ehp with loading equipment		**265442**	NOK	Gross yield 2 and more cut		**118**	FEm
53		Trailer 10 tonn		**42000**	NOK	Net pasture yield, after cuti		**40**	FEm
54		Trailer wagon		**61670**	NOK	Gross yield hay		**196**	FEm
55		KVERNLAND reversible 2 share plough		**74890**	NOK	Net pasture yield after first		**44**	FEm
56		KONGSKILDE harrow 2,1 m working width		**24100**	NOK	Gross Yield, autumn replac		**200**	FEm
57		Reel, 4 m working width		**30900**	NOK	Gross yield, spring replace		**227**	FEm
58		BØGEBALLE centrifugal fertilizer distributor		**27891**	NOK	Greenfodder, process 9		**360**	FEm
59		Manure pump, HLR2		**51210**	NOK	Greenfodder, process 10		**280**	FEm
60		Manure tank wagon, MOI GB 6		**65100**	NOK	Net pasture, process 12		**250**	FEm
61		HARDI tractorsprayer		**12180**	NOK	Loss for silage&hay 10%		**0,9**	
62		Seeding machine CK4000, grass		**50490**	NOK	Loss greenfodder 15%		**0,85**	
63		JFROTOR grass mover 190 cm		**35870**	NOK				
64		BYE side revert rake, 240 cm		**13300**	NOK	**B.3. INPUT OF SEED AND HERBICIDES**			
65		Crosscut rake		**4000**	NOK	Grasseed, Leys, process 6		**3**	Kg/decare
66		JF RAP harvester grass (130cm)		**41000**	NOK	Spraying, weeds, process (		**0,3**	Kg/decare
67		Source: Handbook of farm planning 1999/2000				Pea seed, process 7		**4**	Kg/decare
68			Index value (2000=1)			Barly seed, process 7		**7**	Kg/decare
69		Diesel Price (6,03 in 2000)	**1,000**	**6,03**	NOK/l	Ryegrass process 9		**4**	Kg/decare
70									
71		**B.4. PRICES 2000 FOR FERTILIZERS AND LIME**				**B.5. INPUT OF MANURE AND FERTILIZERS**			
72		Lime	**1,000**	**780**	NOK/ton	Manure for process 1,7,9,1		**5**	tons/decare
73		NPK 21-4-10 incl. freitht -discounts.	**1,000**	**1,93**	NOK/kg	Manure quantities for proc.		**3**	tons/decare
74		NPK 18-3-15 incl. freitht -discounts.	**1,000**	**2,00**	NOK/kg	Manure quantities for proce		**4**	tons/decare
75		NPK 11-5-17(18), inc. freitht -discou	**1,000**	**2,25**	NOK/kg	Fertilizer 22-2-12 process		**60**	Kg/decare
76		NPK 22-2-12, incl freight&discounts	**1,000**	**1,96**	NOK/kg	Fertilizer 22-2-12, process		**90**	Kg/decare
77		Calciumnitrate indl f&d	**1,000**	**1,40**	NOK/kg	Calsiumnitrate CaNO3, prc		**0**	Kg/decare
78						Calsiumnitrate CaNO3, prc		**26**	Kg/decare
79		**B.6. COSTS FOR SILAGE OR HAYMAKING**				Calsiumnitrate CaNO3, prc		**47**	Kg/decare
80		Formic acid (based on of farm accou	**1,000**	**0,160**	NOK/FEm	Fertilizer 18,3,15, process		**58**	Kg/decare
81		Electricity for drying hay	**1,000**	**0,15**	NOK/FEm	Fertilizer 18,3,15, process		**45**	Kg/decare
82		Plastic for cover of silage	**1,000**	**16**	NOK/cubic m	Fertilizer 18,3,15, process		**68**	Kg/decare
83		Feeding units for silage		**140**	FEm/cubic m	Fertilizer 21,4,10, process		**32**	Kg/decare
84						Lime, process 6,7		**400**	Kg/decare
85		**B.7. PRICES FOR SEED AND HERBICIDES**							
86		Rape seed	**1,000**	**36**	NOK/kg				
87		Meadow seed mixture	**1,000**	**45**	NOK/kg				
88		Barley for cover crop	**1,000**	**3,85**	NOK/kg	**B.8. LABOUR COEFFICIENTS FOR FIELDWORK**			
89		Green fodder peas	**1,000**	**7,00**	NOK/kg	Ploughing, 2 ploughshares		**0,4**	h/decare
90		Ryegrass	**1,000**	**16**	NOK/kg	Harrowing, kongskildeharrow		**0,2**	h/decare
91		Ariane S		**91,8**	NOK/l	Number of times harrowing, (		**3**	
92						Spreading of artificial fertilize		**0,1**	h/decare
93		**B.9. COSTS FOR BAILING GRASS**				Prepare storage and harvest		**0,44**	h/decare
94		Energy per bale		**135**	FEm/Bale	Preparing storage and equip		**0,165**	h/decare
95		Baling of grass costs including net		**58**	NOK/bale	Preparing storage and equip		**0,035**	h/decare
96		Wrapping of plastic around a bale		**50**	NOK/bale	Harvesting for silage first cut		**0,8**	h/decare
97		Dry matter per metric ton of predried grass		**760**	kg	Harvesting for silage last cut		**0,6**	h/decare
98						Grass cutting (tractor with gr		**0,2**	h/decare
99						Raking and cording grass for		**0,32**	h/decare
100		**B.10 GOVERNMENTAL SUPPORT FOR ANIMALS AND RELIEF PAYMENTS**				Raking and cording grass for		**0,64**	h/decare
101		Support per cow, less than 16 cows		**3330**	NOK/animal	Transport of silage bales, fro		**0,33**	h/decare
102		Support per calf/young cattle on Jan 1.		**660**	NOK/animal	Loading, transport and unloa		**1,3**	h/ton dry ma
103						Covering of bunker silo		**0,016**	h/decare
104		Support for relief, marginal value, for cows		**1207**	NOK/animal	Pasture renovation (do up)		**0,2**	h/decare
105		Marginal support for relief, calf/young cattle Jan 1		**437**	NOK/animal	Seeding grass and rape seed		**0,2**	h/decare
106						Spraying against weeds		**0,1**	h/decare
107		**B.11. OTHER PRICES USED**				Gather rocks		**0,5**	h/decare
108		Selling heifers alive		**12500**	NOK/animal	Pumping of manure		**0,0483**	h/ton manur
109		Local Price Baby Calf, live weight		**24,0**	NOK/kg	Spreading of manure		**0,035**	h/ton manur

The rates for governmental premiums for animals and support for relief payments are displayed in the cells D101–105 of part B.10 of the model. These are standard rates for the whole country. The prices for live animals in D108–09 are taken from the annual editions of the handbook (NILF, 2000).

Standard energy yields for different plant processes are shown in the cells H51–60. The standard yield per decare for the first cut of meadows for silage is 242 FEm, the second cut is assumed to be 118 FEm, making a total yield of 360 FEm if the meadow is cut twice. If the farmer chooses to pasture the re-growth after a first cutting the net pasture yield is assumed to be 40 FEm whereas for hay and silage the loss rates are 10% (from field to mouth) and 15% for green fodder as displayed in H61–62. The losses are subtracted from the standard values to calculate net production that is utilized by the animals. The energy yields are calibrated (in Part H) by multiplying with a yield calibration factor, specific for each farm, to reach the values transferred to constraint 14 for indoor feed and constraint 20 for pasture feed in the LP matrix. When calibrating the model the number of times the meadow can be cut per season also has to be decided. The yield for the third (or more) cutting is similar to the second and it is assumed that fertilizer has to be applied before each cut.

Further in the cells H65–84 is displayed the quantities of seed and fertilizers including manure used for different plant processes in the LP model. Manure can be used on open fields, i.e. green fodder or meadow replacement area, or in limited amounts spread on meadows. In the latter case manure is spread only once a year on the same field and will replace one treatment with artificial fertilizer on that field. The prices for lime and fertilizers are displayed in the cells D72–77 and updated with separate price indexes. Normally farmers also have to pay for freight, but different discounts have to be subtracted and it is assumed these factors outweigh each other. Lime is assumed added in the year of meadow replacement only. The cost and quantity data are used for computing the costs of the crops processes that are transferred to the objective function with a negative sign.

The cells H89–109 show coefficients for labour use in h per decare (or tons of yield or manure) for different kinds of field work operations. The coefficients are worked out for the tractors and the equipments above. Most field operations like ploughing are conducted only once, however harrowing before sowing is conducted three times. The coefficients have been put together based on information in Handbook of farm planning (NILF, 2000). The coefficient for loading, transport and unloading of pre-dried grass for haymaking is based on Kiel and Sørland (1982). The data are used for computing the labour input coefficients of the crops processes (see plant crop calculations). The field work has to be done during the summer season.

4 Machinery, milk production and labour

The calculations of the hourly machinery costs for each kind of machinery are conducted in part C.1 of the model. The actual costs of machinery will depend on their use which is determined in part E. Starting with the tractors the cost per h is composed of costs of fuel and lube oil plus maintenance of the tractor. Use of diesel is 8.5 and 5.5 l per h respectively (C119–C120), and this is multiplied with the price of diesel and adding 3.7 percent for lube, hydraulic oil and grease (D119–D120). The used coefficients for fuel consumption are based on Mangerud, (1984) assuming a similar rate of flow for the tractor for all kinds of equipment.

Based on the replacement values of farm tractor and equipment the coefficients for purchased maintenance are displayed in column F below and the farmers work share of the replacement costs in column G. Cost and work with maintenance and repair of the different kinds of tractor equipment is calculated based on studies by Hegrenes (1985), Svensson (1987), Larsson (1983) and Lønnemark (1971). These authors estimate costs of maintenance as depending on repurchase value (i.e. a current list price) (in 1000 NOK) and h of use for each kind of equipment.

	A	B	C	D	E	F	G	H	I
114	**Part C of the Model where intermediate CALCULATIONS are Done**								
115	**C.1.CROP MACHINERY FUEL, VARIABLE COSTS AND WORK WITH MAINTENANCE AND REPAIR OF FIELD MACHINERY**								
116				Increment		Maintenance coefficients			Maintenance
117			Fuel consum.	for lube oil	Replacement	Total per 1000	Farmers	Cost per h	by farmer
118			l diesel/h*	& grease	value	replacem. val.E	share	of use	per h of use
119		Tractor 92 hp with load equipment	**8,50**	**1,037**	406050	0,091	0,2	**92**	1,053
120		Tractor 52 hp with loading equipm.	**5,50**	**1,037**	265442	0,091	0,2	**60**	1,053
121		Trailer 10 tonn			42000	0,07	n.e.	**95**	0,001
122		Trailer wagon			61670	0,28	0,25	**13**	0,054
123		KVERNLAND reversible 2 share plough			74890	0,94	0,31	**141**	0,110
124		KONGSKILDE harrow 2,1 m working width			24100	1,02	0,33	**109**	0,143
125		Reel, 4 m working width			30900	0,07	n.e.	**95**	0,001
126		BØGEBALLE centrifugal fertilizer distributor			27891	0,7	n.e.	**112**	0,167
127		Manure pump, HLR2			51210	0,48	n.e.	**85**	0,074
128		Manure tank wagon, MOI GB 6			65100	0,44	0,25	**114**	0,074
129		HARDI tractorsprayer			12180	2,7	0,67	**103**	0,249
130		Seeding machine CK4000, grass			50490	0,48	0,47	**105**	0,185
131		JFROTOR grass mover 190 cm			*35870*	0,65	n.e.	**116**	0,126
132		BYE side revert rake, 240 cm			*13300*	1,6	n.e.	**114**	0,148
133		Crosscut rake			*4000*	1,02	0,33	**95**	0,024
134		JF RAP harvester grass (130cm)	**		*41000*	0,66	0,33	**110**	0,092

Purchased maintenance amounts to 0.091 NOK per 1000 NOK of repurchase value for both tractors. The smallest tractor will still have the lowest cost of maintenance due to a lower repurchase value. Together with fuel consumption, fuel price and the amendment for lube oil and grease the cost per h are calculated for each kind of machinery (i.e. tractor with equipment) in column H. Farmers work with maintenance of farm machinery is displayed in column I. For each h use of the tractor 0.053 h is added for maintenance and if he uses the tractor for one h together with e.g. a plough another 0.110 h of maintenance work for the plough has to be added. Farmers work with machinery maintenance is added to the field works in the calculations of farm crops in part D of the model.

In part C.2 of the model a seasonal distribution of the farm milk production has been calculated. A standard lactation curve with 6307 kg of milk is defined in the LP Model sheet and displayed below. The standard lactation curve is assuming 365 days between each calving (366 days in leap years)[2] and the dry period is 61 (62) days before each calving. The curve is adjusted so that it matches the actual milk production on each farm by multiplying with a milk yield calibration factor shown in line 143 below. The calculated milk production is distributed over the months in accordance with calving time and the standard lactation curve. In the outlay below calving take place on January 10 2000 and there is no milk production in December and very little in November. The total raw milk production will be 108 kg. As the cows will be in the dry period during much of the summer there is very little milk production on pasture.

[2] The data format in Excel works with 366 days in leap years.

	A	B	C	D	E	F	G	H	I	J	K	L	M
140	**C.2. MONTHLY AND PASTURE MILK PRODUCTION DEPENDING ON TIME OF CALVING**												
141													
142			**Kg milk per l of milk**			**1,025**			**Summarizing computed milk production on months**				
143			Milk production increment factor			1,077			Calving time	10.1.00			
144			Standard curve	Days (+1 dry d	Augmented	Sum	**Fetus production feed**		Distribution	Total milk	Pasture	Days with	Dry
145		Milk production after calving	kg per day	in leap years)	kg milk/day	milkprod	**FEm/day**	**AAT g/day**	on months	production	milk	milk	days
146		Raw milk	20	5	21,5	108	0	0	January	569	0	22	9
147		Milk	25	15	26,9	404	0	0	February	843	0	29	0
148		Milk	27	31	29,1	901	0	0	March	834	0	31	0
149		Milk	25	31	26,9	834	0	0	April	773	0	30	0
150		Milk	24	28	25,8	723	0	0	May	763	0	31	0
151		Milk	23	31	24,8	768	0	0	June	674	0	30	0
152		Milk	21	30	22,6	678	0	0	July	631	610	31	0
153		Milk	19	31	20,5	634	0	0	August	579	579	31	0
154		Milk	17,5	30	18,8	565	0	0	September	515	258	30	0
155		Milk	16	31	17,2	534	0	0	October	496	0	31	0
156		Milk	15	31	16,1	501	0,3	33	November	112	0	8	22
157		Milk	13	10	14,0	140	0,5	50	December	0	0	0	31
158		Dry	0	20	0,0	0	1,5	100					
159		Dry	0	31	0,0	0	2,2	186,7		6790	1448	304	62
160		Dry (+1day leap years)	0	11	0,0	0	2,5	230					
161		**Sum production, kg per cow**	**6307**	**366**		**6790**							

The milk production figure in each month is used to calculate monthly distribution of feed requirement for milk production by the cows in part F.1 (Chapter 7). In addition the time of calving determines when the cows will need extra feed for growth of the calf foetus. The feed requirement for growth of calf foetus amounts to 2.5, 1.5 and 0.5 FEm and 230, 100, and 50 gram AAT per day in the three last months before calving and is computed in the columns G and H. The monthly feed requirements are further used to calculate the distribution of the feed requirements on the indoor and pasture periods in part F.2 which is transferred to the LP tableau.

Regarding total <u>labour input</u> a regression between labour use in h per day for animal husbandry and the number of animals for the indoor period is displayed in the cells C214–C217 and for the grazing period in the cells E214–E217. The regressions have been calculated by Jerven (1985). In the cells C219–C220 a similar regression has been carried out for other farm work measured in h per year, based on the same source. Other farm work comprises different tasks that are not related to either field works or work with animals. Most important are the maintenance of farm buildings and administration (e.g. accounting) of the farm. The other farm work has been regressed on farm land area with 276.4 h/year as constant and 0.98 h per decare of farm land (H214–H215).

The constant coefficients for daily work with animals are multiplied with the number of days in each period and summarized in D220 for the grazing period and in C220 for the whole year i.e. the indoors and grazing periods together. Other farm work is calculated in line 221, and the sums are displayed in the cells C222 and D222. The marginal labour force is the total labour force minus the constant and the numbers in these cells are therefore transferred to the constraint 10 of process 30 for the grazing period and constraint 11 for the whole year. Regarding the coefficients for daily marginal labour input per cow, calf and other cattle in the indoor and grazing periods are multiplied with length of each season and transferred to their respective cells in the LP tableau for the constraints 10 and 11.

	A	B	C	D	E	F	G	H	I	J	K	L	M
210	C.3. STANDARD LABOUR INPUT FOR HUSBANDRY ANIMALS AND OTHER FARM WORK												
211													
212		Regression between work with animals (i.e. care and feeding) and number of cows, calves and other cattles											
213		**Work with animals**	Indoor feeding period		Grazing period		**Other farm work**						
214		Constant	**4,59**	h/day	**3,66**	h/day	Constant	276,4	h/year				
215		Calves 0-1 years	**0,02**	h/day	**0,04**	h/day	Area factor	0,98	h/decare				
216		Other cattle 1-2 years	**0,01**	h/day	**0,03**	h/day	Other farm work encompass maintenance of buildings, administration etc.						
217		Cows	**0,14**	h/day	**0,10**	h/day							
218													
219			Total year	Grazing									
220		Work with animals	**1605,5**	**278,4**	h/year								
221		Other work	512,3	155,8	h/year	Maintenanc and repair of farm machinery is computed on the crop processes, the factor used here is for r							
222			**2117,8**	**434,2**	h/year								
223													
224		Minimum hired labour to obtain relief payments					**160**	h/year					

In order to qualify for relief payment from the government farmers have to hire relief work for an amount equal to the extra relief payments granted for the first 8 cows (cell D39). The number of h is calculated in cell G224 as the minimum relief payment divided by the hourly wage for hired farm work and amounts to 142 h/year for the farm above. This is transferred to constraint 13 for process 30 of the LP.

5 Farm crops

The crop processes are calculated in the lines 228–365. There are 11 crop processes with numbers from 1 to 11 in the LP tableau. Of these, 10 have been worked out for cultivated farm land and one for uncultivated pasture land. The processes 1 and 2 are for meadows harvested for silage winter feed only, either with (1), or without (2) use of manure. Farmers will use the manure produced by the animals in the indoor period and purchase fertilizers to cover for the rest of their fertilizer need. The yield is the same for both processes and both can be harvested traditionally or bailed. Bailing is worked out in the columns I, J and K on the right hand side and leads to higher costs and lower farm labour input compared to a traditional harvesting in the columns E, F and G. The costs in the cells E239 and I239 are weighted together based on the shares of the meadow that is bailed and transferred to the LP objective function for process 1 and E343 and I343 for process 2. The work requirement coefficients for the year and for the pasture period are transferred to the LP-tableau for constraint 10 and 11 for the respective processes.

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q
228	**Part D. PLANT CROP CALCULATIONS**																
229	**Plant crop process nr. 1 SILSIL**				**1 cut**	**2 cut**	**Sum**						**Comment, documentation etc.**				
230	Energy value of yield, Fem No. 1				201,2	98,1	299,2										
231										Bailing of grass							
232				**Quantity**	**Costs**	**Tot work tim**	**Summer work**		**Costs**	**Tot work**	**Summer work**						
233	Manure. pump out and load, tons			5,0	-19	0,27	0,27										
234	Transport and spreading, tons				-18	0,20	0,20										
235	Fertilizer NPK22-2-12, kg/daa no weed spra			60,0	-138	0,24	0,24										
236	Preparing storage and harvesting equipment					0,2	0,2		-43	0,47	0,47	Grass cutting (tractor with grassmower)					
237	Harvest silage (cut+transp.+unload+return) No. 1				-160	1,68	1,68		-67	0,77	0,77	Raking and cording of grass, hay rake on tractor					
238	Unload, pressing and cover of silage, 1 person using trac				-110	1,49	1,49		-239	0,66	0,66	Bales, wrapping of plastic, intransport closing work					
239	**Sum process 1 No. 1**				**-446**	**4,1**	**4,1**		**-524**	**2,6**	**2,6**	**Sum silage harvesting with bales**					
240																	
241	**Prosess 2 SILSIL Without use of animal manure**																
242	Fertilizer NPK22-2-12, kg/daa			90,0	-197	0,24	0,24										
243	**Sum process 2 No. 1**				**-467**	**3,6**	**3,6**		**-546**	**2,1**	**2,1**	**Sum silage harvesting with bales**					

A similar procedure is applied for the other crop processes. Process number 3 and 4 are worked out for areas that are harvested once and the re-growth is pastured. If the pasturing takes place in the spring before the cutting, the yields are usually a little higher and the feed quality will also be slightly different. However this can be regulated by a shorter grazing period during the spring. The costs and labour input are assumed to be the same for spring and late summer grazing. The results are transferred to the LP tableau for process 3 and 4.

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q
245	**Plant crop process nr. 3 SILPASTURE**																
246					**1 cut**	**Past2cut**	**Sum**										
247	Energy value of yield, FEm silage + pasturing second cu				201,2	36,9	238,1										
248																	
249				**Quantity**	**Costs**	**Tot work tim**	**Summer work**										
250	Manure. pump out and load, tons			3,0	-11	0,16	0,16										
251	Transport and spreading, tons				-11	0,12	0,12										
252	NPK 22-2-12, + limenitrate kg/		60,0	0,0	-138	0,24	0,24										
253	Preparing storage and harvesting equipment					0,165	0,165										
254	Harvest silage (cut+transp.+unload+return)				-124	0,96	0,96		-21	0,24	0,24	Grass cutting (tractor with grassmower)					
255	Unload, pressing and cover of silage, 1 person using tra				-66	0,85	0,85		-33	0,38	0,38	Raking and cording of grass, hay rake on tractor					
256	Cutting, transport and unload raw grass for direct feedin				-69	0,72	0,72		-161	0,33	0,33	Bales, wrapping of plastic, intransport closing work					
257	**Sum process 3**				**-419**	**3,2**	**3,2**		**-445**	**2,2**	**2,2**	**Sum silage harvesting with bales**					
258																	
259																	
260	**Process nr. 4 SILPASTURE Without use**			**of animal manure**													
261	NPK 18,3,15+NPK 21,4,10		58,0	32,0	-198	0,24	0,24										
262	**Sum process 4**				**-457**	**2,9**	**2,9**		**-483**	**1,9**	**1,9**	**Sum silage harvesting with bales**					

Hay making is troublesome in Northern Norway and a barn dryer is required. Farmers may decide to purchase hay or do without it. However, calves should preferably have some hay in their feed ration and this has to be supplied one way or another. The process 5 below is worked out for hay making in combination with spring or autumn pasture. The grass is cut, turned and corded into a string, loaded and transported to the barn where it is levelled manually.

	A	B	C	D	E	F	G	H	I	J	K	L	M
264	**Plant crop process nr. 5 HAYPASTURE**												
265					**1 cut**	**Past2cut**	**Sum**						
266	Energy value of yield, FEm of hay pasturing second cut				163,2	40,7	203,9						
267													
268				**Quantity**	**Costs**	**Tot work time**	**Summer work**						
269	Manure. pump out and load, tons			3,0	-12	0,16	0,16						
270	Transport and spreading, tons				-11	0,12	0,12						
271	NPK 22-2-12, + limenitrate kg/daa no weed spray		60,0	0,0	-139	0,24	0,24						
272	Preparing storage and harvesting equipment					0,44	0,44						
273	Preparation+cut(drum mover with stem cracker)				-22	0,24	0,24						
274	Turn, cording of grass in a string				-68	0,77	0,77						
275	Loading, transport and unloading, crosscutrake				-25	0,30	0,30						
276	Level hay on the dryer manual + hayfork (electricity for drying)				-24	0,28	0,28						
277	Cutting, transport and unload raw grass for direct feeding				-70	0,72	0,72						
278	**Sum process 5**				**-370**	**3,3**	**3,3**						

Haymaking is quite labour intensive compared to silage and process 5 can only provide the minimum amounts of hay required for constraint 18. Haymaking has decreased in Norwegian agriculture in recent years, in particular since silage bales became common. Silage bales are often based on pre-dried grass and depending on water content can be used almost as hay, and for instance fed in un-insulated farm buildings or outdoor in the snow during the winter. Some farmers still prefer hay in particular for horses and calves. The rainfall is quite high in Northern Norway and haymaking is of little importance compared to silage.

Process 6 is worked out for area that is replaced in the early fall after taking one cut of grass first. This way it is possible to establish a new meadow right after the first cut before the snow. An alternative assuming baling of the grass is to the right. The area has to be ploughed, harrowed three times and lime is added before sowing with grass or a meadow seed mixture. Manure can be added before (or after) ploughing and farmers would use as much as possible to avoid spreading manure on meadows. The default value is 4 tons of manure per decare.

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q
281	**Plant process nr. 6 EARLYAUTUMNSEEDING**																
282					**1 cut**		**Sum**										
283	Energy value of yield, FEm				166,2		166,2										
284																	
285				**Quantity**	**Costs**	**Tot work tim**	**Summer work**										
286	Manure. pump out and load, tons			4,0	-15	0,22	0,22										
287	Transport and spreading, tons				-15	0,16	0,16										
288	Harvest silage (cut+transp.+unload+retum)				-118	0,96	0,96										
289	Unload, pressing and cover of silage, 1 person using trac				-66	0,85	0,85										
290	Ploughing 2 ploughshare				-53	0,47	0,47										
291	Harrowing 3 times				-60	0,63	0,63										
292	Lime 3 spreads			400,0	-343	0,37	0,37										
293	Gather and transport stones				-43	0,53	0,53		-21	0,24	0,24	Grass cutting (tractor with grassmower)					
294	Seeding with meadowseed, 2.5 kg			2,5	-132	0,25	0,25		-33	0,38	0,38	Raking and cording of grass, hay rake on tractor					
295	Spraying against weeds (0.3 l Ariane S/daa			0,3	-37	0,12	0,12		-133	0,33	0,33	Bales, wrapping of plastic, intransport closing work					
296	**Sum process 6**				**-882**	**4,5**	**4,5**		**-886**	**3,7**	**3,7**	**Sum silage harvesting with bales**					

Process 7 is worked out for replacement of the meadow in the springtime. The field is ploughed during springtime and the necessary fieldworks conducted before sowing with a mixture of grass and clover seeds. Costs and work with lime and manure are added and a once time spraying against weeds is assumed. Process 8 is worked out for spring replacement for area that has been exposed to winter damage. It is assumed a little simpler field work procedure to restore such areas without use of lime and manure. A small harvest of silage is possible the same fall and worked out with traditional harvesting or bales for both processes.

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q
299	**Process nr. 7 SPRINGSEEDING with animal manure**																
300					**Yield 1-2 cut**		**Sum**										
301	Energy value of yield, FEm				172,2		172,2										
302																	
303				**Quantity**	**Costs**	**Tot work tim**	**Summer work**										
304	Ploughing is omitted due to use of area with green fodder the previous year																
305	Manure. pump out and load, tons			5,0	-19	0,27	0,27										
306	Transport and spreading, tons				-18	0,20	0,20										
307	Harrowing 3 times				-60	0,63	0,63										
308	Lime 3 spreads			400,0	-343	0,37	0,37										
309	Gather and transport stones				-43	0,53	0,53										
310	Seeding with meadowseed, 2.5 kg			2,5	-132	0,25	0,25										
311	Cover crop peas+barley		4,0	7,0	-110	0,25	0,25										
312	Spraying against weeds (0.3 l Ariane S/daa			0,3	-37	0,12	0,12		-21	0,24	0,24	Grass cutting (tractor with grassmower)					
313	Harvest silage (cut+transp.+unload+return)				-119	0,96	0,96		-33	0,38	0,38	Raking and cording of grass, hay rake on tractor					
314	Unload, pressing and cover of silage				-66	0,85	0,85		-138	0,33	0,33	Bales, wrapping of plastic, intransport closing work					
315	**Sum process 7**				**-948**	**4,4**	**4,4**		**-955**	**3,6**	**3,6**	**Sum silage harvesting with bales**					
316																	
317																	
318	**Process nr. 8 SPRINGSEEDING without animal manure (repair)**																
319	Ploughing 2 ploughshare				-53	0,47	0,47										
320	NPK 18,3,15 + limenitrate kg/d		45,0	0,0	-98	0,12	0,12		-21	0,24	0,24	Grass cutting (tractor with grassmower)					
321	Harrowing 2 times				-40	0,42	0,42		-33	0,38	0,38	Raking and cording of grass, hay rake on tractor					
322	Other costs as process 7 except lime				-507	2,95	2,95		-138	0,33	0,33	Bales, wrapping of plastic, intransport closing work					
323	**Sum process 8**				**-698**	**4,0**	**4,0**		**-706**	**3,1**	**3,1**	**Sum silage harvesting with bales**					

Process 9 and 10 are for green fodder. Farmers may use manure when establishing green fodder and sowed with ryegrass that is either pastured or fed directly in the barn (zero grazing). The labour requirement is assumed equal, in case of zero grazing, extra time to feed the cattle may be outweighed by time saved in pasturing for instance arranging strip grazing.

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q
326	**Plant crop process nr. 9 GRENFODP Green fodder for grazing or zero grazing**																
327					**Yield**		**Sum**										
328	Energy value of yield, FEm				273,2		273,2										
329																	
330				**Quantity**	**Costs**	**Tot work tim**	**Summer work**										
331	Ploughing 2 ploughshare				-53	0,47	0,47										
332	Manure. pump out and load, tons			5,0	-19	0,27	0,27										
333	Transport and spreading, tons				-18	0,20	0,20										
334	Limenitrate, kg			47,0	-76	0,12	0,12										
335	Harrowing 3 times				-60	0,63	0,63										
336	Seeding with ryegrass			4,0	-83	0,25	0,25										
337	Harvest silage (cut+transp.+unload+return) same when				-92	0,96	0,96										
338	**Sum process 9**				**-401**	**2,9**	**2,9**										
339																	
340	**Plant process nr. 10 GRENFODI Green fodder for indoor feed**																
341					**Winterfeed yield**		**Sum**										
342	Energy value of yield, FEm				212,5		212,5										
343																	
344				Quantity	Costs	Tot work time	Summer work										
345	Ploughing 2 ploughshare				-53	0,47	0,47										
346	Manure. pump out and load, tons			5,0	-19	0,27	0,27										
347	Transport and spreading, tons				-18	0,20	0,20										
348	Limenitrate, kg			47,0	-76	0,12	0,12										
349	Harrowing 3 times no lime or stone gathering				-60	0,63	0,63										
350	Seeding with barley/oats 15 kg		15	9	-140	0,25	0,25		-21	0,24	0,24	Grass cutting (tractor with grassmower)					
351	Harvest silage (cut+transp.+unload+return)				-126	0,96	0,96		-33	0,38	0,38	Raking and cording of grass, hay rake on tractor					
352	Unload, pressing and cover of silage				-66	0,85	0,85		-170	0,33	0,33	Bales, wrapping of plastic, intransport closing work					
353	**Sum process 10**				**-558**	**3,7**	**3,7**		**-591**	**2,9**	**2,9**	**Sum green fodder silage harvesting with bales**					

The process 10 is for green fodder to be used as winterfeed. The only difference compared with process 9 is that the area is sowed with a mixture consisting of barley, oats and peas to be harvested for silage or bailed. The final process 11 is worked out for permanent pasture on farmland. On such area farmers will add artificial fertilizers three times during the season and also have to do up the pasture between each grazing.

	A	B	C	D	E	F	G	H	I	J	K	L	M
357	**Plant process nr. 11 PASTPERM Pasturing on permanent pasture land**												
358					**Pasture yield**			**Comment, documentation etc.**					
359	Energy value of yield, FEm				231,2		231,2	Net pasture yield					
360													
361				**Quantity**	**Costs**	**Tot work time**	**Summer work**						
362	NPK18-3-15 + limenitrate kg/daa no weed spraying		68,0	26,0	-180	0,37	0,37	3 spreads.					
363	Pasture clean up and supplementary work				-62	0,69	0,69						
364	Sum Costs with pasture				**-242**	**1,1**	**1,1**						

Support for area and cultural landscape is added in the processes 12 and 13 with 30 percent lower values for permanent pastures.

6 Feed quality and purchase of feed

The protein content of silage, green fodder, hay and pasture in kg of AAT per FEm is displayed in line 369 below and used when calculating the amount of protein in constraint 15 and 21 of the LP tableau for the indoor and pasture periods respectively. In line 370 is shown feed concentration with rates from 0.69 to 0.96 FEm per kg of dry matter. These are used to calculate the amount of roughage dry matter for the different roughage feed and pasture processes. The constraints 16 and 17 of the LP-model are the minimum and maximum amount of roughage dry matter for the indoor period and the constraints 21 and 22 are for the pasture period.

Purchased hay or bales of silage is assumed to have the same quality as the home grown feed. Farmers sometimes buy bales of silage, however the silage quality is varying and there are no regular price quotations for silage bales. Another option for a farmer is to purchase grass “on the root” and organize harvesting himself. He will then pay a price for the raw grass and has a control of the grass quality. Assuming he pays the costs of fertilizer for the raw grass and that harvesting costs are the same as on his own fields, the price per bale of silage is calculated in cell D372 and his labour input per bale is calculated in cell E372. The values are transferred to process 14 of the LP-tableau. The price of hay in cell G371 is per 100 kg and is transferred to process 15. The hay is produced further south in Norway (e.g. in Trøndelag) or imported from Northern Sweden or from Finland. It is also possible to replace hay with (ammonia treated) straw from southern Norway, using the numbers in column H.

Two kinds of concentrate feed are available during the winter, one with low protein content and another with high protein content. The cheapest alternative is also available as supplementary feed during the grazing period together with a medium protein content alternative. In addition farmers purchase a special concentrate for calves. There are five processes for purchase of concentrate feed in the LP model, numbered from 16 to 20.

	A	B	C	D	E	F	G	H	I	J	K	L
366	**Part E. FEED QUALITY AND PRICES FOR PURCHASED FEED**											
367	**E.1. ROUGHAGE FEED**			**GRASS SILAGE CUT**		**GREEN FODDER**			**PASTURING OF**		**PERMANENT**	
368				**EARLY**	**FALL LATE**	**SILAGE**	**HAY**	**STRAW**	**MEADOW**	**GREEN FO**	**INFIELD PASTURE**	
369		PROTEIN CONTENT KG AAT/FEm		0,088	0,087	0,095	0,091	0	0,076	0,083	0,076	
370		FEED CONCENTRATION, FEm/KG DRY MATTER		0,81	0,84	0,7	0,76	0,69	0,93	0,93	0,96	
371		MARKET PRICE KR PER 100FEm	100	FEm			355	315				
372		PURCHASING SILAGE BALES	NOK/Bale	**-220,61**	**0,86**	Hoursper bale						
373												
374	**E.2. PURCHASED RUMINANT CONCENTRATE FEED**											
375				97 High	105 Low	Extra High	Calf feed					
376		FEED CONCENTRATION, FEm/100 KG		93	100	95	96					
377		PROTEIN CONTENT KG AAT/FEm		0,097	0,105	0,140	0,094					
378		KG AAT		9,021	10,5	13,3	9,024					
379												
380		MARKET PRICE KR PER 100 KG		272,0	268,0	308,0	295,0					

The energy and protein content of the concentrate feeds are displayed in the lines 376 and 377 which are transferred to the LP matrix. There are no feeding requirements regarding dry matter content for concentrates. The prices of the different kinds of concentrates in line 380 are transferred to the objective function of the processes 16–20. The prices of concentrates are for bulk deliveries (which are not always the case) and do not include minerals, freight and losses which can vary between farms. These costs are considered when calibrating the model.

7 Feed uptake by animals

The basic assumptions for calculation of feed intake by cows are displayed in the lines 385–420 in part F.1 of the model. The unit is a milking cow with 1.0 calf per year as displayed in C386. The share of male calves is 0.51 (G386) and the default rate of replacement is 0.35 (G387). These values are transferred to the LP tableau for the constraints 26 and 27. The raw milk period lasts for 5 days and raw milk production is subtracted from total milk production to arrive at sellable milk production which is distributed over months in line 392.

The default live weight of the milking cows is 550 kg (C401) requiring 4.8 FEm of energy and 367 g AAT for maintenance per day (F402–403) according to the Handbook of Farm planning (NILF, 2000). The cows are a little heavier than 2 years old heifers (485 kg, see cell K449 later), and the difference has to be accounted for. It takes 3 FEm, each with 90 gram of AAT, to add one kg of live weight for cows according to the norms and the figures are displayed in I402–403. The number of cow years is calculated as the inverse of the replacement rate and the growth is distributed over the cow years to arrive at daily requirement for growth in the cells J402–403. The feed requirement for milk production is 0.45 FEm and 45 g AAT per kg of milk, displayed in the cells M402–403.

On the basis of the calving time and distribution of milk production the energy and protein requirement for milk and foetus production is calculated for each month of the indoor and pasture periods in the lines 405–413. Together with maintenance (the feed for maintenance will be the same all days) and growth requirements the total energy requirement of the milking cows is calculated in the cells D417–D418 and protein in E417–E418 for the indoor and pasture periods. These numbers go to the LP-tableau for the milking cows feed requirement i.e. the constraint 14–15 and 20–21 for process 21 (milking cows). The maximum amounts of roughage dry matter are 10 kg a day (also depending on cows weights) and calculated in the cells J417–J418 for the indoors and pasture periods. The minimum amounts are 7.2 kg/day indoors and 2.7 kg/day on pasture and the sums are calculated in the cells K417–K418. The maximum and minimum amounts of roughage dry matter are transferred to the constraints 16–17 and 22–23 for process 21.

Large amounts of low fibre roughage in green fodder may distort the digestion for the milking cows. This will generally not be a problem indoors where farmers have different kinds of roughage, however on pasture the farmer may have to limit green fodder uptake by cows and other cattle. In cell M418 is calculated a maximum amount of low fibre roughage on pasture based on a maximum of 5 FEm of green fodder daily and 35 days of such pasture. The total amount is 175 FEm (cell O418) and it is transferred to the constraint 24 for process 21 (milking cows). As for other animals this is taken care of with a maximum 17.6 percent green fodder share of total pasture feed uptake in cell M420, the same share as for milking cows.

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
384	Part F. NUTRIENT REQUIREMENT IN MILK AND MEAT PRODUCTION														
385	F.1 NUTRIENT REQUIREMENT FOR COWS				Date of calving:		10.jan				Stochastic yield		6992,8		
386	Number of calves per calving		1,00		Share of male calves		0,51				Milk yield - rawmilk		6682		
387	Raw milk production, days		5		Replacement rate		0,35								
388			Jan.	Febr.	March	April	May	June	July	Aug.	Sept.	Okt.	Nov.	Dec.	Sum
389		Days	31	29	31	30	31	30	31	31	30	31	30	31	366,0
390		Total milkproduction incl raw milk	569,5	842,9	834,3	772,9	763,3	673,9	630,8	579,2	514,6	496,3	112,0	0,0	6789,6
391		Pasture milk prod incl raw milk	0,0	0,0	0,0	0,0	0,0	0,0	610,4	579,2	258,4	0,0	0,0	0,0	1447,9
392		Total milkproduction excl raw milk	461,8	842,9	834,3	772,9	763,3	673,9	630,8	579,2	514,6	496,3	112,0	0,0	6682
393		Pasture milk prod excl raw milk	0,0	0,0	0,0	0,0	0,0	0,0	610,4	579,2	258,4	0,0	0,0	0,0	1447,9
394	Indoors	Stochastic sellable milk yield	483,3	882,1	873,1	808,9	798,8	705,3	21,4	0,0	268,1	519,4	117,2	0,0	5477,5
395	Pasture	Stochastic sellable milk yield	0,0	0,0	0,0	0,0	0,0	0,0	638,8	606,1	270,4	0,0	0,0	0,0	1515,3
396	Total days with milk production		22	29	31	30	31	30	31	31	30	31	8	0	304
397	Pasture days with milkproduction		0	0	0	0	0	0	30	31	15	0	0	0	76
398	Total	Dry days	9	0	0	0	0	0	0	0	0	0	22	31	62
399	Pasture	Dry days	0	0	0	0	0	0	0	0	0	0	0	0	0
400				Maintenance/kg live weight				Gain in weight from heifer to cow							
401		Living weight for cows, kg	550	Base value	Per kg value	Maintenance feed per day			Pr kg w.ga	Growth feed per da	Nutrition requirement for milk produc				
402			Energy	1,11	0,01	4,80	FEm/day	Energy	3	0,19	FEm/day	Energy	0,45	FEm/kg milk	
403			Protein	81,42	0,52	367,3	AAT g/day	Protein	270	16,75	AAT g/day	Protein	45	AAT, g/kg milk	
404															
405	FEm/Montl	Milk on pasture	0,0	0,0	0,0	0,0	0,0	0,0	287,5	272,8	121,7	0,0	0,0	0,0	682
406	AAT g/Mor	Milk on pasture	0,0	0,0	0,0	0,0	0,0	0,0	28745,3	27275,1	12167,3	0,0	0,0	0,0	68187,6
407	FEm/Montl	Milk indoors	268,2	397,0	392,9	364,0	359,4	317,4	9,6	0,0	120,7	233,7	52,7	0,0	2516
408	AAT g/Mor	Milk indoors	26818,8	39695,9	39290,3	36400,5	35944,3	31736,4	963,2	0,0	12065,9	23371,4	5272,5	0,0	251559
409															
410	FEm/Montl	Fetus on pasture	0	0	0	0	0	0,0	0,0	0,0	0,0	0	0	0	0
411	AAT g/Mor	Fetus on pasture	0	0	0	0	0	0,0	0,0	0,0	0,0	0	0	0	0
412	FEm/Montl	Fetus indoors	20	0	0	0	0	0,0	0	0	0,7	10,7	38,3	67,8	138
413	AAT g/Mor	Fetus indoors	1840	0	0	0	0	0,0	0	0	66,7	1066,7	2773,3	5873,3	11620
414															
415			Total nutrient requirement for cows				Uptake of roughage Dry Matter						Max low fibre roughage		
416			Days	FEm	AAT		Maxim kg	Min. share	Min kg/da	Max kg	Min kg		*FEm/day	Days	Total
417		Indoors	290	4097,9	374,6		10	0,4	7,0	2900	2024		3	331	993
418		Pasture	76	1060,5	97,4		10		5,8	760	442		5	35	175
419															
420							Maximum share of pasture feed that can be low fibre (greer						0,176		

The energy and protein requirements for growing animals are calculated in the parts F.2–F.6 below and distributed on the indoor and pasture periods depending on time of calving and length of the grazing period. In general the grazing period is 1–2 weeks longer for young cattle than for cows and an extended period is calculated in the cells F426–G426 in the layout below. In particular castrates and heifers can utilize the cheaper pasture for an extended period. However, there are restrictions on letting bulls out on pasture after an age of one year. In the model neither baby calves nor intermediate calves will use any pasture no matter when they are born.

The default living weight of offspring is 38 kg for females and 42 kg for males and living weights are calculated for baby calves that are sold for feeding after weaning at 4–5 weeks or as intermediate calves for slaughtering at an age of 5–6 months. The daily growth rate for baby calves is displayed in the cell I430 and age when weaned in J430. Regarding the feed requirements for baby calves and intermediate calves it is assumed that all the raw milk produced during the first days is given to the calf and this requires that some of the raw milk is acidulated. In addition another 70 kg of milk and 4 Fem of concentrate and 3 FEm of hay is required for baby calves, this is displayed in the cells K431–K433 and transferred to the LP-tableau for process 23 (baby calves).

	A	B	C	D	E	F	G	H	I	J	K	L
425	**F.2. BABY CALVES AND INTERMEDIATE CALVES**			Spring	Fall	Pasture period for cattle						
426		Extended pasture period for heifers, young cattle		3	10	28.06.2000	25.09.2000					
427												
428			**Raw milk, kg**		**Calf concentrate, kg**				Growth	Days when		
429	**Week nr**	**Days**	**per day**	**Sum**	**per day**	**Sum**			kg/day	weaned.		
430	1	7	4,5	31,5			**Baby calf, 4-5 weeks**		0,5	32		
431	2	7	4,5	31,5			Calf concentrate, minimum				**4**	FEm
432	3	7	4,5	31,5			Milk in addition to rawmilk, min.quantities				**70**	Kg
433	4	7		5,5	3	21	Minimum quantities of hay				**3**	FEm
434	5	7			5	35						
435	6	7			5	35						
436	7	7			5	35			Growth	Days when		
437	8	7			5	35			kg/day	slaughtered		
438	9	7			5	35	**Intermediate calf, 5 m**		1,2	150		
439	10	7			3	21	Calf concentrate, minimum quantities				**250**	FEm
440	11	7			3	21	Milk in addititon to rawmilk for feeding/sucklin				**870**	Kg
441	12-22	70				12	Minimum quantities of hay				**35**	FEm
442		**Sum**		100		250	Other concentrate, minimum quantities				**0**	FEm

The growth rate of intermediate calves is displayed in the cell I438 above. This is used to calculate living weight at slaughter and also the slaughter weights in part G. The feed requirements for intermediate calves are shown in K439–K442. Intermediate calves would require a substantial amount of milk in addition to the raw milk. The calculated feed requirements are transferred to the LP tableau for process 24 (intermediate calves).

For heifers the feed requirements are calculated in the lines 445–471 below. Heifers have their first calf at an age of 24 months so the calculations sum up the feed requirement from birth to that age. If calves that are to become heifers are born during the summer they are released on pasture after the baby calf period of 4–5 weeks, and heifers may thus have some grazing in three seasons. Heifers born in January as in the example farm here have two full grazing seasons before their first calf.

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S
445	**F.3. NUTRIENT REQUIREMENT FOR HEIFERS**																		
446	Age, months		0	3	6	9	12	15	18	21	24	Mated at 15 months, heifer weight includes fetus							
447	Age, days		0	91,26	183	274	365	456	548	639	730								
448	Growth, kg/day			0,6	0,6	0,7	0,5	0,7	0,6	0,6	0,6								
449	Weight, kg		38	93	148	211	257	321	376	430	485								
450	FEm/day		1,6	2,6	3,1	3,6	3,8	4,3	4,9	6	8,7								
451	Sum FEm		0	192	452	757	1095	1465	1884	2382	3052	**2243,6**	Indoor feeding Fem (Total minus pasture)						
452	AAT, g/day		180	280	300	340	365	400	440	520	770								
453	Sum AAT, g		0	20988	47450	76650	108816	143719	182044	225844	284700	**210,0**	Indoor feeding, kg protein (Total minus pasture)						
454			**Jan.**	**Febr.**	**March**	**April**	**May**	**June**	**July**	**Aug.**	**Sept.**	**Okt.**	**Nov.**	**Dec.**					
455	Accumulated day		31	60	91	121	152	182	213	244	274	305	335	366					
456	Age of heifer at end of month		21	50	81	111	142	172	203	234	264	295	325	356					
457			Unadjus	**FIRST GRAZING SEASON**				**SECOND GRAZING SEASON**				**THIRD GRAZING SEASON**							
458			age, da	Age, da	FEm/da	AAT/g day		Age, day	FEm/day	AAT/g day		Age, da	FEm/day	AAT/g day					
459	At pasture release,		170	170	2,76	277,62		536	5,63	506,22		0	1,43	171,44					
460	At pasture end		259	259	3,46	333,21		625	6,33	561,81		0	1,43	171,44	**808,7**	Pasture FEm			
461	Difference/average			89,00	3,11	305,42		89	5,98	534,02		0	0	0	**74709,9**	Pasture AAT, gram			
462																			
463			Minimu	First ye	Total for		Minimum	Second	Total for										
464			share	Kg/day	the period		share	Kg/day	the period										
465	Max roughage dry matter, indoors			5	1380			9	2484		3864,0	Max roughage DM indoor feeding							
466	Min roughage dry matter, indoors		0,5	1,8	505,1		0,5	3,2	879,9		1385,0	Min roughage DM indoor feeding, 50 % of the indoor feed from roughage							
467	Max roughage dry matter for pasture period			5	445			10	890,0		1335,0	Max roughage DM pasture							
468	Min roughage dry matter for pasture period		0,5	1,6	144,1		0,5	3,1	277,1		421,2	Min roughage DM pasture, 50 % of the pasture feed from roughage							
469	Min amounts of hay (also for bulls and castrates)				25														
470	Min quantity of calf concentrate				210														
471	Milk for calf period of heifers (+raw milk)				250														

The daily weight gains for heifers, depending on age, are displayed in line 448 and live weights at different ages are calculated in line 449. The energy requirements per day at different ages are displayed in line 450 and the accumulated energy requirements in line 451. The protein requirements per day follow in the line 452 and are accumulated in line 453. The accumulated feed requirements from birth to 24 months are distributed on the indoor

(L451and L453) and (O461 and O462) the pasture period. The numbers are transferred to the constraints 14–15 and 20–21 in the LP-tableau for process 22 (heifers). The maximum and minimum dry matter requirements are calculated in the lines 465–468 and the sums in the cells K465–K468 are transferred to the constraints 16–17 and 22–23 of this process. The minimum feed requirements that have to be hay, special calf concentrate or milk supplied in the calf period is displayed in the cells E469–471. The hay for the calf period is also necessary for bulls and for castrates.

Similar calculations are conducted for 18 months old bulls in the lines 473–495. Bulls only use pasture the first year due to difficulties to keep them fenced and to gather them. From the table it is also possible to calculate feeding requirements for 15 months old bulls. However, to reach slaughter maturity at that age bulls would normally require a stronger feeding the first half year, starting with the growth rates and feeding requirements for the intermediate calf.

	A	B	C	D	E	F	G	H	I	J	K	L	M	N
473	**F.4. BULLS ON STRONG FEEDING, 18 MONTHS**													
474	Age, months		**0**	**3**	**6**	**9**	**12**	**15**	**18**					
475	Age, days		0	91,26	183	274	365	456	548					
476	Growth, kg/day			0,6	0,8	1,1	1,2	1,2	1,1					
477	Weight, kg		42	97	170	270	380	489	590					
478	FEm/day		1,7	2,7	3,4	5	6,6	8,4	8,6					
479	AAT, g/day		200	300	340	480	580	700	720					
480	Sum FEm		0	201	479	862	1392	2076	2852	2553,4	Sum indoor feed FEm			
481	Sum AAT, g		0	22813	52013	89425	137788	196188	260975	234,4	Sum indoor kg protein			
482				Age, days	FEm/day	AAT/g day								
483	At pasture release			295	5,5	495,88		No second year pasture for 18 months bulls						
484	At pasture end			346	6,2	547,77		298,1	Sum pasture FEm					
485	Difference/average			51	5,85	521,82		26613,0	Sum pasture g protein					
486														
487			Minimum	First year	Total for		Second ye	Total for						
488			share	Kg/day	the period		Kg/day	the period						
489	Max roughage dry matter, indoors			6	1884		9	1643,0		3527,0	Max roughage DM indoor			
490	Min roughage dry matter, indo		0,3	1,3	405,0		3,0	540,7		945,7	Min roughage DM indoor			
491	Max roughage dry matter for pasture perio			6	306		No second year pasture for bulls			306,0	Max roughage DM pasture			
492	Min roughage dry matter for pa		0,3	1,8	93,2		No second year pasture for bulls			93,2	Min roughage DM pasture			
493														
494	Min Quantity of calf concentrate			210										
495	Milk for calf (+raw milk)			325										

Another option would be to feed the bulls a little weaker and keep them until they are 24 months before slaughtering. They would then become somewhat larger, and the calculations for this process are shown in the lines 497–519 of the layout below.

	A	B	C	D	E	F	G	H	I	J	K	L	M	N
497	**F.5. BULLS ON WEAK FEEDING, 24 MONTHS**													
498	Age, months		**0**	**3**	**6**	**9**	**12**	**15**	**18**	**21**	**24**			
499	Age, days		0	91,26	183	274	365	456	548	639	730			
500	Growth, kg/day			0,6	0,6	0,8	0,9	1	1	0,9	0,8			
501	Weight, kg		42	97	152	225	307	398	489	571	644			
502	FEm/day		1,7	2,7	3	4,1	5,2	6,3	7,5	7,9	8,1			
503	AAT, g/day		200	290	300	400	450	500	600	625	650			
504	Sum FEm		0	201	461	785	1209	1734	2363	3066	3796	3464,4	Sum indoor FEm	
505	Sum AAT, g		0	22356	49275	81213	119994	163338	213525	269416	327588	296,5	Sum indoor kg protein	
506				Age, days	FEm/day	AAT/g day								
507	At pasture release			170	3,3	321,3		No second year pasture for 24 months bulls						
508	At pasture end			259	4,2	378,2		331,6	Sum pasture FEm					
509	Difference/average			89	3,7	349,7		31127,6	Sum pasture g protein					
510														
511			Minimum	First year	Total for		Second	Total for						
512			share	Kg/day	the period		Kg/day	the period						
513	Max roughage dry matter, indoors			6	1656		10	3650			5306,0	Max roughage DM indoor feeding		
514	Min roughage dry matter, indoors		0,5	2,0	541,6		5,8	2111,8			2653,4	Min roughage DM indoor feeding		
515	Max roughage dry matter for pasture period		Same as indoor	6	534		No second year pasture for bulls				534,0	Max roughage DM pasture		
516	Min roughage dry matter for pasture period		Same as indoor	2,0	174,7		No second year pasture for bulls				174,7	Min roughage DM pasture		
517														
518	Min Quantity of calf concentrate			210										
519	Milk for calf (+raw milk)			250										

The slow growing bulls still can not be held on pasture for more than the first season, but would otherwise utilize the roughage feed resources somewhat better than the faster growing alternative. For better utilization of ample resources of pasture an alternative with castrates has been worked out in the lines 521–542 below.

	A	B	C	D	E	F	G	H	I	J	K	L	M	N
521	**F.6. CASTRATES, 2 PASTURE SEASONS**													
522	Age, months		**0**	**3**	**6**	**9**	**12**	**15**	**18**	**21**	**24**			
523	Age, days		0	91,26	183	274	365	456	548	639	730			
524	Growth, kg/day			0,6	0,6	0,6	0,5	0,6	0,6	0,5	0,8			
525	Weight, kg		42	97	152	206	252	307	361	407	480			
526	FEm/day		1,6	2,7	3	3,5	4	4,6	5,2	5,6	6,8			
527	AAT, g/day		200	290	300	325	350	400	440	450	550			
528	Sum FEm		0	194	450	743	1080	1467	1908	2394	2952	2183,3	Sum indoor FEm	
529	Sum AAT, g			22050	48600	76725	107100	140850	178650	218700	263700	196,0	Sum indoor kg protein	
530			Age, days	FEm/day	AAT/g da	Age, day	FEm/day	AAT/g day	Age, day	FEm/day	AAT/g day			
531	At pasture release		170	2,9	287,61	536	5,2	437,00	0	1,8	218,22	768,7	Sum pasture FEm	
532	At pasture end		259	3,4	323,94	625	5,8	473,33	0	1,8	218,22	67723,9	Sum pasture protein	
533	Difference/average		89	3,1	305,8	89	5,5	455,2	0	0	0			
534			Minimum	First year	Total for			Second ye	Total for					
535			share	Kg/day	the period			Kg/day	the period					
536	Max roughage dry matter, indoors			6	1656			9	2484			4140,0	Max roughage DM indoor	
537	Min roughage dry matter, indoors		0,5	1,8	493,7			3,1	854,0			1347,7	Min roughage DM indoor	
538	Max roughage dry matter for pasture period			6	534			11	979			1513,0	Max roughage DM pasture	
539	Min roughage dry matter for pasture period		0,5	1,6	146,0			2,9	254,4			400,4	Min roughage DMr pasture	
540														
541	Min Quantity of calf concentrate			210										
542	Milk for calf (+raw milk)			250										

Castrates can be kept on pastures for two seasons and can grow fairly well on medium or low quality pastures. However their weights at 24 months are not comparable to that of bulls and in some cases they may have to be kept for up to three years before slaughtered. Castrates are used in rather extensive cattle farming systems as they will require less concentrate feed than bulls and more land such as unfertilized pastures on forest land, mountainous or other outfield land.

8 Receipts from animal production

The gross margins for milking cows are calculated in the cells F551–F557 below. The income comes from milk, meat and governmental support and the recorded costs of different animal expenses and other items of use per animal are subtracted based on the recorded values. The amounts of cow's meat depend on the living weight of cows, slaughter percentage and replacement rate for the milking cows. The default slaughter percentage in cell J550 is 52 percent, i.e. the carcass weight of cows is 52 percent of live weight at slaughter. The premiums are calculated per cow and consist of a general premium per animal and a premium per animal for relief payments that are balanced with a requirement to hire labour in constraint 13. The sum of receipts in cell F557 is transferred to the objective function of process 21.

	A	B	C	D	E	F	G	H	I	J	K	L	M
548	**Part G. RECEIPTS FROM ANIMAL PRODUCTION**												
549													
550	**G.1. RECEIPTS FOR MILKING COWS**			January 1				Slaughter percent, co		0,52			
551		Milk Receipts per cow				25053				Marginal work h per cow			
552		Slaughtered (discarded) cows			100,1	3617				Total wo	Pasture h		
553		Other items of use				-1259		Hours per cow		47,0	7,6		
554		Different expences for animals				-2021							
555		Support for relief, marginal valu		1207		1207				Per	Indoor		
556		Support per animal, less than 1		3330		3330				month	period		
557		Sum recipts (objective function)				29927		Manure production, to		1,4	13,5		
558													
559													
560	**G.2. BABY CALVES 4-5 WEI**		Support Jan	Living	Price/kg					Work hours per calf			
561			1 or July 31	weight	liv. weight	Receipts				Indoors	Pasture period		
562		Sale of the calf		56,04	23,96	1342,8		Hours per calf		0,55	0,00		
563		Support per calf or	660			0,00							
564		Milk for feed				-267							
565		Sum recipts (objective function)				1075,7		Manure production, tons			0,1	Indoors all	
566													
567	**G.3. RECEIPTS FOR INTERMEDIATE CA**			Slaughter	Price								
568				Weight	per kg	Receipts							
569		Sale of intermediate calf		113,22	38,46	4354,4		Slaughter percent		0,51			
570		Support per calf on Jan 1 or July 31				0,00				Work hours per calf			
571		Support for relief, marginal valu		437		437				Total	Pasture season		
572		Extra support from marketing b		0		0		Hours intermediate ca		2,60	0,00		
573		Milk for feed				-3320							
574		Sum recipts (objective function)				1472		Manure production, tons			0,6	Indoors all	
575													
576	**G.4. RECEIPTS FOR HEIFERS (SUM FROM 0-24 MONTHS)**					Receipts							
577		Receipts for own production				0				Work hours per heifer			
578		Support per animal (Jan1), 2 years				1320				Total	Pasture season		
579		Insemination				-100		Heifer, 24 months		12,52	5,3		
580		Support for relief, 2years				874				Total 2 y	Indoors		
581		Milk for feed				-954		Manure production, to		16	12,0		
582		Sum recipts (objective function) apart from the animal valu				1140,1		6 tons first year and 10 tons the second year.					
583													
584				Slaughter	Price								
585	**G.5. RECEIPTS FOR 18 MONTHS OLD B**			weight	per kg	Receipts		Slaughter percent		0,52			
586		Sale of bull		308,2	24,50	7550				Work h/bull 18 months			
587		Support per animal (Jan1), marginal value.				660				Total	Pasture season		
588		Support for relief, marginal value				437		BULL 18MONTHS		9,5	3,6		
589		Milk for feed				-1240							
590		Sum recipts (objective function)				7407				Total 18	Indoors		
591								Manure production, ton			9,5		
592				Slaughter	Price			6 tons first year and 5 tons the second half year.					
593	**G.6. RECEIPTS FOR 24 MONTHS OLD B**			weight	per kg	Receipts							
594		Sale of bull		333,6	24,50	8172							
595		Support per animal (Jan1), marginal value.				1320		Slaughter percent		0,52			
596		Support for relief, marginal value				874				Work h/bull 24 months			
597		Milk for feed				-954				Total	Pasture season		
598		Sum recipts (objective function)				9412		BULL24MONTHS		10,6	3,6		
599													
600				Slaughter	Price			Manure production, ton			14,5	Indoor second year	
601	**G.6. RECEIPTS FROM CASTRATES, 24 M**			weight	per kg	Receipts		6 tons first year and 10 tons the second year.					
602		Sale of castrate		246,9	24,50	6047							
603		Support per animal (Jan1), marginal value.				1320		Slaughter percent		0,51			
604		Support for relief, marginal value				874				Work h/castrate 24 months			
605		Milk for feed				-954				Total	Pasture season		
606		Sum recipts (objective function)				7288		Castrate 24 months		12,52	5,3		
607								Manure production like heifers					

The marginal work requirement in number of h per cow is calculated in the cells J553–K553 for the indoor and pasture periods based on coefficients for marginal work requirement in C217 above and length of the indoor and grazing periods. Production of manure during the indoor period is calculated in K557. The model calculates number of months indoor and only the production of manure per month has to be specified.

Baby calves are sold alive at an age of 4–5 weeks. A governmental support premium will be paid out based on number of calves on January 1 and July 31, with half the rate for each date. The premium will only apply for baby calves born in December (or June). For intermediate calves the premium will be paid out unless they are born and sold between those dates. The meat marketing board may pay an extra premium for intermediate calves displayed in cell D572, however this is normally worked into the price. The costs of the milk used during the calf period, based on the amounts of milk fed and the milk price have to be subtracted. The net receipts are transferred to the objective function of the baby calf and intermediate calf processes. Based on the daily labour requirement and age the marginal work requirement is calculated in cell J562 for baby calves and in J572 for intermediate calves and transferred to the constraints 10 and 11 for the two processes.

Similar calculations have been conducted for heifers, bulls and castrates. Meat production by young cattle, bulls and castrates are depending on the weights at slaughtering and slaughter percentages. The numbers for heifers and castrates are quite similar whereas meat production for bulls depends on the intensity of the feeding. The figures for income from the different animal processes are transferred to the objective function for the processes of the LP tableau below. Manure production of has been calculated for each of the animals considered and is distributed on the indoor and pasture periods in accordance with the length of the grazing period.

9 Model calibration

In part H the meadow and pasture yield modification factor, freight and losses of concentrate, and labour efficiency have all been calibrated to the recorded farm average values for the years 1999, 2000 and 2001. The three years average will normally take out most of the year to year variation. In the calibration run the purchase of roughage feed is set equal to the recorded value, and the yield factor is determined so that average yields equals recorded averages. The calibration factor for costs of concentrates is increased when the LP-solution show less use of concentrate and a higher income than recorded. The number of animals older than one year to be slaughtered also has to be equal to or larger than the recorded numbers. Finally, the labour efficiency factor is altered so that the use of labour matches the recorded values for input of family and hired labour. As for the meadow replacement rate, the share of silage that is bailed and the number of times spreading fertilizer and cutting meadows have not been altered in the calibration, but determined on the basis of information from the farms or used standard values.

The average recorded values are shown in the lines 611–622 for column F, G and H while the same results of the calibration runs are reproduced in the columns J, K and L. The comparison is conducted for farm profit, farm area, roughage yields, purchases of concentrates and roughage, number of cows and other animals, and use of hired and family labour. The model values come fairly close to the recorded, however it is not possible nor necessary to have a 100 percent match, some discrepancies can be accepted.

The yields of leys and pastures are calibrated by multiplying the standard yield of each meadow and pasture process in the LP-tableau with the calibration parameter in line 622. For the farms shown here the model yields have become quite similar to the average yields using a calibration factor of 0.89, 1.03 and 1.19 for the three farms. The default or standard value of the meadow replacement rate in line 624 is 6 percent, resulting in about 16 years as average duration of life for the meadow. The rate has been kept for the three farms. The number of cuts of silage and the share of the silage that is bailed are based on info from the farms and have not been altered. In Northern Norway farmers usually cut the meadow one or two times during the summer, in lowland areas in southern Norway they may cut from three to five times. Farmers fertilize the meadow a month or so before each cutting. By selecting a higher number of cuts the number of h for fertilizing and grass harvesting is adjusted accordingly. Harvesting is worked out with either a traditional cutting or with bailing and the percentage used for bailing is displayed in line 626, based on information from the farm. It is possible to assume that farmers have 100 percent of the meadow made into bales of silage as this technique is becoming more dominant in recent years.

The number of cows in the model solution is slightly higher than the recorded numbers for the farms A and B and the number of slaughtered animals younger than one year is also higher on farm A and slaughtered animals older than 1 year is larger than the recorded on farm B. On farm C the number of cows and young cattle matched quite well. In order to balance the model use of concentrate to the recorded purchase of concentrates on the farms, between 40 and 80 percent has to be added for losses and freight, minerals etc. This calibration is shown in line 627. The quality of the roughage feed (determined in part E1) is assumed to be similar on all farms, and has not been altered in the model. Generally farmers have to buy more concentrates if the quality of the roughage feed is poorer than assumed.

The actual or recorded input of labour hours may be quite different from one farm to another, depending on efficiency. Labour use is calibrated in line 628 by multiplying with a coefficient of labour efficiency. The labour efficiency rate is lower than 1 for all farms, varying from 0.56 to 0.93. Presumably the efficiency of hired workers would vary as much as that of the farmers. Hiring of labour matched well on Farm A, but had to be lowered on Farm B and increased on Farm C to ensure that the labour requirement is in line with amount of time recorded.

	A	B	C	D	E	F	G	H	I	J	K	L
608	**Part H. Where some output from the LP is compared with the farm data to calibrate the model**											
609						**Average for 1999-2001**				Calibrated solutions		
610	**LP REPRO**			**FARMDATA**		**Farm A**	**Farm B**	**Farm C**		**Farm A**	**Farm B**	**Farm C**
611	244	**Cultivated area, decare**		**244**	673	**244**	**252**	**198**		244	252	198
612	25	**Pasture area, decare**		**25**	674	**25**	**-**	**-**		25	0	0
613	23	**Green Fodder area, decare**		**23**	675	**23**	**41**	**36**		23	41	36
614	265	**Recorded yield, FEm/decare**		**263**	676	**263**	**269**	**379**		265	269	381
615	639	**Hired labor, h**		**639**	677	**639**	**1 340**	**425**		639	938	510
616	2452	**Family labor, h**		**2467**	678	**2 467**	**2 439**	**3 000**		2452	2439	2990
617	14,5	**Cows, animal years**		**13,5**	679	**13,5**	**13,2**	**18,5**		14,5	14,1	18,8
618	6,7	**Animals >1 year slaughtered**		**6,7**	680	**6,7**	**7,3**	**9,0**		6,7	9,2	9,0
619	2,7	**Animals <1 year slaughtered**		**1,0**	681	**1,0**	**1,0**	**3,0**		2,7	0,0	3,2
620	-11414	**Purchase of roughage**		**11414**	682	**11 414**	**25 348**	**21 847**		-11414	-25348	-21847
621	155001	**Purchase of concentrate**		**158717**	683	**158 717**	**122 041**	**171 481**		155001	123526	168086
622	118853	**Farm profit**		**124259**	684	**124 259**	**3 435**	**264 860**		118853	2494	227957
623		Yield modification factor for farn		**0,86**	685	0,86	1,03	1,20	Modified value			
624		Normal replacement rate for ma		**0,06**	686	0,06	0,06	0,06	Standard value			
625		Number of times spreading ferti		**2,00**	687	2	2	1	Based on info from the farms			
626		Share of silage that is bailed (1=		**0,20**	688	0,20	0,40	0,06	Based on info from the farms			
627		Concentrate, losses and freight		**1,80**	689	1,80	1,50	1,40	Modified value			
628		Labor Efficiency depending on f		**0,56**	690	0,56	0,76	0,93	Modified value			

With these changes the recorded farm profit is somewhat higher than in the model. This may be due to e.g. other farm incomes (minor), but these issues have not been considered.

10 Stochastic variables

The following eight variables have been made stochastic: Greenfodder area, Fodder yield, Milk per cow, Leys yield, Interest costs, Milk price, Meat price, Fuel costs and the prices for concentrates. The data for the stochastic variables for the period are displayed in the cells C638–J652 below.

	A	B	C	D	E	F	G	H	I	J	K	L	M	N
634				Farm										
635	**I.1. THE HISTORY OF THE RANDOM VAF**			1										
636		Farm A												
637		**farm**	Greenfodde	Fodder Yield	Milk/cow KG	Leys Yield K	Interest C	Meat Price	Milk Price	Fuel Cos	Rum. conc	Rum con	Ruminant	Calf feed
638		**1991**	**20,0**	**175,5**	**6 485,8**	**245,5**	**0,050**	**47,873**	**4,784**	**5,00**	**367**	**361**	**572**	**405**
639		**1992**	**10,0**	**85,8**	**6 641,1**	**237,1**	**0,050**	**46,067**	**4,642**	**5,20**	**328**	**325**	**422**	**322**
640		**1993**	**23,0**	**199,1**	**6 535,9**	**294,6**	**0,050**	**41,893**	**4,447**	**5,30**	**321**	**322**	**405**	**318**
641		**1994**	**7,0**	**171,4**	**5 890,4**	**286,1**	**0,080**	**48,609**	**4,593**	**5,40**	**307**	**311**	**392**	**309**
642		**1995**	**100,0**	**133,0**	**6 477,8**	**354,2**	**0,070**	**35,875**	**4,486**	**5,60**	**279**	**287**	**317**	**289**
643		**1996**	**40,0**	**245,0**	**6 562,5**	**238,5**	**0,065**	**43,914**	**4,333**	**5,80**	**275**	**279**	**310**	**303**
644		**1997**	**40,0**	**245,0**	**6 198,4**	**232,3**	**0,060**	**37,416**	**4,256**	**6,00**	**275**	**278**	**295**	**300**
645		**1998**	**45,0**	**248,9**	**6 565,9**	**223,3**	**0,065**	**36,027**	**4,416**	**6,20**	**270**	**273**	**285**	**295**
646		**1999**	**45,0**	**155,6**	**6 675,7**	**284,2**	**0,070**	**37,817**	**4,355**	**6,40**	**266**	**270**	**339**	**290**
647		**2000**	**25,0**	**196,0**	**6 789,6**	**351,4**	**0,070**	**24,534**	**4,316**	**6,20**	**272**	**268**	**308**	**295**
648		**2001**	**10,0**	**175,5**	**7 170,7**	**276,2**	**0,070**	**24,998**	**4,314**	**6,10**	**237**	**274**	**312**	**297**
649		**2002**	**20,0**	**85,8**	**7 060,4**	**340,5**	**0,070**	**27,871**	**4,700**	**6,00**	**240**	**288**	**318**	**299**
650		**2003**	**20,0**	**245,0**	**7 176,1**	**275,9**	**0,050**	**36,318**	**4,114**	**6,20**	**242**	**278**	**315**	**306**
651		**2004**	**45,0**	**196,0**	**6 307,3**	**307,9**	**0,040**	**27,976**	**4,407**	**6,30**	**242**	**272**	**309**	**296**
652		**2005**	**23,0**	**155,6**	**7 515,3**	**298,9**	**0,030**	**28,435**	**3,735**	**7,30**	**236**	**275**	**321**	**299**
653		**Year of Forecast for Yields**												
654		**2009**												
655		**Standard no. Hec**	7,0											
656			Greenfodde	Fodder Yield	Milk/cow KG	Leys Yield K	Interest C	Meat Price	Milk Price	Fuel Cos	Rum. conc	Rum con	Ruminant	Calf feed
657		**Means**	31,5	180,9	6670,2	283,1	0,1	36,4	4,4	5,9	277,1	290,7	348,0	308,2
658														
659	**I.2. CALCULATING TRENDS IN HISTORIC VARIABLES**													
660			Greenfodde	Fodder Yield	Milk/cow KG	Leys Yield K	Interest C	Meat Price	Milk Price	Fuel Cos	Rum. conc	Rum con	Ruminant	Calf feed
661		**Intercept**	224,19762	-2305,7621	-108177,103	-6615,444	1,62919	3079,285	78,89554	-224,55	16239,73	9574,3	22868,3	7443,91
662		**Slope**	-0,0964286	1,2445642	57,4811278	3,45272559	-0,00079	-1,52298	-0,03729	0,11536	-7,989286	-4,6464	-11,271	-3,57143
663		**R-Square**	0,0003475	0,0109653	0,37577277	0,129393	0,065394	0,689285	0,428423	0,7939	0,85743	0,59716	0,46057	0,31751
664		**F-Ratio**	0,0045194	0,144129	7,82574973	1,93211067	0,909599	28,83904	9,744093	50,0761	78,18297	19,2708	11,0995	6,04777
665		**Prob(F)**	0,9474243	0,7103397	0,01510314	0,18787088	0,357619	0,000127	0,008103	8,3E-06	7,35E-07	0,00073	0,00541	0,02871
666		**S.E.**	1,4343825	3,2782465	20,5476568	2,48396839	0,000824	0,283598	0,011945	0,0163	0,903549	1,05845	3,38319	1,45226
667		**T-Test**	-0,0672265	0,3796433	2,79745415	1,39000384	-0,95373	-5,3702	-3,12155	7,07644	-8,842113	-4,3899	-3,3316	-2,45922
668		**Prob(T)**	0,947352	0,7099069	0,01425155	0,18623442	0,356399	9,88E-05	0,007504	5,5E-06	4,19E-07	0,00062	0,00494	0,02755

It is possible to have more (or fewer) stochastic variables following the same principles as shown here. For each variable the means and standard deviation in the period has been calculated below followed by intercept, slope and R-square and F-ratio of a linear trend curve for each variable. For green fodder area also the minimum value has been calculated. Next follows calculation of output for an empirical distribution of 15 observations as percent deviation from mean for the stochastic variables:

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
670	**I.3. OUTPUT FOR EMPIRICAL DISTRIBUTION WITH 15 OBSERVATIONS AS PERCENT DEVIATIONS FROM MEAN**														
671	**1**		Output for Empirical Distributions with 15 Observations as Percent Deviations from Mean												
672	**2**		Unsorted Deviations from Mean												
673	**3**		Obs.	Greenfodder	Fodder Yield	Milk/cow KG	Leys Yield	Interest Co	Meat Price	Milk Price	Fuel Cost	Rum. con	Rum conc	Ruminant	Calf feed
674	**4**		1	-11,5	-5,4	-184,4	-37,6	-0,009	11,499	0,391	-0,93	89,8667	70,2667	224	96,8
675	**5**		2	-21,5	-95,1	-29,1	-46,0	-0,009	9,692	0,249	-0,73	50,8667	34,2667	74	13,8
676	**6**		3	-8,5	18,3	-134,3	11,5	-0,009	5,518	0,054	-0,63	43,8667	31,2667	57	9,8
677	**7**		4	-24,5	-9,4	-779,8	3,0	0,021	12,234	0,199	-0,53	29,8667	20,2667	44	0,8
678	**8**		5	68,5	-47,9	-192,4	71,1	0,011	-0,500	0,093	-0,33	1,86667	-3,7333	-31	-19,2
679	**9**		6	8,5	64,1	-107,7	-44,6	0,006	7,540	-0,061	-0,13	-2,1333	-11,733	-38	-5,2
680	**10**		7	8,5	64,1	-471,8	-50,8	0,001	1,041	-0,137	0,07	-2,1333	-12,733	-53	-8,2
681	**11**		8	13,5	68,0	-104,3	-59,8	0,006	-0,348	0,022	0,27	-7,1333	-17,733	-63	-13,2
682	**12**		9	13,5	-25,3	5,5	1,1	0,011	1,442	-0,038	0,47	-11,133	-20,733	-9	-18,2
683	**13**		10	-6,5	15,1	119,4	68,3	0,011	-11,841	-0,078	0,27	-5,1333	-22,733	-40	-13,2
684	**14**		11	-21,5	-5,4	500,5	-6,9	0,011	-11,377	-0,080	0,17	-40,133	-16,733	-36	-11,2
685	**15**		12	-11,5	-95,1	390,2	57,4	0,011	-8,504	0,307	0,07	-37,133	-2,7333	-30	-9,2
686	**16**		13	-11,5	64,1	505,9	-7,2	-0,009	-0,057	-0,279	0,27	-35,133	-12,733	-33	-2,2
687	**17**		14	13,5	15,1	-362,9	24,8	-0,019	-8,399	0,014	0,37	-35,133	-18,733	-39	-12,2
688	**18**		15	-8,5	-25,3	845,1	15,8	-0,029	-7,939	-0,658	1,37	-41,133	-15,733	-27	-9,2
689	**19**		Mean	31,5	180,9	6 670,2	283,1	0,059	36,375	4,393	5,93	277,133	290,733	348	308,2
690	**20**		St.Dev.	22,348353	51,3500534	405,1315	41,47057	0,013275	7,925516	0,24613	0,559365	37,2771	25,9781	71,757	27,3842
691	**21**		C.V.	70,872156	28,3894456	6,0737622	14,64865	22,37338	21,78844	5,60261	9,427495	13,451	8,93537	20,6198	8,8852
692	**22**		Autocorrelat	0,0088446	-0,06981596	0,17653779	0,103309	0,620481	0,619154	0,07425	0,858064	0,93656	0,92266	0,84214	0,72661
693	**23**														
694	**24**		Unsorted Deviations from Mean as a Percent of Mean												
695	**25**		Obs.	Greenfodder	Fodder Yield	Milk/cow KG	Leys Yield	Interest Co	Meat Price	Milk Price	Fuel Cost	Rum. con	Rum conc	Ruminant	Calf feed
696	**26**		1	-0,3657505	-0,02972882	-0,027638	-0,13277	-0,1573	0,316112	0,08907	-0,157303	0,32427	0,24169	0,64368	0,31408
697	**27**		2	-0,6828753	-0,5256452	-0,0043572	-0,16254	-0,1573	0,266444	0,05657	-0,123596	0,18355	0,11786	0,21264	0,04478
698	**28**		3	-0,2706131	0,10091466	-0,0201393	0,040692	-0,1573	0,151703	0,0123	-0,106742	0,15829	0,10754	0,16379	0,0318
699	**29**		4	-0,7780127	-0,05223816	-0,1169104	0,010554	0,348315	0,336342	0,0454	-0,089888	0,10777	0,06971	0,12644	0,0026
700	**30**		5	2,1712474	-0,26469477	-0,028849	0,251031	0,179775	-0,01375	0,02117	-0,05618	0,00674	-0,0128	-0,08908	-0,0623
701	**31**		6	0,2684989	0,35450963	-0,0161391	-0,15764	0,095506	0,207274	-0,0138	-0,022472	-0,0077	-0,0404	-0,1092	-0,0169
702	**32**		7	0,2684989	0,35450963	-0,0707298	-0,17949	0,011236	0,028628	-0,0312	0,011236	-0,0077	-0,0438	-0,1523	-0,0266
703	**33**		8	0,4270613	0,37600978	-0,0156354	-0,21139	0,095506	-0,00956	0,00511	0,044944	-0,0257	-0,061	-0,18103	-0,0428
704	**34**		9	0,4270613	-0,13999389	0,00082028	0,003883	0,179775	0,03964	-0,0086	0,078652	-0,0402	-0,0713	-0,02586	-0,0591
705	**35**		10	-0,2071882	0,0836077	0,01790559	0,241093	0,179775	-0,32552	-0,0177	0,044944	-0,0185	-0,0782	-0,11494	-0,0428
706	**36**		11	-0,6828753	-0,02972882	0,07503179	-0,02434	0,179775	-0,31278	-0,0181	0,02809	-0,1448	-0,0576	-0,10345	-0,0363
707	**37**		12	-0,3657505	-0,5256452	0,05849568	0,202806	0,179775	-0,23379	0,0699	0,011236	-0,134	-0,0094	-0,08621	-0,0299
708	**38**		13	-0,3657505	0,35450963	0,07585071	-0,02532	-0,1573	-0,00157	-0,0635	0,044944	-0,1268	-0,0438	-0,09483	-0,0071
709	**39**		14	0,4270613	0,0836077	-0,0544072	0,087475	-0,32584	-0,2309	0,00324	0,061798	-0,1268	-0,0644	-0,11207	-0,0396
710	**40**		15	-0,2706131	-0,13999389	0,12670135	0,055965	-0,49438	-0,21827	-0,1498	0,230337	-0,1484	-0,0541	-0,07759	-0,0299
711	**41**														
712	**42**		Correlation Matrix												
713	**43**			Greenfodder	Fodder Yield	Milk/cow KG	Leys Yield	Interest Co	Meat Price	Milk Price	Fuel Cost	Rum. con	Rum conc	Ruminant	Calf feed
714	**44**		Greenfodder	1	0,07911255	-0,2236431	0,276262	0,125916	-0,09774	-0,0366	0,083372	-0,1428	-0,3128	-0,33827	-0,3262
715	**45**		Fodder Yield		1	-0,1888478	-0,43006	-0,04652	0,045347	-0,381	0,164932	-0,1198	-0,301	-0,28233	-0,0662
716	**46**		Milk/cow KG			1	0,21276	-0,34835	-0,58059	-0,5505	0,592562	-0,5326	-0,3124	-0,23779	-0,1564
717	**47**		Leys Yield KG				1	0,153641	-0,55414	-0,0342	0,209988	-0,3385	-0,2518	-0,23415	-0,3457
718	**48**		Interest Cost					1	0,071282	0,43185	-0,284306	0,01028	-0,1532	-0,19001	-0,2656
719	**49**		Meat Price						1	0,45368	-0,716019	0,80283	0,71325	0,64598	0,54937
720	**50**		Milk Price							1	-0,830012	0,62171	0,62702	0,55371	0,47108
721	**51**		Fuel Cost								1	-0,836	-0,8009	-0,68214	-0,5928
722	**52**		Rum. concentrate, 97 H (93 FEm/100 kg 9,7%Prot)									1	0,90043	0,8673	0,77636
723	**53**		Rum concentrate, 105 Low (100 fem/kg10,5%prot)										1	0,95341	0,87714
724	**54**		Ruminant concentrate, 105 Extra High Elite pellets first years)											1	0,93384
725	**55**		Calf feed												1
726	**56**														
727	**57**		Sorted Deviations from Mean as a Percent of Mean												
728	**58**		F(x)	Greenfodder	Fodder Yield	Milk/cow KG	Leys Yield	Interest Co	Meat Price	Milk Price	Fuel Cost	Rum. con	Rum conc	Ruminant	Calf feed
729	**59**		0	-0,7780905	-0,52569776	-0,1169221	-0,21141	-0,49443	-0,32555	-0,1499	-0,157319	-0,1484	-0,0782	-0,18105	-0,0623
730	**60**		0,0333333	-0,7780127	-0,5256452	-0,1169104	-0,21139	-0,49438	-0,32552	-0,1498	-0,157303	-0,1484	-0,0782	-0,18103	-0,0623
731	**61**		0,1	-0,6828753	-0,5256452	-0,0707298	-0,17949	-0,32584	-0,31278	-0,0635	-0,123596	-0,1448	-0,0713	-0,1523	-0,0591
732	**62**		0,1666667	-0,6828753	-0,26469477	-0,0544072	-0,16254	-0,1573	-0,23379	-0,0312	-0,106742	-0,134	-0,0644	-0,11494	-0,0428
733	**63**		0,2333333	-0,3657505	-0,13999389	-0,028849	-0,15764	-0,1573	-0,2309	-0,0181	-0,089888	-0,1268	-0,061	-0,11207	-0,0428
734	**64**		0,3	-0,3657505	-0,13999389	-0,027638	-0,13277	-0,1573	-0,21827	-0,0177	-0,05618	-0,1268	-0,0576	-0,1092	-0,0396
735	**65**		0,3666667	-0,3657505	-0,05223816	-0,0201393	-0,02532	-0,1573	-0,01375	-0,0138	-0,022472	-0,0402	-0,0541	-0,10345	-0,0363
736	**66**		0,4333333	-0,2706131	-0,02972882	-0,0161391	-0,02434	0,011236	-0,00956	-0,0086	0,011236	-0,0257	-0,0438	-0,09483	-0,0299
737	**67**		0,5	-0,2706131	-0,02972882	-0,0156354	0,003883	0,095506	-0,00157	0,00324	0,011236	-0,0185	-0,0438	-0,08908	-0,0299
738	**68**		0,5666667	-0,2071882	0,0836077	-0,0043572	0,010554	0,095506	0,028628	0,00511	0,02809	-0,0077	-0,0404	-0,08621	-0,0266
739	**69**		0,6333333	0,2684989	0,0836077	0,00082028	0,040692	0,179775	0,03964	0,0123	0,044944	-0,0077	-0,0128	-0,07759	-0,0169
740	**70**		0,7	0,2684989	0,10091466	0,01790559	0,055965	0,179775	0,151703	0,02117	0,044944	0,00674	-0,0094	-0,02586	-0,0071
741	**71**		0,7666667	0,4270613	0,35450963	0,05849568	0,087475	0,179775	0,207274	0,0454	0,044944	0,10777	0,06971	0,12644	0,0026
742	**72**		0,8333333	0,4270613	0,35450963	0,07503179	0,202806	0,179775	0,266444	0,05657	0,061798	0,15829	0,10754	0,16379	0,0318
743	**73**		0,9	0,4270613	0,35450963	0,07585071	0,241093	0,179775	0,316112	0,0699	0,078652	0,18355	0,11786	0,21264	0,04478
744	**74**		0,9666666	2,1712474	0,37600978	0,12670135	0,251031	0,348315	0,336342	0,08907	0,230337	0,32427	0,24169	0,64368	0,31408
745	**75**		1	2,1714645	0,37604738	0,12671402	0,251056	0,348349	0,336376	0,08907	0,23036	0,3243	0,24171	0,64374	0,31411

This calculation starts with the unsorted deviations from the mean of each of the variables, e.g. in year 1 fodder area is 20 and the mean for the period is 31.5 and the deviate is -11.5 (displayed in the cell D674). The percent deviations are then calculated in the cells D696–O710 and the correlation matrix between the percent deviations is calculated in the cells D714–O725. The percent deviates are further sorted in intervals in the cells D729–O745.

The correlation matrix can be factored and the factored matrix multiplied with a vector of Independent Standard Normal Deviates (ISNDs) calculated in Simetar by using the NORM function. The product of the multiplication is the Correlated Standard Normal Deviates CSNDs. The CSNDs above are then made into Correlated Uniform Standard Deviations (CUSDs) by using the NORMSDISTRIBUTION function of Excel which returns a standard cumulative normal distribution with an average of 0 and a standard deviation of 1. In line 750 these operations are conducted directly using the CUSD function in Simetar.

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
748	I.4. FACTOR THE CORRELATION MATRIX AND MULTIPLY IT WITH ISNDs TO PRODUCE THE CSNDs AND CUSDs.														
749				Greenfodde	Fodder Yield	Milk/cow KG	Leys Yield	Interest C	Meat Pric	Milk Pric	Fuel Cost	Rum. co	Rum con	Ruminant	Calf feed
750		NEW CUSD() Cnt	CUSDs No.	0,3200129	0,05011761	0,93170765	0,997619	0,801203	0,124983	0,46601	0,474878	0,3822	0,53373	0,65825	0,38062
751			% Deviates No. 1	-0,366	-0,526	0,100	0,251	0,180	-0,283	-0,003	0,011	-0,037	-0,042	-0,058	-0,035
752				Average	Average	Average	Average	NILF	NILF	NILF	NILF	NILF	NILF	NILF	NILF
753		Forecast of Means for 2009		31,53	180,88	6670,19	283,10	0,07	36,37	4,39	5,93	277,13	290,73	348,00	308,20
754			Stoch value	20,0	85,8	7337,4	354,2	0,083	26,074	4,381	6,000	266,932	278,506	327,728	297,418
755															
756															
757															
758															
759															
760	I.5. THE STOCHASTIC VALUES TO GO TO THE CALCULATIONS OR DIRECTLY TO THE LP														
761		Conversion Coefficients		NO. 1											
762		Yield of harvested Leys fed		1,15	=$D$620*(1+G751)										
763		Yield of Leys grazed by catt		1,15	=$D$620*(1+G751)										
764		Yield of green fodder, mult		0,44	=$D$620*(1+E751)										
765															
766		Interest Cost		62 779	=$D$22*(H754/H753)										
767		Fixed Cost		209 554	=$D$20+D766										
768		Fuel Price		6,10	=$D$69*(K754/K753)										
769		Milk Price		3,793	=$D$28*(J754/J753)										
770		Milk/Cow		7337,4	=F754										
771		Meat Price		23,396	=$D$29*($I$754/$I$753)										
772		Percentage Change in Meat P		0,7168	=I754/I753										
773		Green Fodder area restored		13,0	=MAX(0,D754-$C$655)										

It is then possible to calculate empirical percent deviations of the CUSDs by using the empirical (EMP) function in Simetar for each of the CUSDs. This is done in the cells D751–O751, i.e. to calculate the percent deviation for fodder yield in cell E751 we use the sorted fodder yield percent deviations (in E729–E745) and the CUSD for fodder yield (in E750) to arrive at a stochastic value of -0.526 in this example. When this percentage value is added to the trend value 180.88 we arrive at a stochastic value of 85.8 for fodder yield. The stochastic values for each stochastic variable are reproduced in the box in the cells D754–O754. The stochastic values are calculated below and transferred to the LP matrix or for use elsewhere in the model before entering the LP.

11 The LP-matrix

The layout below shows the LP-tableau. There are 28 constraints and 30 processes in the model. The farm profit is calculated in cell C785. Constraint 1 and 2 are equalities meaning that all the farm area has to be utilized while the other processes are inequalities that normally have to be less than a certain value, quite often zero.

The stochastic values in the LP-matrix are coloured in turquoise. The selection of stochastic variables is related to areas where we think are or will become important that is yields, energy, feed costs, interests. Perhaps if one more variable should have been stochastic it would be costs of fertilizers since they are also related to energy costs.

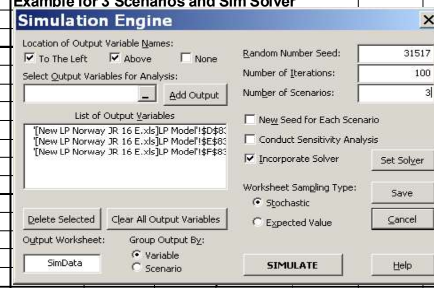
	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q
779	**Part J. The LP Model**																
780																	
781		**MODEL FOR MILK AND MEATPRODUCTION IN NORTHERN-NORW**					**2009**										
782		Process contributi	0	0	-49834	-3924	-849	0	0	-8809	-3431	-1923	0	93060	0	-87743	0
783		Process size	0,0	0,0	154,9	10,9	2,1	0,0	0,0	15,0	10,8	4,2	0,0	198,0	0,0	549,0	0,0
784		Process no.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
785		Maximize Farm Pr	**367729**														
786																	
787			Silage from all cuts		Silage and pasture		Hay+pastu	E. autumn	Spring replacement		Green fodder for		Permn.	Landscape support		Purchage of	
788			manure	no manure	manure	no manure	manure	replaceme	manure	no manu	pasturing	indoor fee	pasture	0-199	gt 199	sil.bale	hay
789		Constraint ?Object	-344	-364	-322	-359	-395	-796	-849	-587	-316	-463	-223	470	220	-159,83	-355
790	1	Cultivated area	1	1	1	1	1	1	1	1	1	1					
791	2	Pasture land											1				
792	3	Norm replacement	0,06	0,06	0,06	0,06	0,06	-1	-1	-1							
793	4	MeadowRepl/greenfBalance						-1	-1	-1	1	1					
794	5	Restoring area							1	1	1	1					
795	6	Animal manure, to	-5,0		-3,0		-3,0	-4,0	-5,0		-5,0	-5,0					
796	7	Landscape suppor	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-0,7	1	1		
797	8	Max landscape support 1												1			
798	9	Max landscape support 2													1		
799	10	Work requirment s	2,0	1,5	1,2	0,9	3,3	2,6	2,4	1,9	1,8	1,8	0,0			0,27	
800	11	Total work req. far	2,0	1,5	1,2	0,9	3,3	2,6	2,4	1,9	1,8	1,8	0,0			0,27	
801	12	Hired labour maximum															
802	13	Minimum hired labour															
803	14	Energy req indoors	-482,9	-482,9	-324,6	-324,6	-262,9	-268,3	-279,4	-279,4		-344,6				-135	-100
804	15	Protein requirm. in	-42,5	-42,5	-28,2	-28,2	-23,9	-23,3	-26,5	-26,5		-32,7				-11,9	-9,10
805	16	Max dry matter inn	596,2	596,2	386,4	386,4	345,9	319,4	399,1	399,1		492,3				166,7	131,6
806	17	Min dry matter inn	-596,2	-596,2	-386,4	-386,4	-345,9	-319,4	-399,1	-399,1		-492,3				-166,7	-131,579
807	18	Dietfeed hay/straw calves					-262,9										-100
808	19	Min concentrate calves															
809	20	Energy req pasture, FEm			-59,6	-59,6	-65,6				-443,1		-372,6				
810	21	Protein requirm. Pasture			-5	-5	-5				-36,8		-30,9				
811	22	Max dry matter pasture			64,1	64,1	70,5				476,4		400,7				
812	23	Min dry matter pasture			-64,1	-64,1	-70,5				-476,4		-400,7				
813	24	Max low fiber pasture									443,1						
814	25	Min replacement rate															
815	26	Number of calves/cow															
816	27	Number bulls/castrates															
817	28	Milk quota kg															

	R	S	T	U	V	W	X	Y	Z	AA	AB	AC	AD	AE	AF	AG	AH
779																	
780																	
781																	
782	-8611	-25539	0	-2101	-16827	646180	6649	0	0	0	51883	0	34818	-55465	-199806		
783	25,1	57,7	0,0	5,5	40,2	18,4	6,4	0,0	0,0	0,0	9,4	0,0	2,6	496,6	1,0		
784	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30		
785																	
786																	
787	Concent. indoor		Concent. pasture		Calf	Milk	Replm.	Calf	Calf	Bull	Bull	Castrate	Selling	Hired	Fixed	Right hand	
788	Nr. 97	Nr. 140	Nr. 97	Nr. 105	concent.	cows	heifer	4-5 wks	5 mnts	18 mnts	24 mnts	2 years	heifer	work	costs	side	
789	-342	-442	-342	-382	-419	35164	1034	248	-1115	4883	5536	4392	13534	-112	-199806		Coinstraint
790																198,0	Cultivated area,chng
791																0,0	Pasture land
792																0	Norm replacem. bala
793																0	MeadowRepl/greenf
794																36	Restoring area
795						15,3	13,7	0,1	0,6	10,2	15,2	13,7	13,7			0	Animal manure, tons
796																0	Landscape support
797																200	Max landscape supp
798																200	Max landscape supp
799						3,5	2,5	0,0	0	1,5	1,7	2,5	2,5	-1	208	312	Work requirment su
800						45,0	10,0	0,5	2,4	8,0	8,9	10,0	10,0	-1	2111	3000,0	Total work req. famil
801														1		717,0	Hired labour maximu
802						10,8	7,8		3,9	7,8	7,8	7,8	7,8	-1	154	0	Minimum hired labou
803	-93	-95			-96	5016,2	2504,6	7	285	2553,4	3554,2	2442,7	2504,6			0	Energy req indoors,
804	-9,0	-13,3			-9,0	463,4	235,2	0,3	3,2	234,4	306,3	220,5	235,2			0	Protein requirm. indo
805						-3280	-4396	-3,9	-46,1	-3527,0	-5534,0	-4710,0	-4396			0	Max dry matter inndo
806						2477	1546	3,9	46,1	945,7	2453,3	1507,9	1546			0	Min dry matter inndo
807							25	3	35	25	25	25	25			0	Dietfeed hay/straw c
808					-96		210	4	250	210	210	210	210			0	Min concentrate calv
809			-93	-100		284,4	547,7			298,1	241,8	509,3	547,7			0	Energy req pasture,
810			-9,0	-10,5		22,7	49,5			26,6	21,3	43,2	49,5			0	Protein requirm. Pas
811						-380,0	-765			-306,0	-306,0	-867,0	-765			0	Max dry matter pastu
812						118,5	285			93,2	97,0	265,3	285			0	Min dry matter pastu
813						-175	-96,5			-52,5	-42,6	-89,8	-96,5			0	Max low fibre pastur
814						0,35	-1									0	Min replacement rat
815						-1,00	1	1	1	1	1	1	1			0	Number of calves/co
816						-0,51			1	1	1	1				0	Number bulls/castra
817						7303,8	-250	-70	-870	-325	-250	-250	-250			101436	Milk quota kg

12 The Key Output Variables

The key output variables (KOVs) or summary variables of the LP model are reproduced below together with two other alternatives called Base and Stoch. Basically the Base do a stochastic simulation using the data from the farm accounts while the Stoch uses the LP output from a deterministic run for a stochastic simulation. The Base and Stoch outputs are developed elsewhere in the sheet and not explained in this paper.

	A	B	C	D	E	F	G	H
833	K.1 STANDARD LP VALUES							
834				Base	LP Plan	Stoch		Put Simetar in Expected Value
835	1	Farm Profit	Profit	225 919,6	133 934,3	165 105,7		Solve the LP and Keep the solution
836		Cows	Cows	16,0	14,1	14,1		Simulate 100 iterations with 3 columns of KOVs
837		Milk Production	Milkp Prod	105 054,4	92 869,0	92 869,0		Activate Incorporate Solver
838		Meat production	Meat Prod	4 746,7	3 822,2	4 199,7		
839		Roughage Produ	Rough Proc	52 778,7	65 089,4	69 630,5		Example for 3 Scenarios and Sim Solver
840	2	PurchRough	PurchRoug	67 500,0	33 611,8	33 611,8		
841	3	PurchConcentrat	Purch Conc	19 413,3	20 035,8	20 035,8		
842	4	Milk production p	Milk/Cow	6 565,9	6 565,9	6 565,9		
843		Milk Price	Milk Price	4,4	4,4	4,4		
844		Meat Price	Meat Price	36,3	36,3	36,3		
845		Concentrate 97	Concent Pr	272,0	272,0	272,0		
846	5	Fodder Yield	Fodder Yiel	175,5	175,5	175,5		
847		Greenfodder	Greenfodde	23,0	23,0	23,0		
848		Ley Yield	Ley Yield	284,2	284,2	284,2		
849		Roughage Yield	Rough Yiel	119,7	139,7	149,4		
850	10	Green Fod Area	GFod Area	23,0	23,0	23,0		
851	11	Roughage Area	Rough DA	441,1	466,0	466,0		
852	12	Ley area	Ley Area	165,0	215,2	215,2		
853	13	Ley Replacement	Ley Replac	56,1	50,8	50,8		
854	14	Perm.Past	Perm.Past	25,0	25,0	25,0		



Generally the numbers are developed from the processes in the LP solution like purchase of concentrate that is a summary of the use of the different feed ingredients, or they are the numbers used in calculating the objective function of the LP like the milk price.

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