

No milk without meat: Dynamic implications of the biological link between milk and bovine meat production on nutrition guidelines

Supplementary material – technical documentation

1 MODEL STRUCTURE.....2

2 MODEL EQUATIONS4

3 REFERENCES12

1 Model structure

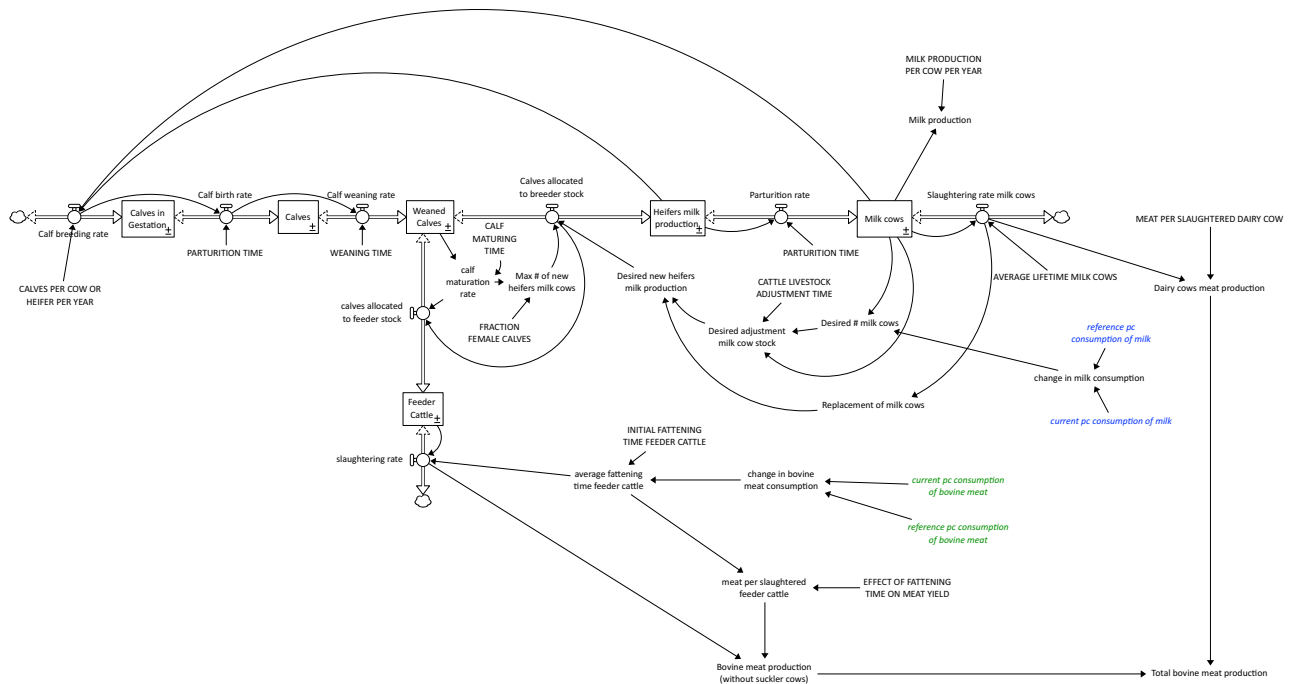


Figure A-1: Structure of the model: Main herd structure with milk and bovine meat production

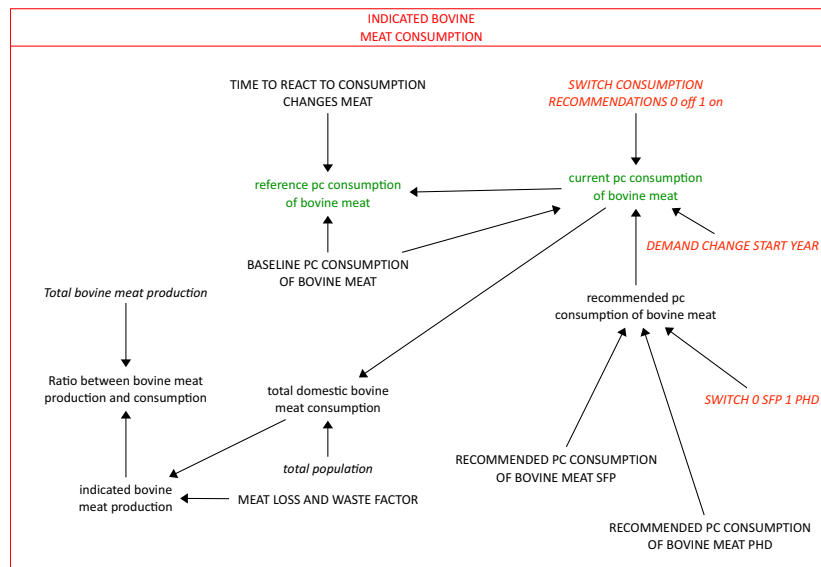


Figure A-2: Structure of the model: Meat demand

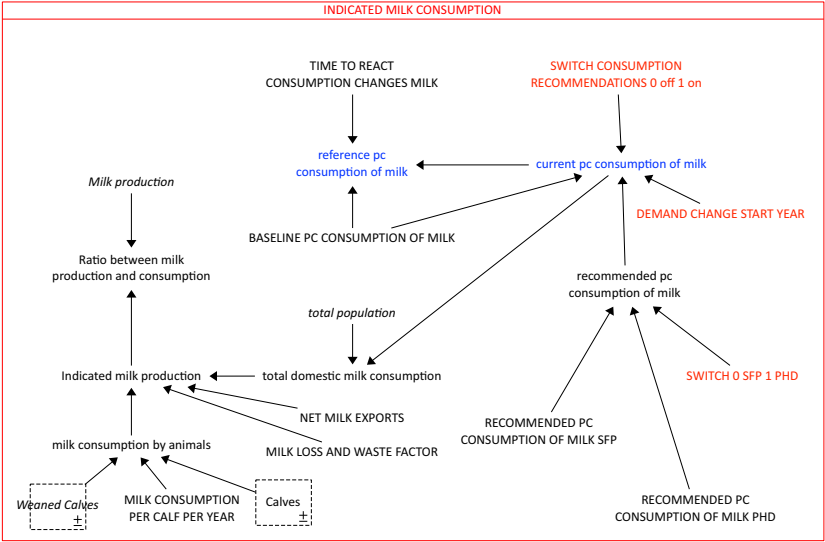


Figure A-3: Structure of the model: Milk demand

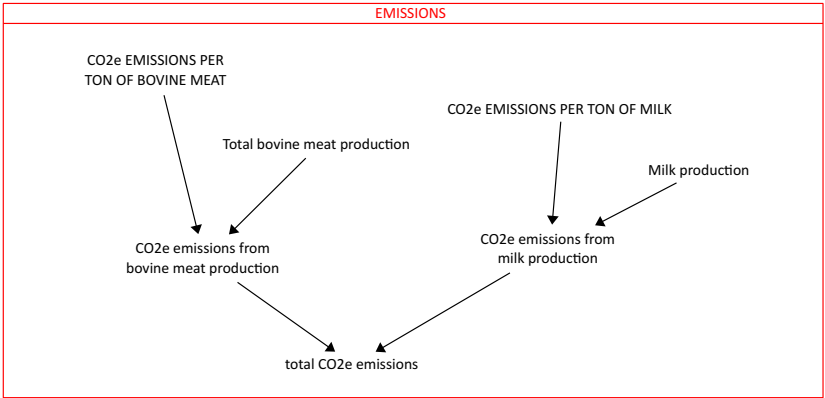


Figure A-4: Structure of the model: Emissions

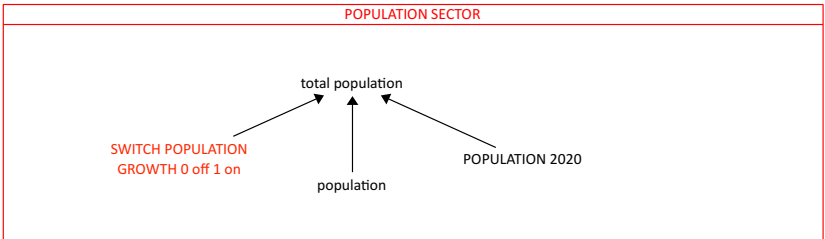


Figure A-5: Structure of the model: Population

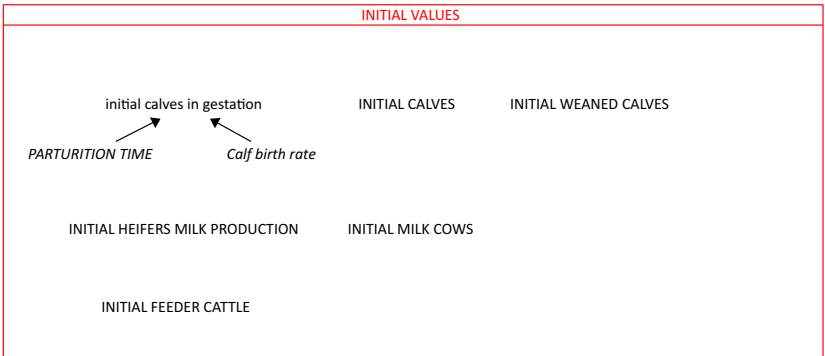


Figure A-6: Structure of the model: Initial values

2 Model equations

Table A.1 List of Model Equations – Stocks

Where to find	Variable Name	Equation	Units	Interpretation	Initial
Herd structure	Calves	$\text{Calves}(t) = \text{Calves}(t - dt) + (\text{Calf_birth_rate} - \text{Calf_weaning_rate}) * dt$	animal	This is a stock variable that calculates the number of calves at each point in time based on the initial value of calves plus the integrated difference between calf birth rate and calf weaning rate over time.	INITIAL_CALVES
Herd structure	Calves in Gestation	$\text{Calves_in_Gestation}(t) = \text{Calves_in_Gestation}(t - dt) + (\text{Calf_breeding_rate} - \text{Calf_birth_rate}) * dt$	animal	This is a stock variable that calculates the calves in gestation at each point in time based on the initial value of calves in gestation plus the integrated difference between calf breeding rate and calf birth rate over time.	INIT Calves_in_Gestation = initial_calves_in_gestation
Herd structure	Feeder Cattle	$\text{Feeder_Cattle}(t) = \text{Feeder_Cattle}(t - dt) + (\text{calves_allocated_to_feeder_stock} - \text{slaughtering_rate}) * dt$	animal	The stock of cattle who are fattened and later slaughtered.	INIT Feeder_Cattle = INITIAL_FEEDER_CATTLE
Herd structure	Heifers milk production	$\text{Heifers_milk_production}(t) = \text{Heifers_milk_production}(t - dt) + (\text{Calves_allocated_to_breeder_stock} - \text{Parturition_rate}) * dt$	animal	This is a stock variable that calculates the number of heifers at each point in time based on the initial value of heifers plus the integrated difference between the calves allocated to the breeder stock and the parturition rate over time.	INIT Heifers_milk_production = INITIAL_HEIFERS_MILK_PRODUCTION
Herd structure	Milk cows	$\text{Milk_cows}(t) = \text{Milk_cows}(t - dt) + (\text{Parturition_rate} - \text{Slaughtering_rate_milk_cows}) * dt$	animal	This is a stock variable that calculates the number of dairy cows at each point in time based on the initial value of milk cows plus the integrated difference between the parturition rate and the slaughtering rate over time.	INIT Milk_cows = INITIAL_MILK_COWS
Herd structure	Weaned calves	$\text{Weaned_Calves}(t) = \text{Weaned_Calves}(t - dt) + (\text{Calf_weaning_rate} - \text{Calves_allocated_to_breeder_stock} - \text{calves_allocated_to_feeder_stock}) * dt$	animal	This is a stock variable that calculates the number of weaned calves at each point in time based on the initial value of weaned calves plus the integrated difference between calf weaning rate and calf maturation rate over time.	INIT Weaned_Calves = INITIAL_WEANED_CALVES

Table A.2 List of Model Equations - Flows

Where to find	Variable Name	Equation	Units	Interpretation
Herd structure	Calf birth rate	$\text{Calf_birth_rate} = \text{DELAY3}(\text{Calf_breeding_rate}, \text{PARTURITION_TIME})$	animal/Year	The number of calves born each year after a delay equal to the average parturition time.
Herd structure	Calf weaning rate	$\text{Calf_weaning_rate} = \text{DELAY3}(\text{Calf_birth_rate}, \text{WEANING_TIME})$	animal/Year	The number of calves weaned each year after a delay equal to the average weaning time.
Herd structure	Calf breeding rate	$\text{Calf_breeding_rate} = (\text{Milk_cows} + \text{Heifers_milk_production}) * \text{Calves_per_cow_or_heifer_per_year}$	animal/Year	The number of calves that are born each year depends on the size of the stocks of cows and heifers and on the number of calves that each cow and heifer produce per year.
Herd structure	Calf birth rate	$\text{Calf_birth_rate} = \text{DELAY3}(\text{Calf_breeding_rate}, \text{PARTURITION_TIME})$	animal/Year	The number of calves born each year after a delay equal to the average parturition time.

Supplementary material: No milk without meat

Herd structure	Calves allocated to feeder stock	$\text{calves_allocated_to_feeder_stock} = \text{calf_maturation_rate} - \text{Calves_allocated_to_breeder_stock}$	animal/Year	The number of matured calves each year that are allocated to the feeder stock. the number is calculated from the total number of weaned calves.
Herd structure	Slaughtering rate	$\text{slaughtering_rate} = \text{Feeder_Cattle} / \text{average_fattening_time_feeder_cattle}$	animal/Year	This is the outflow to the stock of feeder cattle. Feeder cattle are slaughtered when they reach the average fattening time. The average fattening time is not constant but depends on the profitability of meat. In this simplified model, we equate profitability with demand (desired meat consumption).
Herd structure	Calves allocated to breeder stock	$\text{Calves_allocated_to_breeder_stock} = \text{MIN}(\text{Desired_new_heifers_milk_production}, \text{Max_}_\text{of_new_heifers_milk_cows})$	animal/Year	The desired number of calves that are allocated to the breeding stock can be higher than the maximum possible number of new breeder calves given the existing herd structure. Under such extreme conditions, the minimum function makes sure that not more calves are allocated to the breeding stock than are physically available (the “maximum number of new heifers milk cows”).
Herd structure	Parturition rate	$\text{Parturition_rate} = \text{Heifers_milk_production} / \text{PARTURITION_TIME}$	animal/Year	This flow describes the process of heifers becoming dairy cows after having their first calf.
Herd structure	Slaughtering rate milk cows	$\text{Slaughtering_rate_milk_cows} = \text{Milk_cows} / \text{AVERAGE_LIFE_TIME_MILK_COWS}$	animal/Year	This is the outflow from the stock of dairy cows. Dairy cows are slaughtered when they reach their average lifetime.
Herd structure	Calf maturation rate	$\text{calf_maturation_rate} = \text{Weaned_Calves} / \text{CALF_MATURING_TIME}$	animal/Year	This is the outflow from the stock of weaned calves. Calves are weaned when they reach the average calf maturing time. The number of weaned calves each year is subsequently allocated to either the breeder or the feeder stock.
Herd structure	Calf weaning rate	$\text{Calf_weaning_rate} = \text{DELAY3}(\text{Calf_birth_rate}, \text{WEANING_TIME})$	animal/Year	The number of calves weaned each year after a delay equal to the average weaning time.
Herd structure	Calves allocated to breeder stock	$\text{Calves_allocated_to_breeder_stock} = \text{MIN}(\text{Desired_new_heifers_milk_production}, \text{Max_}_\text{of_new_heifers_milk_cows})$	animal/Year	The desired number of calves that are allocated to the breeding stock can be higher than the maximum possible number of new breeder calves given the existing herd structure. Under such extreme conditions, the minimum function makes sure that not more calves are allocated to the breeding stock than are physically available (the “maximum number of new heifers milk cows”).
Herd structure	Calves allocated to feeder stock	$\text{calves_allocated_to_feeder_stock} = \text{calf_maturation_rate} - \text{Calves_allocated_to_breeder_stock}$	animal/Year	The number of matured calves each year that are allocated to the feeder stock. the number is calculated from the total number of weaned calves

Table A.3 List of Model Equations – Other Variables

Where to find	Variable Name	Equation	Units	Interpretation
Herd structure	Average fattening time feeder cattle	average_fattening_time_feeder_cattle = initial_fattening_time_feeder_cattle*change_in_bovine_meat_consumption	Year	The average fattening time of feeder cattle depends on the demand for bovine meat. if demand increases, cattle are fattened for longer than if demand decreases
Herd structure	Bovine meat production	"Bovine_meat_production (without_suckler_cows)" = slaughtering_rate*meat_per_slaughtered_feeder_cattle	ton/Year	Tons per year produced by the slaughtered feeder cattle withing the bovine livestock but excluding the suckler cow line
Herd structure	Change in bovine meat consumption	change_in_bovine_meat_consumption = current_pc_consumption_of_bovine_meat/reference_pc_consumption_of_bovine_meat	Dmnl	The change in demand, i.e., the current demand relative to the reference demand. in this simplified model, we assume that a change in consumption will lead to the same change in production. the more advanced version of this model considers a series of additional factors such as price elasticity of demand and supply, fodder availability and environmental regulations.
Herd structure	Change in milk consumption	change_in_milk_consumption = current_pc_consumption_of_milk/reference_pc_consumption_of_milk	Dmnl	The change in demand, i.e., the current demand relative to the reference demand. in this simplified model, we assume that a change in consumption will lead to the same change in production. the more advanced version of this model considers a series of additional factors such as price elasticity of demand and supply, fodder availability and environmental regulations.
Emissions	CO2e emissions from bovine meat production	CO2e_emissions_from_bovine_meat_production = CO2_emissions_per_ton_of_bovine_meat*Total bovine meat production	ton co2/Year	the total number of tons of CO ₂ equivalents per year resulting from bovine meat production
Emissions	CO2e emissions from milk production	CO2e_emissions_from_milk_production = CO2_emissions_per_ton_of_milk*Milk_production	ton co2/Year	the total number of tons of CO ₂ equivalents per year resulting from milk production
Meat demand	Current per capita consumption of bovine meat	current_pc_consumption_of_bovine_meat = (IF TIME < demand_change_start_year THEN base-line_pc_consumption_of_bovine_meat ELSE (1-switch_consumption_recommendations_0_off_1_on)*baseline_pc_consumption_of_bovine_meat+recommended_pc_consumption_of_bovine_meat*switch_consumption_recommendations_0_off_1_on)	ton/(person*Year)	the per capita consumption of bovine meat per year in the activated scenario
Milk demand	Current per capita consumption of milk	current_pc_consumption_of_milk = (IF TIME < demand_change_start_year THEN base-line_pc_consumption_of_milk ELSE (1-switch_consumption_recommendations_0_off_1_on)*baseline_pc_consumption_of_milk+recommended_pc_consumption_of_milk*switch_consumption_recommendations_0_off_1_on)	ton/(person*Year)	the per capita consumption of milk per year in the activated scenario
Herd structure	Dairy cows meat production	Dairy_cows_meat_production = Meat_per_slaughtered_dairy_cow*Slaughtering_rate_milk_cows	ton/Year	Tons of bovine meat per year produced by the slaughtered dairy cows
Herd structure	Desired number of milk cows	Desired_#_milk_cows = Milk_cows*change_in_milk_consumption	animal	The desired number of milk cows is calculated by adjusting the current number of milk cows upward if the demand for

				milk products increases and downward if the demand for milk products decreases. in this simplified model, we assume that a change in consumption will lead to the same change in production. the more advanced version of this model considers a series of additional factors such as price elasticity of demand and supply, fodder availability and environmental regulations.
Herd structure	Desired adjustment milk cow stock	$\text{Desired_adjustment_milk_cow_stock} = (\text{Desired_}\#_ \text{milk_cows} - \text{Milk_cows}) / \text{Cattle_livestock_adjustment_time}$	animal/Year	The desired adjustment of the milk cow stock compares desired and available numbers of milk cows and adjusts this difference not immediately, but over the cattle livestock adjustment time.
Herd structure	De-sired new heifers milk production	$\text{Desired_new_heifers_milk_production} = \text{MAX}(0, \text{De-sired_adjustment_milk_cow_stock} + \text{Replacement_of_milk_cows})$	animal/Year	The desired new heifers are the sum of the calves needed for replacing the current milk cow stuck plus the desired adjustment of the milk cow stock
Meat demand	Indicated bovine meat production	$\text{indicated_bovine_meat_production} = \text{total_domestic_bovine_meat_consumption} * \text{MEAT_LOSS_AND_WASTE_FACTOR}$	ton/Year	indicated bovine meat production represents demand. in this simplified model, price does not mitigate desired consumption. total demand is the domestic consumption, adjusted for the meat loss and waste along the entire value chains. net exports in the case of bovine meat are negligible, especially compared to net milk exports
Milk demand	Indicated milk production	$\text{Indicated_milk_production} = (\text{total_domestic_milk_consumption} + \text{NET_MILK_EXPORTS} + \text{milk_consumption_by_animals}) * \text{MILK_LOSS_AND_WASTE_FACTOR}$	ton/Year	indicated milk production represents demand. in this simplified model, price does not mitigate desired consumption. total demand is the sum of domestic consumption, consumption by animals and exports, adjusted for the milk loss and waste along the entire value chains
Initial values	Initial calves in gestation	$\text{initial_calves_in_gestation} = \text{Calf_birth_rate} * \text{PARTURITION_TIME}$	animal	The initial value of calves in gestation, calculated to initialize the model in equilibrium.
Herd structure	Maximum number of new heifers milk cows	$\text{Max_}\#_ \text{of_new_heifers_milk_cows} = \text{calf_maturation_rate} * \text{FRAC_TATION_FEMALE_CALVES}$	animal/Year	The maximum number of new heifers is the number of female weaned calves each year.
Herd structure	Meat per slaughtered feeder cattle	$\text{meat_per_slaughtered_feeder_cattle} = \text{LOOKUP}(\text{effect_of_fattening_time_on_meat_yield}, \text{average_fattening_time_feeder_cattle})$	ton/animal	The meat per slaughtered feeder cattle depends on the age of the animal and the value of meat per animal is read from the table “effect of fattening time on meat yield”.
Milk demand	Milk consumption by animals	$\text{milk_consumption_by_animals} = (\text{Calves} + \text{Weaned_Calves}) * \text{MILK_CONSUMPTION_PER_CALV_PER_YEAR}$	ton/Year	the amount of milk consumed by calves every year. in the more elaborate model, also pigs are fed with milk from dairy cows
Herd structure	Milk production	$\text{Milk_production} = \text{Milk_cows} * \text{MILK_PRODUCTION_PER_COW_PER_YEAR}$	ton/Year	This variable calculates milk production per year as a function of both, the number of milk cows and the average milk production per cow per year.
Meat demand	Ratio between bovine meat production and consumption	$\text{Ratio_between_bovine_meat_production_and_consumption} = \text{Total_bovine_meat_production} / \text{indicated_bovine_meat_production}$	Dmnl	this ratio compares supply and demand. the total demand is adjusted for the bovine meat loss and waste along the entire value chains. net exports in the case of bovine meat are negligible, especially compared to net milk exports.
Milk demand	Ratio between milk production and consumption	$\text{Ratio_between_milk_production_and_consumption} = \text{Milk_production} / \text{Indicated_milk_production}$	Dmnl	this ratio compares supply and demand. the total demand is the sum of domestic consumption, consumption by animals and exports, adjusted for the milk loss and waste along the entire value chains.
Meat demand	Recommended per capita	$\text{recommended_pc_consumption_of_bovine_meat} = \text{recommended_}$	ton/(Year*person)	the recommended per capita consumption of bovine meat for one of the two

Supplementary material: No milk without meat

	consumption of bovine meat	$\text{ed_pc_consumption_of_bovine_meat_SFP} * (1 - \text{switch_0_sfp_1_phd}) + \text{switch_0_sfp_1_phd} * \text{recommended_pc_consumption of bovine meat phd}$		nutrition recommendation scenarios: Swiss Food Pyramid or Planetary Health Diet
Milk demand	Recommended per capita consumption of milk	$\text{recommended_pc_consumption_of_milk} = \text{recommended_pc_consumption_of_milk_SFP} * (1 - \text{switch_0_sfp_1_phd}) + \text{recommended_pc_consumption_of_milk_PHD} * \text{switch_0_sfp_1_phd}$	ton/(person*Year)	the recommended per capita consumption of milk for one of the two nutrition recommendation scenarios: Swiss Food Pyramid or Planetary Health Diet
Meat demand	Reference per capita consumption of bovine meat	$\text{reference_pc_consumption_of_bovine_meat} = \text{SMTH3}(\text{current_pc_consumption of bovine meat}, \text{TIME_TO_REACT_TO_CONSUMPTION_CHANGES_MEAT}, \text{baseline_pc_consumption_of_bovine meat})$	ton/(person*Year)	the reference demand represents the per capita demand of bovine meat in the recent past. the time horizon over which demand changes are taken into consideration for adjusting production is indicated by the parameter "time to react to consumption changes meat"
Milk demand	Reference per capita consumption of milk	$\text{reference_pc_consumption_of_milk} = \text{SMTH3}(\text{current_pc_consumption_of_milk}, \text{TIME_TO_REACT_CONSUMPTION_CHANGES_MILK}, \text{baseline_pc_consumption_of_milk})$	ton/(person*Year)	the reference demand represents the per capita demand of milk in the recent past. the time horizon over which demand changes are taken into consideration for adjusting production is indicated by the parameter "time to react to consumption changes milk"
Herd structure	Replacement of milk cows	$\text{Replacement_of_milk_cows} = \text{Slaughtering_rate_milk_cows}$	animal/Year	This variable calculates the number of dairy cows needed to replace the dairy cows that are slaughtered.
Meat demand, Milk demand	Switch between Swiss Food Pyramid and Planetary Health Diet	$\text{switch_0_sfp_1_phd} = 0$	Dmnl	this is a scenario switch that allows alternating between the Swiss Food Pyramid recommendations (switch = 0) and the recommendations of the Planetary Health Diet (switch = 1)
Meat demand, Milk demand	Switch between consumption recommendations	$\text{switch_consumption_recommendations_0_off_1_on} = 0$	Dmnl	this is a switch that allows alternating between current and recommended consumption patterns. 0 means current consumption patterns, 1 means recommended consumption patterns
Population	Switch between population growth and no growth	$\text{switch_population_growth_0_off_1_on} = 0$	Dmnl	this is a switch that allows alternating between a constant population size and a time-dependent population size. 0 means constant population, 1 takes population from historical and projected data
Herd structure	Total bovine meat production	$\text{Total_bovine_meat_production} = \text{"Bo-vine_meat_production (without suckler cows)"} + \text{Dairy_cows_meat_production}$	ton/Year	the total amount of bovine meat produced in one year. this variable only calculates bovine meat production from the dual-purpose meat/dairy stock but excludes bovine meat from the suckler cow line
Emissions	Total CO2e emissions	$\text{total_CO2e_emissions} = \text{CO2_emissions_from_bovine_meat_production} + \text{CO2_emissions_from_milk_production}$	ton co2/Year	the total number of tons of CO ₂ equivalents per year resulting from milk and bovine meat production
Meat demand	Total domestic bovine meat consumption	$\text{total_domestic_bovine_meat_consumption} = \text{total_population} * \text{current_pc_consumption_of_bovine_meat}$	ton/Year	the total amount of bovine meat consumed per year by the Swiss population
Milk demand	Total domestic milk consumption	$\text{total_domestic_milk_consumption} = \text{total_population} * \text{current_pc_consumption_of_milk}$	ton/Year	the total amount of milk consumed per year by the Swiss population
Population	Total population	$\text{total_population} = (1 - \text{switch_population_growth_0_off_1_on}) * \text{population_2020} + \text{switch_population_growth_0_off_1_on} * \text{population}$	person	the total population of Switzerland, used to calculate total milk and bovine meat consumption

Table A.4 List of Model Equations – Parameters, their Values and Sources

Where to find	Parameter name	Name in model	Value	Units	Interpretation	Source
Herd structure	Average life-time of milk cows	AVER-AGE_LIFE-TIME_MILK_COWS	4	Year	The number of years, on average, that a milk cow is kept on lactation	Agridea/FiBL, 2019, section Tierhaltung
Meat demand	Baseline per capita consumption of bovine meat	BASE-LINE_PC_CONSUMPTION_OF_BOVINE_MEAT	0.01044	ton/(person*Year)	Per capita consumption under baseline conditions.	SBV, 2021
Milk demand	Baseline per capita consumption of milk	BASE-LINE_PC_CONSUMPTION_OF_MILK	0.3189	ton/(person*Year)	Per capita consumption under baseline conditions.	SBV, 2021
Herd structure	Calf maturing time	CALF_MATURING_TIME	0.56	Year	The time it takes for calves to fully mature. the constant assumes the value of the remaining 205 days until calves reach the age of 1 year, where the female animals destined for milk production get inseminated for the first time	SBV, 2021
Herd structure	Calves per cow or heifer per year	CALVES_PER_COW_OR_HEIFER_PER_YEAR	1.02	1/Year	The number of calves that, on average, each cow and heifer produce per year.	Agridea/FiBL, 2019, section Tierhaltung
Herd structure	Cattle livestock adjustment time	CATTLE_LIVESTOCK_ADJUSTMENT_TIME	10	Year	The long adjustment time is rooted in the long lifetime of cattle livestock buildings and related infrastructure, which limit the flexibility with which farmers enter and exit the cattle sector.	Kopainsky et al., 2020
Emissions	CO2e emissions per ton of bovine meat	CO2E_EMISSIONS_PER_TON_OF_BOVINE_MEAT	13	ton co2/ton	tons of CO2 equivalents produced per ton of bovine meat. data source: FAOSTAT	FAOSTAT, Climate Change, Emission Intensities: https://www.fao.org/fao-stat/en/#data/EI
Emissions	CO2e emissions per ton of milk	CO2E_EMISSIONS_PER_TON_OF_MILK	1.6	ton co2/ton	tons of CO2 equivalents produced per ton of milk.	Bussa et al., 2020
Meat demand, Milk demand	Demand change start year	DEMAND_CHANGE_START_YEAR	2022	Year	this is a scenario variable that allows defining the year in which consumption changes start.	User choice
Herd structure	Fraction of female calves	FRACTION_FEMALE_CALVES	0.5	Dmnl	The fraction, on average, of calves that are female.	Agridea/FiBL, 2019, section "Tierhaltung".
Initial values	Initial number of calves	INITIAL_CALVES	304353	animal	The initial value of calves	calculated from calibration
Herd structure	Initial fattening time feeder cattle	INITIAL_FATTENING_TIME_FEEDER_CATTLE	0.43	Year	An average of the average fattening time for veal fattening and bull fattening, weighted by the livestock units of calves and bulls in the initial year of the simulation	Agridea/FiBL, 2019, section "Tierhaltung".

Supplementary material: No milk without meat

					and estimated to keep the model in equilibrium	
Initial values	Initial feeder cattle	INITIAL_FEEDER_CATTLE	240197	animal	The initial number of feeder cattle	SBV, 2021 Cattle aged 365-730 days
Initial values	Initial heifers milk production	INITIAL_HEIFERS_MILK_PRODUCTION	135005	animal	The initial value of heifers.	milk production per dairy cow (7 ton/year; SBV, 2020) and livestock numbers (total of 677863 cows - of which 542857 must be dairy cows and the rest heifers for milk production; SBV, 2021)
Initial values	Initial number of milk cows	INITIAL_MILK_COWS	542857	animal	The initial value of milk cows	SBV, 2021
Initial values	Initial number of weaned calves	INITIAL_WEANED_CALVES	391800	animal	The initial value of weaned calves	calculated from calibration
Meat demand	Meat loss and waste factor	MEAT_LOSS_AND_WASTE_FACTOR	1.1	Dmnl	calculated from SBV. (2021).	SBV, 2021 total production (incl. net exports) vs. total consumption 2020.
Herd structure	Meat per slaughtered dairy cow	MEAT_PER_SLAUGHTERED_DAIRY_COW	0.3	ton/animal	Meat yield is set at 38% of the live weight (700kg).	Agriidea/FiBL, 2019, section "Tierhaltung".
Milk demand	Milk consumption per calf per year	MILK_CONSUMPTION_PER_CALF_PER_YEAR	0.6	ton/(animal*Year)	calculated from SBV (2021)	SBV, 2021 Kälber bis 160 Tage, Jungvieh 160-365 Tage; total milk consumption by calves and weaned calves: 400'000 ton/year
Milk demand	Milk loss and waste factor	MILK_LOSS_AND_WASTE_FACTOR	1.13		calculated from SBV (2021)	SBV, 2021
Milk demand	Milk production per cow per year	MILK_PRODUCTION_PER_COW_PER_YEAR	7	ton/(animal*Year)	The amount of milk produced, on average, per cow and year	SBV, 2020
Milk demand	Net milk exports	NET_MILK_EXPORTS	189000	ton/Year	the net amount of milk exported per year.	SBV, 2020
Herd structure	Parturition time	PARTURITION_TIME	1	Year	The parturition time is 9 months but heifers and cows only get inseminated once per year.	Agriidea/FiBL, 2019
Population	Population	POPULATION_2020	8.67054e+06	person	the population in Switzerland in 2020	BfS, 2021
Meat demand	Recommended per capita consumption of bovine meat (Planetary Health Diet)	RECOMMENDED_PC_CONSUMPTION_OF_BOVINE_MEAT_PHD	0.00511	ton/(person*Year)	recommended per capita consumption of bovine meat according to the planetary health diet.	The data is from the integrated model developed in the NRP69 project, described in Kopainsky, et al., 2020
Meat demand	Recommended per capita consumption of bovine meat (Swiss Food Pyramid)	RECOMMENDED_PC_CONSUMPTION_OF_BOVINE_MEAT_SFP	0.00544	ton/(person*Year)	per capita consumption in the Swiss Food Pyramid Scenario	The data is from the integrated model developed in the NRP69 project, described in Kopainsky, et al., 2020
Milk demand	Recommended per capita consumption of milk (Swiss Food Pyramid)	RECOMMENDED_PC_CONSUMPTION_OF_MILK_SFP	0.2788	ton/(person*Year)	per capita consumption in the Swiss Food Pyramid Scenario	The data is from the integrated model developed in the NRP69 project, described in Kopainsky, et al., 2020
Milk demand	Recommended per capita consumption of milk	RECOMMENDED_PC_CONSUMPTION_OF_MILK	0.09125	ton/(person*Year)	recommended per capita consumption of milk according to the planetary health diet	The data is from the integrated model developed in the NRP69 project, described in Kopainsky, et al., 2020

	(Planetary Health Diet)	SUMP-TION OF MILK PHD				
Milk demand	Time to react to consumption change - milk	TIME_TO_REACT_CONSUMPTION_CHANGES_MILK	10	year	the time horizon over which demand changes are taken into consideration for adjusting production. The lower value for meat than for milk reflects the capital intensity of bovine meat production compared to milk production (stables and milking equipment)	Kopainsky, et al., 2020
Meat demand	Time to react to consumption change – meat	TIME_TO_REACT_TO_CONSUMPTION_CHANGES_MEAT	5	Year	the time horizon over which demand changes are taken into consideration for adjusting production.	Kopainsky, et al., 2020
Herd structure	Weaning time	WEANING TIME	0.44	Year	The time it takes to wean calves	SBV, 2021 Calves aged up to 160 days

Table A.5 List of Model Equations – Nonlinear Functions

Where to find	Parameter name	Name in model	Points	Units	Interpretation	Source
Herd structure	Effect of fattening time on meat yield	effect_of_fattening_time_on_meat_yield = GRAPH(0+0)	(0.3400, 0.0700), (0.4300, 0.1050), (1.2000, 0.1970)	ton/animal	Meat yield is set at 38% of the live weight of animals. The low value is for veal fattening and the high value for bull fattening.	Agriidea/FiBL, 2019, section "Tierhaltung"
Population	Population	population = GRAPH(TIME)	(2000.00, 7164440), (2001.00, 7197640), (2002.00, 7255650), (2003.00, 7313850), (2004.00, 7364150), (2005.00, 7415100), (2006.00, 7459130), (2007.00, 7508740), (2008.00, 7508740), (2009.00, 7701860), (2010.00, 7785810), (2011.00, 7870130), (2012.00, 7954660), (2013.00, 8039060), (2014.00, 8139630), (2015.00, 8339510), (2020.00, 8757650), (2025.00, 9159870), (2030.00, 9541470), (2035.00, 9856970), (2040.00, 10044300), (2045.00, 10176100)	person	the total population in Switzerland	Historical data: BfS, 2021 Future projections: BfS, 2015; Referenzszenario A-00-2015

3 References

- Agridea/FiBL. (2019). Deckungsbeiträge. Ausgabe 2019. Lindau & Frick, Switzerland: Agridea and Forschungsinstitut für biologischen Landbau FiBL.
- BfS. (2015). Szenarien zur Bevölkerungsentwicklung der Schweiz 2015-2045. Neuchâtel, Switzerland: Bundesamt für Statistik (BfS).
- BfS. (2021). Die Bevölkerung der Schweiz im Jahr 2020. In B. f. S. (BfS) (Ed.). Neuchâtel, Switzerland.
- Bussa, M., Eberhart, M., Jungbluth, N., & Meili, C. (2020). Ökobilanz von Kuhmilch und pflanzlichen Drinks: ESU-services GmbH.
- Kopainsky, B., Frehner, A., & Müller, A. (2020). Sustainable and healthy diets: Synergies and trade-offs in Switzerland. *Systems Research and Behavioral Science*, 37(6), 908-927. doi: <https://doi.org/10.1002/sres.2761>
- SBV. (2020). Milchstatistik der Schweiz, 2020. Brugg, Switzerland: Schweizerischer Bauernverband (SBV).
- SBV. (2021). Statistische Erhebungen und Schätzungen 2020 über Landwirtschaft und Ernährung. Brugg, Switzerland: Schweizerischer Bauernverband (SBV).