APPENDIX 4. The primary submodels of the DECUMA model, with descriptions. Submodels are generally sorted as they are called in DECUMA (Appendix 3), with duplicates and trivial processes not shown. Looping applied to groups of statements is indicated, except for implied looping across landscape cells. Most accumulators are not cited explicitly, but are listed in the output submodels.

Initialize_Values

Set random seed (non-looping).

Input simulation parameters (e.g., pathways, map names, months to model) (non-looping).

Initialize_Metrics

Input parameters common across households, shown in Appendix 2 (non-looping).

Initialize_Landscapes

Read in maps describe the cells comprising the landscape: Study area; Household density; Subareas; Group ranches; Slope; Dry season distance to water; Transition season distance to water; Wet season distance to water; Force map, helping define access to grazing areas by livestock (non-looping).

Initialize_Livestock

For each species

Read in initial gender-specific age density distribution. These are proportions, one value for each age cohort, for the species in question. They are used to distribute livestock herds of a given size into specific age cohorts.

Read in population parameters: Month of birth; Effect of condition index on birth rate; Effect of condition index on death rate; Female and male intrinsic survival rates; Birthing rate; Female and male Tropical Livestock Unit equivalents (see Methods); Female and male probability to sell; Female and male probability to buy.

Read in energy parameters: Minimum and maximum body mass ratios, used in setting 0 and 1 endpoints for body condition indices; Female and male lean mass and Brody curve parameters, yielding expected masses; Maximum body mass loss and gain rates; Basal energy use; Voluntary energy use; Gestation costs; Lactation costs; Thermal costs; Travel costs.

Initialize_Houses

For each household

Read and initialize attributes for households, in the Kajiado application including 3820 files similar to the example in Appendix 1. In that application, 184 of the households were observed, the remainder were located stratified randomly using methods described in the manuscript.

Initialize_Herds

For each household

For each species

Distribute initial livestock holdings (read in under *Initialize_Houses*) to the appropriate age cohorts in the Leslie matrix (see Methods), using the initial age proportion distribution read in under *Initialize_Livestock*.

Assign expected body masses for each age cohort in each sex. This uses Brody curves (i.e., expected weight = lean mass * (1 – exp(B)), where B equals (-1 * β) * (Current age / Maximum age). Here β is a species specific parameter (see Methods for citations by Leslie) and ages are in days.

For each household

Calculate tropical livestock units owned by the house, given livestock holdings and equivalents read in under *Initialize_Metrics*.

Calculate veterinary expenses, based on household specific veterinary expenses (e.g., Appendix 1) and current tropical livestock units owned.

Restore_HSID_Long_Term

For each species

Reads long-term habitat suitability index maps, one for each species, if the user has requested that those be saved in a preliminary spin-up simulation. These maps are used by household herders when deciding whether to move their temporary camps. These maps capture long-term expected forage production, which herders consider when making decisions regarding movement. In decision making, the households consider both long-term expected suitability and short-term forage availability, and weight the expected benefits against the costs of moving.

Restore_Agents

For each household

Reads in all state variables for individual households, using a file created during a preliminary spin-up simulation. The states of households are restored to the condition they were in prior to the termination of the spin-up simulation.

Livestock_Update_Summarize

For each household

For each species

For each sex

Recalculates body mass condition indices, comparing simulated and expected masses.

Updates total herd sizes, given the numbers of animals in the age cohorts.

Livestock_Distribute

For each species

Read habitat suitability index maps from the ecosystem model.

Convert habitat suitability indices and density parameters per km^2 (Appendix 2) to maximum tropical livestock units per landscape cell.

Add habitat suitability indices to long-term suitabilities (see *Restore_HSID_Long_Term*).

Random household order, used to randomize the order herders select grazing lands (non-looping).

For each household
  For each species
    Based on habitat suitability and values in force maps, locate the best grazing location (i.e., landscape cell) within a defined grazing orbit (Appendix 2) around the current location of the permanent household or temporary camp.
    Place the animals in the best grazing area identified for that species.
    If a landscape cell has reached capacity, and no more animals can be placed there, place animals on second-best or third-best landscape cells within the grazing orbit (up to 10 subherds modeled).
For each species
  Write-out the landscape map with total numbers of animals per landscape cell. These maps include numbers of animals on cells across *all* households, and are used by the ecosystem model to simulate grazing.

Livestock_Energy_Acquired
For each species
  Read energy acquired by all the animals of a given species grazing in the distribution derived (see *Livestock_Distribute*), in units of MJ animal^{-1} day^{-1}.
For each household
  For each species
    Calculate average energy acquired for animals of a given herd across all subherds (see *Livestock_Distribute*). This yield a measure of the average metabolizable energy (MJ animal^{-1} day^{-1}) acquired by each herders animals in the distribution simulated.

Livestock_Energy_Used
For each household
  For each species
    For each sex
      Zero-out accumulators of energy used.
      Calculate average body mass.
      Calculate average body condition index.
      Calculate baseline energy use, reflecting basal metabolism, i.e., E = average mass * basal energy use, yielding MJ animal^{-1} day^{-1} here and in what follows.
For each household
  For each species
    Calculate the effect of condition indices on voluntary energy use, VCI. Animals with poor body condition can conserve energy by resting. A linear regression between condition index and parameters reflecting the effect of condition on energy use is used.
    Calculate total travel to acquire water, using current locations of animals and distant-to-water maps (see *Initialize_Landscapes*).
    Calculate average slope of lands grazed by animals.

Calculate vertical travel distance, V = horizontal distance * (average slope / 2.), given that half the travel is up-slope.
Calculate effect of horizontal travel H = horizontal distance * average body mass * horizontal travel costs per km.
Calculate effect of vertical travel VT = vertical distance * average body mass * vertical travel costs per km.
Adjust horizontal travel cost to incorporate voluntary energy savings, H = H * VCI.
Adjust vertical travel cost to incorporate voluntary energy savings, VT = VT * VCI.

Calculate snow depth (note: snow modeling was not used in Kenya) (non-looping)

<u>For each species</u>

Calculate effect of snow depth on species, given brisket height.

<u>For each household</u>

<u>For each species</u>

Calculate effect of snow on travel costs, if snow depth < 0.3, then S = (0.71 * effect on species * exp(0.019 * effect on species)) / 100, else S = (1.23 * effect on species * exp(0.0223 * effect on species)) / 100. (Parker et al. 1984).
Adjust effect of horizontal travel to include snow, H = H * S.
Adjust effect of vertical travel to include snow, VT = V * S.
Calculate lactation cost, if a month of lactation, L = basal energy use * average body mass * lactation cost.
Adjust lactation cost to include only the portion of the herd that is lactating. DECUMA uses the number of suckling animals to reflect that: L = L * (newborns / total herd size).
Calculate gestation costs, if a month of gestation, g = 0.000024 * ((gestation month * 100) ** 3.13) / 100. (Hobbs 1985).
Calculate effect of gestation, G = g * basal energy use * average body mass.
Calculate the total number of pregnant animals, based on condition indices and its effect on birthing rates, pregnant = pregnancy rate * total number of females.
Adjust effect of gestation based on pregnancy: G = G * pregnant / total herd size.
Calculate thermal energy costs, T = average degrees * (cost per degree when active * proportion active) * (cost per degree when bedded * proportion bedded) (Note: not used in Kenya, as temperature is above critical temperature).
Calculate effect of temperature: T = T * basal energy used * average body mass.
Calculate voluntary costs, tied to condition indices: V = (maximum energy used – basal energy used) * average body mass * VCI.
Calculate total energy used: energy = E + G + L + T + H + VT + V, or basal, gestation, lactation, thermal, horizontal travel, vertical travel, and voluntary energy costs.

Livestock_Weight_Change

<u>For each household</u>

<u>For each species</u>

Compare energy acquired (see *Livestock_Energy_Acquired*) to energy used (Livestock_Energy_Used), and knowing energy required to gain or loose 1 km (26 MJ net energy per kg, Coppock et al. 1983), covert to change in kg, then daily value to change per month, i.e., * 365/12.

Trim body mass change to not exceed a maximum gain, or maximum loss.
Apply change in body mass to all age cohorts, not allowing cohorts to exceed a maximum, or fall below a minimum, body mass.

Livestock_Mortality

For each household

For each species

For each age

For each sex

Calculate monthly death rate correction based on body condition index, and coefficients reflecting the effect of condition indices on death rate. A linear regression is used to yield an adjustment (0.-1.) on death rates due to body condition.

Calculate monthly death rate, based on intrinsic survival probability (read in under *Initialize_Livestock*) and increased by the effect of body condition index on death rate.

Decrement cohort, removing dead animals.

Livestock_Age_Herds

For each household

For each species

For each age

For each sex

If the month is designated to when animals are aged (e.g., December), then shift animals in each cohort to the next year in the matrix.

Correct body mass to reflect the current body condition index of the animal, relative to the expected body mass of the animal's new age. If this is not done, animals essentially loose body mass simply by aging. That is, even if they are at exactly expected body mass at year N, as they move to year N+1, they would likely be below expected body mass.

Zero-out cohort matrix cells, condition indices, and body masses for newborns. They will be restored in *Livestock_Give_Birth*.

Livestock_Give_Birth

For each household

For each species

For each age

For each sex

If it is a designated birth month for the species, then calculate monthly birth rate correction based on body condition index, and coefficients reflecting the effect of condition indices on birth rate. A linear regression is used to yield an adjustment (0.-1.) on birth rate due to body condition.

Calculate births, based on intrinsic birth rates per age cohort (read in under *Initialize_Livestock*) and multiplied by the effect of body condition index on birth rate.

Fill cohort matrix cells with new births. Animals are initialized to be healthy, as females will take their own systems to benefit offspring.

Update_Agents

For each household

Calculate household adult equivalents (see Methods), ∑ number in age-sex class * adult equivalent (Note: Done for completeness, but redundant when called each month. This version of DECUMA does not modify household composition).

Calculate household energy requirement, ∑ number in age-sex class * calories required * days in month (Note: Done for completeness, but redundant when called each month. This version of DECUMA does not modify household composition).

For each household

For each species

For each sex

Update tropical livestock units owned by household: ∑ number of animals * tropical livestock units per animal.

For each household

Calculate tropical livestock units per human adult equivalent.

Calculate a running income over the previous four month period.

Harvest_Crops

For each household

For each crop

If the month is one in which crops (here, maize, beans, onions, or tomatoes) should be harvested, then calculate accumulated rainfall in the previous months (see Appendix 1 for harvest and rainfall accumulation flags).

Calculate yield per ha, using accumulated rainfall and a linear regression relating rainfall and yield using coefficients (see Appendix 2).

Calculate total yield in metric tons per ha, in the current application for rainfed (e.g., = yield per ha), irrigated (e.g., = yield per ha * 2.0 + 0.5) and Loitotitok rainfed (e.g., = yield per ha * 1.4), with multipliers crop specific and based on household survey results, and with those for maize shown.

Calculate total harvest for the crop by summing the three production types (Note: not all crops are grown in each system (rainfed, irrigated, Loitokitok rainfed). For example, maize is not irrigated, onions and tomatoes are).

Add stored harvest to the current harvest to yield a total available (Note: Onions and beans are not stored long-term, but are sold).

Agent_Cash_Flows

For each household

Zero accumulators for harvests sold, assets, other income, etc. (for each: household).

For each household

For each crop

For each cropping system

Calculate crops sold, ∑ crop harvested * proportion sold * (1. – proportion going to partners). Partners are land owners who receive a portion of the harvested crop. Cropping systems include rainfed, irrigated, and Loitokitok rainfed in the Kajiado application.

For each household

Calculate total plant energy sold, based on total harvest that is sold and caloric values (see Appendix 2).

Calculate other income, ∑ wage income, livestock trading income, business income for the month (see Appendix 1).

Calculate total income, ∑ maize sold, beans sold, onions and tomatoes sold, other income, government leases income (Note: the last is not used in Kajiado).

Calculate total expenditures, ∑ tea and sugar, general and school fees, crop inputs, veterinary care per tropical livestock unit owned (see Appendix 1).

Calculate assets, ∑ new cash in, cash box.

If assets > expenditures, pay all expenses, add the surplus to net income.

Otherwise, if assets > tea and sugar, purchase tea and sugar, important for all households, and decrement from assets.

If remaining assets > veterinary costs, pay for veterinary costs, and decrement from assets.

If remaining assets > crop inputs, pay for crop inputs, and decrement from assets.

If remaining assets > general expenses and school fees, pay for general expenses and school fees, and decrement from assets.

Agent_Cash_Needs

For each household

Calculate the income that can be anticipated over the next three months, ∑ wage income, livestock trading income, business income.

Add cash box to anticipated income, as it is a resource available (for each: household).

Calculate anticipated expenses for the next three months, ∑ tea and sugar, general and school expenses, crop inputs, veterinary costs.

Calculate the net need, as a positive value, anticipated income – anticipated expenses, and if the result is less than zero, change its sign.

Agent_Livestock_Trades

For each household

If anticipated cash needs (see *Agent_Cash_Needs*) exceeds a large value representing a trigger amount (see Appendix 2) and animals are owned, sell a large animal (i.e., cattle). Based on the probability of selling assigned to age-sex cohorts, and ensuring a cohort is not empty, identify an age-sex cohort from which to sell an animal.

Trade the animal, i.e., decrement cohort, decrement total animals, calculate meat expected based on condition of animal and based on that, accumulate total animal energy sold by household (for each: household), increment animals sold, add sale price to net income, cash box, and to income from species.

If anticipated cash needs (see *Agent_Cash_Needs*) exceeds a small value representing a trigger amount (see Appendix 2) and animals are owned, sell a small animal (i.e., goat or sheep). Based on the probability of selling assigned to age-sex cohorts, and ensuring a cohort is not empty, identify an age-sex cohort from which to sell an animal. The likelihood of selling a goat or sheep is calculated based on the ratio of the two species; the most common species owned by the household is most likely to be sold.

Trade the animal, i.e., decrement cohort, decrement total animals, calculate meat expected based on condition of animal and based on that, accumulate total animal energy sold by household (for each: household), increment animals sold, add sale price to net income, cash box, and to income from species.

Agent_Energy_Flows

For each household

Zero-out accumulators of energy gained.

Calculate average body condition index for females.

Calculate total number of calves, including calves that recently died and have cows that are still lactating.

Calculate milk production, adjusted for body condition of females, = calves * milk produced animal^{-1} day^{-1}, multiplied by an index from 0.-1. calculated using a linear regression of condition index and coefficients relating that to milk production.

Convert milk production to total milk energy, milk production * caloric content * days in month.

If milk energy > energy required by household, sell surplus and consider energy requirements to have been met. Increment milk income, cash box, net income, income from selling by the value of the milk sold.

Otherwise, milk energy equals milk energy acquired.

Calculate energy acquired from sugar in tea. Used regardless of need.

For each species

For each age

Calculate average condition index

Calculate expected meat from animals given their condition indices, and a linear regression relating condition index to meat produced (see Appendix 2).

Calculate meat energy acquired, ∑ meat per animal * deaths * proportion dead that are edible * caloric content.

For each species

Add to meat energy acquired that from animals slaughtered as part of ceremonies.

For each household

Calculate total meat energy used by household, trimming to a maximum amount (30%) of total requirements.

If needs have not already been met, calculate energy from other crops (∑ onions, tomatoes kg * caloric content), and subtract what is used from those stored crops. Do these first, in that they will not store as well as maize.

If beans remain in storage, and household needs have not yet been met, calculate energy used from beans (kg * caloric content), and subtract what is used from the stored beans.

If maize remains in storage, and household needs have not yet been met, calculate energy used from maize (kg * caloric content), and subtract what is used from the stored maize.

Calculate the total energy used by the household, and determine if maize should be purchased, ∑ milk energy, meat energy, maize energy, bean energy, other crop energy, sugar in tea energy.

If energy is still required, and the cash box is not empty, buy the maize needed, or as much as the household can afford. Decrement cash box and net income by the cost of the maize.

If energy is still required after consuming purchased maize, that is assigned as gifted supplemental energy.

Agent_Livestock_Buying

<u>For each household</u>

If the household cashbox exceeds cash needs (see *Agent_Cash_Needs*) by more than an assigned large trigger (see Appendix 2), purchase a large animal (e.g., cattle). Based on the probability of purchasing a given age-sex class (see *Init_Livestock*) and stratified random selection, purchase an animal of that type, increment cohort count, total herd count, set body condition to a mid-point (0.50), and body mass to an expected value. Decrement cash box by the amount spent on the animal.

If the household cashbox exceeds cash needs (see *Agent_Cash_Needs*) by more than an assigned smaller trigger (see Appendix 2), purchase a small animal (e.g., goat or sheep, selected randomly). Based on the probability of purchasing a given age-sex class (see *Init_Livestock*) and stratified random selection, purchase an animal of that type, increment cohort count, total herd count, set body condition to a mid-point (0.50), and body mass to an expected value. Decrement cash box by the amount spent on the animal.

Agent_Livestock_Gifting

<u>For each household</u>

<u>For cattle</u>

If household has lost all their animals, give a cow and a bull at least 3 years old.

Locate the closest neighbor to the current camp location who has at least 50 cattle.

Increment herd size for recipient, male count, female count, gifted animals keep their body masses and conditions as they had prior to gifting. Decrement herd size, female count, male count from household doing gifting.

<u>For goats</u>

If household has lost all their animals, give 3 female and 2 male one-year old or older animals.

Locate the closest neighbor to the current camp location who has at least 25 goats.

Increment herd size for recipient, male count, female count, gifted animals keep their body masses and conditions as they had prior to gifting. Decrement herd size, female count, male count from household doing gifting.

<u>For sheep</u>

If household has lost all their animals, give 3 female and 2 male one-year old or older animals.

Locate the closest neighbor to the current camp location who has at least 25 sheep.

Increment herd size for recipient, male count, female count, gifted animals keep their body masses and conditions as they had prior to gifting. Decrement herd size, female count, male count from household doing gifting.

Move_Herd_Camps

Randomize the order households are processed, so that no household moves preferentially through the simulation (non-looping).

For each species

For each household

Randomly select from throughout the study area 10 areas as possible sites to move to.

Calculate for each potential site: number of tropical livestock units already grazing at that location, distance to permanent household, distance to current camp, short-term (current month) habitat suitability and grazing orbit, whether in or outside of group ranch, and long-term habitat suitability.

Assign a score to each of the measures of the site, often using linear regression of the measure and coefficients relating that measure to a score from 0 to 1 (see Appendix 2 for coefficients). In some cases (i.e., being inside or outside the household's group ranch, plus force map values), coefficients are assigned directly, without regression.

Adjust the scores by a measure reflecting a resistance to moving, score = score - resistance, reflecting the costs associated with moving camps.

Adjust the scores by a measure reflecting a desire to return to the permanent household location, score = score + desire to return.

Considering the current location of the household and the 10 alternatives, identify the site with the highest score. In the wet season, very high scores on the probability of returning to the permanent household location make that very likely, as observed in the system. With this approach, households may stay or may move.

If the household moves, increment a counter accumulating moves. Add the tropical livestock units owned by the household to the density map used when assigning scores that influence stocking on movement decision making (i.e., step 2 in this section).

Agent_Outputs

Calculate average responses for the households simulated. These are responses across all households in the simulation (non-looping).

Write to an output ASCII file household energy results for the month: energy acquired, milk energy consumed, own grain energy consumed, bought grain energy consumed, meat energy consumed, plant energy consumed, other energy consumed, relief energy consumed, milk energy sold, plant energy sold, animal energy sold (non-looping).

Write to an output ASCII file household harvest results for the month: rainfed maize harvest, irrigated maize harvest (always zero), Lotokitok rainfed maize harvest, rainfed bean harvest, irrigated bean harvest (always zero), Lotokitok rainfed bean harvest, rainfed onion and tomato harvest, irrigated onion and tomato harvest, Loitokitok rainfed onion and tomato harvest, total maize harvest, total bean harvest, total onion and tomato harvest, maize sold, beans sold, onions and tomatoes sold, cash for maize sold, cash for beans sold, cash for onions and tomatoes sold, maize in storage, beans in storage, onions and tomatoes in storage (non-looping).

Write to an output ASCII file household cash flows for the month: net income, cash income, income selling, other income, cash to buy food, cash to buy animals, running income per adult equivalent, cash needs, cash box, expenditures, debt, cattle income, goat income, sheep income (non-looping).

Write to an output ASCII file other results from households for the month: energy required, adult equivalents, tropical livestock units, tropical livestock units per adult equivalent, the proportion of food requirements met by the households own products, the proportion of food requirements met in total, cattle sold, goats sold, sheep sold, cattle bought, goats bought, sheep bought, cattle gifted, goats gifted, sheep gifted, total milk sold, remaining milk (non-looping).

Livestock_Outputs

Calculate responses for livestock herds owned by the households simulated. These are responses across all households in the simulation. Most are totals across all households, but some are averages and indicated below (non-looping).

For each species

Write to an output ASCII file livestock information for the month: number of herds, average number of subherds, number of animals, number of females, number of males, number of juveniles, number of non-breeding females (e.g., heifers), number of non-breeding males, number of adult females, number of adult males, average condition index, average female condition index, average male condition index, number of deaths, number of female deaths, number of male deaths, number of juvenile deaths, number of non-breeding female deaths, number of non-breeding male deaths, number of adult female deaths, number of adult male deaths, average energy acquired (non-looping).

Spatial_Outputs

Write to an output file in GRIDASCII format the number of households in each landscape cell (non-looping).

Write to an output file in GRIDASCII format the number of camp in each landscape cell (non-looping).

For each species

Write to an output file in GRIDASCII format the number of animals in each landscape cell (non-looping).

Write to an output file in GRIDASCII format the habitat suitability index of households in each landscape cell (non-looping).

Single_Herd_Out

For each species

For each age

For each sex

Write to an output ASCII file values for the month representing: total number, body mass, expected body mass, body condition index (non-looping).

For each species

Write to an output ASCII file information about subherds: camp x location, camp y location, subherd identifier, subherd x location, subherd y location, number in subherd (non-looping).

Write to an output ASCII file livestock information for the month: number of females, number of males, number of animals, average female condition index, average male condition index, average condition index, juvenile deaths, female non-breeding deaths, male non-breeding deaths, female adult deaths, male adult deaths, energy used, energy acquired (non-looping).

Individual_Agent_Outputs

Write to an output ASCII file general household information: household identifier, x UTM, y UTM, x in cell units, y in cell units, adult equivalents, net income, cash box, tropical livestock units, tropical livestock units per adult equivalent, running income, running income per adult equivalent, number of cattle, number of goats, number of sheep, cattle condition index, goat condition index, sheep condition index, cattle deaths, goat deaths, sheep deaths, cattle sold, goats sold, sheep sold, cattle bought, goats bought, sheep bought, cattle gifted, goats gifted, sheep gifted, maize harvested, beans harvested, onions and tomatoes harvest, maize in storage, beans in storage, onions and tomatoes in storage, milk energy, grain energy grown by the household, meat energy, plant energy, other energy, grain energy bought, gifted and relief energy, milk energy sold, plant energy sold, animal energy sold (non-looping).

For each species

Write to an output ASCII file information about the household camp: permanent household x location, permanent household y location, camp x location, camp y location, number of movements during the year (non-looping).

Write to an output ASCII file about household energy: adult equivalents, tropical livestock units per adult equivalents, energy required, percent of requirements filled by different products (i.e., milk, grain grown by the household, beans, onions, and tomatoes grown by the household, meat, other sources, bought grain, and relief), maize in storage, beans in storage, onions and tomatoes in storage, milk energy sold, plant energy sold, animal energy sold, cash box (non-looping).

Smooth_HSID

Zero-out a smooth habitat suitability surface, which stores smoothed long-term habitat suitability indices, used in deciding camp movements by households (non-looping).

Across the landscape, calculate the average long-term habitat suitability, smoothing over a set distance (here, 20 km) (non-looping).

Save_HSID_Long_Term

Write to an output file in GRIDASCII format a set of values storing long-term habitat suitability indices, one per landscape cell. This map may be read in (see *Restore_HSID_Long_Term*) at the beginning of a simulation, allowing a spin-up simulation to be run, and scenario analyses to continue from the end of that simulation (non-looping).

Save_Agents

Save the state of the simulation, used as a bookkeeping tool, so that simulation results may be related to simulation parameters at later dates. These data are also used when a state variable file is stored system (see *Restore_Agents*), with household data appended, so that the household results and the settings used in the simulation are never separated. Information written include: landscape cell size, study area width, study area height, number of livestock species, number of crop species, number of households, application pathway, household file pathway, household file root name, map names (i.e., household density, study area, slope, distance to water in the dry, transitional, and wet seasons, group ranch, force map), and the entire contents of the parameter file shown in Appendix 2 (<u>non-looping</u>).

<u>For each household</u>

Append to the simulation parameter ASCII file the state of the household, to be used during later simulations to initialize the system (see *Restore_Agents*). Information written include: household identifier, cash box, debt, running income, maize in storage, beans in storage, onions and tomatoes in storage.

<u>For each household</u>

<u>For each species</u>

<u>For each age</u>

Append to the simulation parameter ASCII file the state of household animals, including: number of females, female body mass, number of males, male body mass.