

SGS Pasture Model release notes

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Model version 5.5.3, 3 May 2016

The main changes are to the cereal component and the option to customize the export variables for future use.

Crop grazing

Crops can now be grazed in multi-paddock simulations. To access this option, click on 'Management, Multiple paddocks, Crops'. Note the following:

- Single or double cropping can be implemented;
- With double cropping, the second crop is sown immediately after completion of the first crop, in which case the selected date of sowing of the second crop is not used;
- The crop paddock cannot be paddock 1 as this is the holding paddock;
- For cereals:
 - if the option to harvest is selected then the crop won't be grazed beyond stem elongation
 - if the option to harvest is not selected then the crop completes when grazed following stem elongation
- Remember to choose sensible dates for crop sowing. For example, the default is 15 March which is probably appropriate for winter wheat but early for spring wheat.

The crop module is fairly new and is complex. Please let me know if you find any problems with it, or have suggestions for improvement.

Model version 5.4.6, 3 May 2015

This update is a development of the recent one and incorporates brassicas and forbes. While these crops can be included in the grazing management, the main aim at present is to look at how they grow in single paddock crop simulations. I'll be focusing on the grazing component soon.

Brassicas

The brassica crops that are included are rape, kale and turnip. The phases considered for brassicas are simplified in comparison to cereals, with just vegetative to anthesis and anthesis to maturity. The growth characteristics of rape and kale are very similar with both being leafy plants that are best grown while vegetative but, if allowed to flower, resulting in a high proportion of stem material and poor quality feed. Both kale and rape require vernalization for flowering and so, in practice, are generally sown in spring or summer to be grazed as a vegetative crop to fill a feed gap. Consequently, while the model does include vernalization parameters these are generally not relevant in practical situations. The main difference between kale and rape included in the default parameter sets is that the stems in rape have a lower N content and therefore nutritive value. The growth characteristics for turnip differ from kale and rape in that there is no vernalization requirement and bulb initiation and growth occurs.

Note that in the export routines the bulb components of turnip, and therefore other bulb crops that you may set up yourself, are shown as 'grain'. I'll address this soon.

Forbes

Forbes are incorporated as pasture species rather than crops. Default parameter values for plantain and chicory are included based on the work of Keith Pembleton, developed as part of the *More Milk from Forage* DA funded project. In order to acknowledge this contribution, I've included the name of the original developer in the interface – this can be used in future for other developers as required.

Model version 5.4.5, 27 April 2015

The main developments in this version are:

- The ability to incorporate and graze cereal crops in multiple paddock simulations
- Inclusion of maize, which can be used as a template for other C₄ crops.
- Herd dynamics, including breeding stock replacement, for sheep and cattle systems
- Denitrification associated with nitrification of ammonium

In addition, there are some minor changes and bug fixes.

Grazed cereal crops

Crops can now be incorporated into the multiple paddock grazing systems. The following rules apply:

- A paddock is selected as the crop paddock – future releases will relax this and allow for more than one paddock to have crops and for these to vary across the farm
- Crops are grazed as normal based on dry weight criteria, with the following specified:
 - Dry weight at which the crop is to be grazed, default 3 t ha⁻¹
 - Minimum graze residual, default 1 t ha⁻¹
 - Residual at which to move the stock, default 2 t ha⁻¹
 - Note that if the crop is eligible to be grazed this will take precedence over other paddocks
- You can select whether to graze the crop at boot phase. If this is selected, following grazing, the crop is finished and will either be sown back to pasture or to the second crop if selected (see below)
- If the crop is not grazed at booting, then it will be grown out to harvest. This can either be at the soft dough stage, suitable for silage, or at maturity, suitable for grain. If 'Cut at soft dough phase' is not selected, it is grown to maturity.

There can be two crops.

- If only one crop is selected, then sowing occurs at the specified date.
- If both crops are selected, the first crop is sown at the specified date and the second on completion of the first. This means that with two crops selected, the sowing date for the second crop is ignored.

Implementing these rules has involved a bit of programming complexity so please let me know if you find any problems.

Note that, since paddock 1 is reserved as the holding paddock it cannot be selected as the crop paddock.

Default crop parameter sets

The default crops currently available are:

- Winter wheat
- Spring wheat
- Barley
- Maize

Adding maize introduces a C₄ crop which can be used as a template for other C₄ crops.

Although barley has been included, it should be noted that barley and wheat often have very similar growth characteristics and there may be more variation between varieties of the same species than between species. In the model, barley is similar to spring wheat but flowers earlier.

Flock / herd dynamics and breeding stock replacement

The flock and herd dynamics are described here for a ewe/lamb system with the cow/calf approach being identical. The number of ewes, lambing date and lambs per ewe are defined, along with criteria for removing lambs which are the same as for the weaner system. Parameters are defined for:

- Lamb female proportion, %
- Ewe replacement rate, % / year,
- Lamb death rate, % / year,
- Lamb replacement age, years

These parameters are then used to calculate the number of lambs at each lambing that need to be retained for replacement of the breeding flock when they reach replacement age. At each lambing, the existing lambs move into the next age category, while at breeding stock replacement occurs.

The overall flock and herd numbers vary dynamically in response to the model parameters. The breeding flock are identified by their 'ID' number, as are each age category of lambs. As for the weaner systems, graphical and data outputs for each animal ID, and averages over all animals, are accessible.

Denitrification associated with nitrification of ammonium

Denitrification and emission of nitrous oxide during nitrification of ammonium has been included although it should be noted that it is generally significantly less than denitrification from urine in grazed pasture systems. However, for cropping systems it can be an important component of overall nitrous oxide losses.

The treatment in the model is quite simple with a fixed proportion of N lost as N₂O during nitrification. This proportion is defined on the 'Nitrification' page of the 'Soil' module: 'Biophysics', 'Soil' in the main interface then 'Inorganic nutrient dynamics', 'Nitrification'.

Model version 5.4.3, 7 April, 2015

There are modifications to the cereal crops module, as well as a couple of bug fixes in this version.

Cereals

I'm currently doing some significant development work to the crop module. The intention is primarily to incorporate forage crops as part of the model feeding strategies in grazing systems. In practice, forage crops that are grazed generally don't grow to maturity although the model does include the complete growth cycle. Grazing of crops is not yet available but will be soon.

The crop module now has the following growth phases:

- sowing to emergence;
- vernalization requirement if relevant;
- emergence to booting;
- booting to anthesis;
- anthesis to soft dough;
- soft dough to maturity.

Although other models include more detailed breakdown of crop phases, those included here are sufficient when considering crops in grazing systems. Anthesis is a critical phase as this is when the growth dynamics change substantially with the focus shifting from vegetative and root growth to the production of the inflorescence and then grain. Booting is included to define the stage of development after which the plants will die if grazed due to the removal of the plant meristem. If the crop is harvested after the soft dough phase then it is unsuitable for silage.

Vernalization, which is the process where a period of low temperatures are required in order for anthesis to be able to occur, is a requirement in some but not all cereals – for example it is a requirement for winter wheat but not spring wheat.

The sowing date is defined in the main program with germination requiring a specified soil water content (default 85% of field capacity). Once germination occurs, emergence occurs after a specified number of days (default 10 days).

All subsequent phases are defined using the temperature sum, T_{sum} , hypothesis. (A discussion of the temperature sum approach is given in Thornley and Johnson, 2000, *Plant and Crop Modelling*.) For vernalization this is calculated according to

$$\tau_{v,sum} = \sum (T_{v,crit} - T_{mn}), \quad T_{mn} < T_{v,crit} \quad (1)$$

where T_{mn} is the minimum daily temperature and $T_{v,crit}$ is a critical for vernalization effects to occur. The vernalization condition is satisfied when

$$\tau_{v,sum} \geq T_{v,sum} \quad (2)$$

where $T_{v,sum}$ is the cumulative temperature sum required for vernalization to occur.

For the other phases, the temperature sum is calculated according to

$$\tau_{ph,sum} = \sum T_{mean} \quad (3)$$

where T_{mean} is the mean daily temperature and ph represents the various phases. Calculation of the temperature sum for each phase commences following completion of the previous phase. If there is a vernalization requirement then the $\tau_{boot,sum}$ calculation for booting starts following the completion of the vernalization requirement, otherwise it is calculated following emergence.

Consequently, the T_{sum} required to booting may differ for crops with and without a vernalization requirement.

More complex approaches to phase duration have been applied in various crop models. For example, a sequence of warm temperatures may counter partial vernalization requirement. Also, eqn (3) uses a 'base' temperature of zero whereas sometimes a different base temperature is used so that the contribution to $\tau_{ph,sum}$ is $(T_{mean} - T_{ph,base})$. I've adopted the simple approach defined here but, should it be too limiting, I shall extend it in future.

One difficulty in prescribing temperature sum parameters is often the lack of clarity as to how parameter values affect crops in different regions. To help address this, the model interface shows the dates for phase change for any loaded climate file and selected crop. To see this, load a climate file in the main model and then click 'Biophysics', 'Crop', 'Crop development'. The model displays the *average* dates of each phase change for the selected sowing date. Note that the sowing date prescribed here is just for illustration of these calculations – the actual simulation sowing date is defined in the main model.

Comments

I will appreciate feedback on this treatment of cereal growth and the various parameters, particularly those controlling phase duration. If there are significant limitations then these will be addressed. The intention, as always with this model, is to start simple with as few parameters as possible and then develop this if necessary.

Work is also underway on C₄ crops and brassicas which will be available shortly. This will include photoperiod effects on phase duration – should this be necessary for C₃ cereals it will be implemented.

Minor fixes

An error with the definition of grazing date and animal numbers in the single paddock 'Rotational grazing by date' has been fixed.

There was a minor bug in the root depth calculations for annuals – this should not alter results significantly.

Model version 5.4.1, 6 March 2015

This is a substantial version with new features and some bug fixes. There are also issues to do with backward compatibility so please make sure you read that section.

Backward compatibility

As discussed below in detail, the following changes have been made:

- Default parameter values for the 'leaf weighting parameter under grazing' and 'effective minimum LAI' have been changed to give more realistic growth characteristics.
- A bug with the transfer of standing dead to litter has been fixed.
- The metabolic energy cost of dung production has been removed.
- The default values for the live and dead NDF digestibility for ryegrass and white clover have been changed (0.65/0.40 to 0.75/0.45 and 0.65/0.50 to 0.75/0.55 respectively).

This means that when you load old simulations the results will be slightly different. Please appreciate that this is a characteristic of the development of such a complex model. In particular, it is likely that there will be less standing dead material with the present model version. You should focus on the parameter for the transfer of standing dead to litter in the plant module to adjust the dynamics accordingly.

I also strongly recommend that you consider making the following changes to any of your own pasture parameter sets:

- Set the 'Effective minimum LAI', under 'Biophysics, Pasture, Photosynthesis', to 0.5; and (not or!)
- Set the 'Leaf weighting parameter', under 'Biophysics, Pasture, Grazing', to 1.2 for improved species such as perennial ryegrass, and around 1.5 for legumes and natives.

Then explore the 'Model behaviour' graphs.

If you do want to generate results that are very similar to those from the previous version you should set the transfer of standing dead to litter parameter for vegetative growth to be the same as reproductive growth (this is likely to result in too much dead material, particularly for perennial ryegrass). However, I think it is more appropriate to make the changes described above.

New features

Stock rotation

- The stock rotation rules have been refined to allow multiple phases (which was available in version 4).
- The option to 'stay put' when no paddock is eligible for grazing has been removed – it doesn't make practical sense. Stock rotations according to pasture dry weight or leaf stage and pasture dry weight have a secondary condition for situations where no paddock is eligible for grazing. You can choose whether or not to implement this condition. When no paddock can be grazed stock are moved to the holding paddock.

Take care when modifying the management rules for the different phases to make sure you really are changing the one you intend to! (Speaking from experience here.)

Single paddock rotational grazing by date

A recent version allowed you to specify the date at which a single paddock is grazed. This has been extended so that both the date of grazing and number of animals is prescribed. The easiest way to prescribe these values is to copy from Excel.

Fertilizer and irrigation applications by date

The options to apply fertilizer and irrigation amounts by date is now included. As for grazing by date, I suggest you copy these settings from Excel.

Parameter change for grazing 'Leaf preference'

Under 'Biophysics, Plant, Grazing' there is a parameter for the weighting of leaf intake so that, rather than being strictly on a *pro-rata* basis between leaf and sheath/stem, this parameter allows it to weight towards the leaf.

I've added a tab (bottom left) for 'Model behavior' in the 'Plant' module – this was done in collaboration with Dave Chapman of DairyNZ. This shows the regrowth from grazing under constant environmental conditions. The top graph is dry weight and the bottom right the growth rate. The bottom left graph is the mean growth rate calculated as the accumulated dry weight since grazing divided by the number of days. This is, for example, the way average growth rate is generally calculated during regrowth for rotationally grazed pastures. The motivation for including this graph is from the paper by Parsons *et al* (1988, Use of a model to optimize the interaction between frequency and severity of intermittent defoliation and to provide a fundamental comparison of the continuous and intermittent defoliation of grass, *Grass and Forage Science*, **43(1)**, 49-59). I feel that the model should display the general characteristics of the analysis presented in that paper (which uses the basic model from which the present model is built).

Looking at this analysis, it was clear that the previous default parameter values were resulting in too much leaf being defoliated and, as a result, regrowth was too severely restricted for moderately grazed swards. I've therefore revised the default value for this parameter to give more realistic responses.

Parameter change for effective minimum LAI

As part of the analysis of regrowth discussed above, I have altered the default parameter value for the 'Effective minimum LAI'. This is prescribed under 'Biophysics, Plant, Photosynthesis'. The model does not include carbohydrate storage and so, in order to ensure the plants' ability to grow following severe defoliation, there is an effective minimum LAI which is used in the calculation of photosynthesis. This ensures some carbohydrate available to the plant (provided conditions allow for leaf photosynthesis). I have revised the default value from 0.1 to 0.5.

Animal module

In previous versions there was a separate energy cost for the production of dung – this is analogous to the energy cost of producing urine through metabolism in the liver. However, there is no direct energy cost for dung production and so this has been removed. This has a small effect on energy dynamics through the animal which may, in turn, influence animal intake.

Bug fixes

Transfer of standing dead to litter

The 'transfer of standing dead to litter' parameter is prescribed separately for vegetative and reproductive growth. However, there was a bug so that the value for vegetative growth was being ignored and the reproductive growth parameter was always applied. You can see this parameter under 'Biophysics, Plant, Canopy structure'. This has now been fixed.

If you feel that the previous simulations were giving the appropriate dynamics of standing dead material, then set the value for vegetative growth to be the same as that for reproductive growth.

Dung and urine dynamics

If 'Pasture' is not included in the 'Feed management' the stock were receiving other forms of feed while on the grazing paddock and were therefore returning dung and urine to that paddock. This has now been fixed so that nutrient returns go to the holding paddock.

Parameter set authors

Fixed a bug where it was not recording the details of the author of parameter sets. Regardless of the original author, as soon as you save a parameter set it will identify you as the author. In future versions I shall be refining this to identify the original author.

Urine patch dynamics

There was a small error in the urine patch dynamics calculations that has been fixed.

Model version 5.3.11

The main modification is to the interface so that methane emission parameters can now be accessed. There have also been some minor fixes.

Methane emissions

The methane emission parameters have been added to the 'Stock' module. Details of methane dynamics are given in the full model documentation. In brief:

- A proportion of digestible energy intake is assumed to be lost as methane
- This proportion is related to the NDF fraction in diet, and falls as the NDF fraction declines

Model version 5.3.10, 3 November 2014

Parameter set comparison

The main addition for this version is that parameter sets can now be compared directly in each of the biophysical modules. It should be self-explanatory, but here are some notes:

- In each module there is now an extra item in the 'tree' at the bottom left of the window for 'Parameter comparison'.
- The 'Display' button will display the parameters for the selected parameter set.
- The parameter set in column 1 is designated as the 'primary' set and, when more than one parameter set is displayed, parameters are compared with the primary set (column 1). If they are different then they are displayed in blue.
- The 'Remove' button removes the specified parameter set from the table.
- The 'Primary' button allows you to select any of the parameter sets as primary.
- The 'Copy' button allows you to copy the entire grid to the clipboard to be pasted in other applications – probably Excel is the most useful. Note that the colour formatting does not get copied, nor do the column widths.
- The 'Clear' button clears the grid.

Please let me know if you find any parameter values that look wrong, or any spelling errors – they can be easily fixed!

Miscellaneous

As always, a few minor corrections have been made to the code.

Model version 5.3.8, 22 August 2014

- Fixes a bug with setting CO₂
- Added a few things to the export file

Model version 5.3.4, 1 August 2014

New features are the options to have

- ewes with lambs and cows with calves
- specify grazing dates for single paddock rotational grazing.

Ewes/lambs, cows/calves

These options are defined under the 'Stock' component of the 'Management' module, and should be self-explanatory. You can define up to four categories of parent animals along with lambing/calving date, lamb/calve numbers, and how long the lambs/calves remain with the mother. The ID value for each animal class is used in the simulation graphs and outputs. Note that when animals are removed from the mother, they are removed from the simulation.

This means that we now have the broad management categories:

1. Basic wethers/steers that may or not be growing. Non-growing animals are useful for focusing on the pasture so that the animals are just there to graze and return dung and urine. Also, for single paddocks we can look at variable stocking rate or rotational grazing – these use non-growing animals.
2. Weaners. These are brought-in stock that are grown to specified weights or dates. Up to three categories of weaners can be implemented.
3. Ewes/lambs, Cows/calves. These are like the weaner systems, but now have the parent animals on the paddock. Milk is supplied to the lambs/calves. Growing stock are removed according to similar rules as for the weaners. Up to four categories can be run at any one time. This allows, for example, for single or twin lambs/calves, as well as different parturition dates or conditions for selling.

These management strategies will be developed during the WFSAM project to develop more flexible flock/herd dynamics with stock numbers as an emergent property of the model rather than taking fixed specified values.

Specify grazing dates for single paddock rotational grazing

The single paddock rotational grazing module has been extended to allow you to define specific grazing dates. Under 'Management, Single paddock, Graze' there is a new option 'Rotational grazing by date'. Here there is a table that you can enter grazing dates.

The grazing dates can be entered manually, but it is probably easier to do within excel and then copy and paste. For example, if you are running a 30 year simulation and only want to specify the dates for a few years in the middle, you can do something like set the dates to graze every month for the full duration and then just go and modify those dates that you want to specify. The dates are saved and loaded with the simulation.

A handy Excel function for defining dates, which may be familiar to most people, is EDATE, which allows you to easily add a month to a date. For example, if cell D3 has 1/1/1960 then setting D4 to =EDATE(D3,1) will add 1 month (the second argument is the number of months to add. If you want to graze on the last day of each month, and if D3 is now 31/1/1960, then setting D4 to =EDATE(D3+1,1)-1 will make D4 equal to 29/2/1960. So, for example, for a 50 year simulation you can construct a column of dates in Excel to define grazing on the last day of each month and then modify the dates for a few years in the middle.

Note that with this option the animals are non-growing.

Model version 5.3.0, 30 April 2014

This is a major model update with:

- Implementation of the implicit urine patch scheme, which allows the effects of urine patches to be included without having to model them explicitly. Note that I've made 'implement urine patches' true by default which should result in improved N dynamics, particularly fertilizer requirements, leaching, and N fixation in the model. You may have to check the 'implement urine patches' box on the 'Simulation' page for simulations that have been setup with earlier versions of the model.
- 'Greenseeker' nitrogen fertilizer technology. This gives the option for the fertilizer N to be applied to the bulk soil only and not urine patch areas.
- Modification to the leaching component, which results in more realistic leaching when patches are included. Note that, without patches, leaching is probably under-estimated, which is consistent with current understanding. A single *dispersion* coefficient has been introduced which is defined in the 'Water' module of the biophysics. This parameter varies between 0 and 1 and, in general, increasing this component will increase leaching.

Apart from these changes, there are also a few more variables available in the graphs and export routines.

Please read the document 'IJ_WFSAM_April2014.pdf' for more discussion on these topics. This is a short report of work done during the latest phase of model developments.

Model version 5.2.9, 12 March 2014

The changes in this version are described below. There are also some bug fixes:

- I've added a new single paddock rotational grazing option: *Rotational grazing by feed on offer and days on paddock*. This uses the mature, non-growing, selected animal to estimate daily pasture requirement which, in turn is used to calculate the required stock density to graze the paddock from the specified dry weight to graze down to the residual dry weight over the number of days defined for the stock to remain on the paddock. It is designed to allow systematic analysis of a single paddock under controlled rotational grazing.
- The graphs and export now allow you to look at the digestibility of animal intake as well as the total pasture. This is to allow for intake response to species grazing preference, as well as weighting of intake between live and dead, leaf and stem.
- A parameter defining a weighting between live and dead intake has been added (see 'Biophysics, Pasture, Grazing'). I've left the default value as 1 for all but the native species,

where the default is 2. The reasoning is that while stock may prefer live over dead, they are fairly well mixed in the sward – for example, ryegrass leaves die from the tip first. For natives where there may be a significant proportion of dead material, stock may actively select live shoots. This is a tricky area and so you should explore the associated responses. If you are uncomfortable with defining this type of weighting just keep it at 1.

- Fire. The fire at regular time intervals has been modified to specify a reference year. Fire will occur on this year and at the defined interval either side of it. Note that this is not the first year that fire occurs so that, for example, with the default of 1950 and frequency of 5 years, and a simulation starting for example on 1/1/1901, fire will occur in 1905, 1910, 1915 etc.
- I've altered the default parameter values for the native pastures. This is as a result of some work with Natalie Doran-Brown on northern pasture systems.
 - Native C3: C4
 - Digestibilities of NDF in live and dead changed from 55%, 20% to 60%, 30%
 - Native C4 low quality
 - Digestibilities of NDF in live and dead changed from 45%, 20% to 50%, 25%

In addition to these modifications, I've also fixed a bug with trampling in rotational grazing. It is possible that in previous versions, all paddocks were being trampled even when there were no animals on the paddock. Trampling only affects the standing dead material, but with this fix you may get some small differences in simulation output. The general patterns should be unchanged.

Finally, there have been some minor fixes and updates to the interface.

Model version 5.2.7, 24 Feb 2014

- There is now the option to display climate data, and associated statistics, in graphs as well as the export file.

In addition, a few minor issues have been fixed.

If you've not read these notes recently I recommend you keep reading for release 5.2.0.

Model version 5.2.0, 7 Feb 2014

The major feature of these versions is the introduction of a crop model, although some other developments are incorporated.

Crop simulation

At present, this is run as a single paddock simulation and not part of a grazing system. However, once preliminary tests have been made, it will be incorporated into the grazing management.

In the meantime please note that I've not tested the crop model extensively, but the simulations I've done so far for fairly different climatic regions are encouraging.

Note:

- Currently the crop is a generic cereal but brassicas will be implemented in the near future.
- The parameters for defining the crop (under the 'Biophysics' page) are similar to those for pasture species, but now there is an extra set of parameters for 'Crop development'.
- The sowing date for the crop is defined under the management module:

- Make sure you select 'Single paddock', 'Crop' towards the bottom-left of the 'Management' page
- The sowing date is defined under the 'Single paddock', 'Crop', options towards the top-left of the 'Management' page. Make sure you select a sensible sowing date for the particular crop in the simulation.
- When running a long-term crop simulation, you should implement a nitrogen fertilizer regime.

I'll be updating the detailed model documentation to describe the physiology of the crop component soon. In the meantime, note the following key parameter values, which are accessed from 'Crop' option on the 'Biophysics' page, and then selecting 'Crop development':

- Days from sowing to emergence. The crop will germinate on the first day that the soil water content in the top soil layer reaches the specified percent of field capacity. Emergence occurs after the specified number of days.
- Day-degrees for anthesis are calculated differently for crops with and without vernalization requirement, so take care when prescribing these parameter values:
 - For crops without a vernalization requirement, the day-degrees are accumulated following emergence.
 - For crops with a vernalization requirement, the day-degrees are accumulated following 1 July. More detail can be incorporated in the future if necessary.
- Day-degrees for maturity are accumulated following anthesis.

In order to help with the estimation of the day-degrees, I've added an extra graph under 'Climate', 'Summary' to show the average monthly temperature sum (day-degrees).

Simulation output

The grain yield and details can be accessed both through the graphs and Excel export:

- Graphs:
 - Left click menu on any graph, 'Plant', 'Summary' offers graphs for annual grain yield, harvest index, and protein content.
- Output:
 - The same variables can be selected under the 'Paddock data' export options.

NOTE that annual crop yields are reported for the year in which the harvest is actually done. This means, for example, if there is a late harvest in early January and then the following season the harvest is in December, there may be a year with zero yield followed by a year with yield comprising two harvests.

Data export

In previous versions you could define export profiles – that is, a selection of output variables to be included in the Excel export file. This option has been disabled for the time being. However, when you run the data export, you can choose whether all data are exported.

Other model developments

- I've fixed some errors in the rotational grazing system, in particular where the program was ignoring the specified minimum grazing residual.

- The program will now look for climate files either in the location specified when the simulation was saved, or in the same folder where the simulation file is. This helps with passing simulations to colleagues.
- The program is now more pro-active in asking you if you want to save a simulation if changes have been made.
- The option to include urine patches has been disabled. I'm currently working on this and will have an update in the next few weeks.

Model version 5.1.10, 25 Oct 2013

Fixes a problem with the data export to Excel with user defined animals.

Model version 5.1.5 - 5.1.8, 21 Oct 2013

The changes in these versions are described below. There are also some minor bug fixes.

Management options

Management options for weaners are extended to allow stock to remain on-farm for time periods longer than a year.

- The stock duration on the farm can be specified by weeks or months, as well as by date.
- The date option restricts the time to being no longer than a year.
- Up to three groups of weaners can be implemented simultaneously.
- In all cases, a value for animal weight is also specified at which stock will be removed which will override the duration criterion if the stock reach that weight.
- There is an option to allow importing multiple weaner groups in any year.

The option for multiple groups in any year is intended primarily for scenarios where stock remain on the farm for durations greater than a year and imports are staggered, and is most likely to apply to northern Australian pasture systems. Consider, for example, animal groups with ID-2 and ID-3 that are both set to be brought in on 1 Nov and remain for 18 months, and the simulation starts in 1960. If the option 'Allow multiple stock imports per year' is not checked, then the following sequence will occur

	Stock group ID-2	Stock group ID-3
1/11/1960	Import animals	
1/11/1961		Import animals
30/4/1962	Remove animals	
1/11/1962	Import animals	
30/4/1963		Remove animals
1/11/1963		Import animals
30/4/1964	Remove animals	
1/11/1962	Import animals	
30/4/1963		Remove animals
1/11/1963		Import animals
	etc	etc

Pasture species

I've now added default parameters for tall fescue. I've not tested this extensively so please get back to me with any questions or comments.

Excel climate files

- If you use Excel climate files (as opposed to SILO), details are now saved with the simulation file so that the climate file will be opened and read when the simulation file is opened.
- When you use Excel files, the model will open the file when it is being used, but does not close it – you must handle this yourself.
- With Excel files, you should specify the latitude and elevation – these are saved with the simulation. Elevation is not particularly important, but latitude can have a noticeable effect on simulation results. These parameters are embedded in SILO files, and read automatically for those climate files.

Model version 5.1.5, 24 Sept, 2013

This version continues with some minor fixes.

Model versions 5.1.1 to 5.1.4, 3 Sept, 2013

- These versions fix some important issues with the save and load routines.
- There have also been some improvements made to plant transpiration and the 'compensation' parameter has now been dropped. This will be documented in detail very soon.
- I've made some minor modifications to the default parameters for sheep intake in response to available pasture.
- I've removed the high temperature stress for C₃ plants. This option is still available on the interface, but I've found that the new photosynthesis routines based on Johnson *et al.* (2010, *Ann Bot.*, **106**, 735-749) give improved temperature responses.

Model version 5.1.0, released 16 August, 2013

The key aspects of this update are:

- Introduction of a weaner grazing system (sheep and cattle)
- Flexible supplement and feed management strategies
- Improvements to paddock definition
- Refinements to the rotational grazing management routines.

These are discussed in turn. Note that there are also other minor modifications such as the option to prescribe the proportion of nutrients that are removed as dung and urine. Some additional graphs have also been added to the graph options.

Also note:

- It is possible that some of the graphs in your saved layouts may be incorrect. If this is the case, just reset them and save the layout again.

- In earlier versions, simulations required at least 30 years of climate data. I've relaxed this but you should be aware that percentile graphs will not be calculated for less than 10 years of data.
- A graph has been added to show the mean and percentiles for total shoot dry weight.

Finally, take care when interpreting graphs for rotational grazing strategies. Output may differ considerably from paddock to paddock or when compared with the whole farm. This may be particularly apparent for the 'holding paddock', which may receive substantially greater dung and urine inputs than other paddocks as a result of the grazing management strategy.

Weaner systems for sheep and cattle

It is now possible to define up to 3 simultaneous systems for weaner stock. This is straight forward to implement and requires the following parameters to be prescribed:

- Number of animals
- Date and weight to bring stock in
- Date or weight to remove stock

Consider as an example a lamb system. If the parameters for bringing stock in are 1 April at 20 kg then the model grows animals under non-limiting conditions to 20 kg and incorporates these in the simulation on 1 April. If the conditions to remove the stock are 30 November or 45 kg then animal growth is calculated as part of the whole system in the model and will be removed (for example, sold) if the weight reaches 45 kg or on 30 November, whichever occurs first.

Each set of animals is characterised by its ID number – note that ID-1 is reserved for the 'mature wethers steers' option.

Take care to ensure the animal numbers make sense. For example, if you have 30 paddocks each of 1 ha and want 10 steers ha⁻¹ then the total number of animals that are implemented must sum to 300.

When the simulation runs, you can look at animal graphs for each animal ID class, as well as the average over all animals. This is analogous to the paddocks where you can look at individual paddocks or the whole farm.

When analysing animal intake, note that this can be prescribed for the paddock – that is per ha – which is available under the 'Plant' graphs, or per animal which can be found under the 'Stock' graphs.

Supplement and feed management

Supplementary feed components are:

- Concentrate
- Mixed ration
- Forage

For each of these, you can specify the NDF (neutral detergent fibre) and protein percentages, along with the NDF digestibility. The model assumes that all NDS (neutral detergent solubles), which is everything apart from the NDF, has a digestibility of 85%. Using this information, the model calculates the total digestibility. ME available from the feed is calculated in the model in terms of

feed composition as well as other animal metabolic parameters – I shall be documenting this in detail over the next couple of months.

Feed management is now quite flexible. Four animal metabolic stages are considered, although the first of these is not currently available for dairy systems:

- Growing
- Mature/empty
- Pregnant
- Lactating, which may include pregnant

For each of these stages, you can prescribe any sequence for the following:

- Pasture
- Minimum concentrate
- Maximum concentrate
- Minimum mixed ration
- Maximum mixed ration
- Maximum forage

Obviously not all components need be specified. The only constraints are that maximum concentrate cannot precede minimum concentrate, and similarly for mixed ration.

A maximum total intake can also be prescribed. This may be useful to avoid overfeeding the animals when there is plenty of pasture available. For example, if the maximum mixed ration is prescribed to account for times when there is no pasture available, it may be necessary to limit the mixed ration when pasture intake is relatively high.

The feeding sequence is prescribed on a monthly basis, although it is easy to copy one sequence to other months. The feeding sequences are simply prescribed by ‘dragging and dropping’ – this should be self-evident on the ‘Feed management’ tab of the ‘Management’ page.

This flexibility in feed management should allow us to simulate the main feeding regimes used throughout Australia.

In summary, it is possible to prescribe the feeding sequence for each month of the year and for all physiological phases of the animal (although they are unlikely to be empty in practical simulations). This can result in many feed sequence combinations.

Note that care must be taken to ensure the intended feeding strategies are copied correctly between months.

Substitution

The treatment of substitution – that is, a reduction in pasture intake in response to supplement intake – has been refined and is much simpler than in the previous version. Substitution will only occur in response to supplement that is fed prior to pasture. Thus, for example, if a minimum concentrate is fed followed by pasture, and then more concentrate, substitution is calculated in relation to the minimum concentrate only. Obviously, total intake is constrained by animal intake capacity. There is a single substitution coefficient prescribed for the animal on the ‘Stock’ module under the ‘Biophysics’ page. This is the substitution that occurs when pasture availability is non-limiting, and the default is 0.8.

Paddock definition

In previous versions of the model, you specified the number of paddocks to be used in the simulation. Thus, moving for example from 30 to 20 paddocks resulted in all definitions for paddocks 21 to 30 being deleted. The approach to defining paddocks has now been developed so that all 30 paddocks (the maximum allowed in the model) can be defined. You can copy components (pasture species, soil hydraulic characteristics, soil organic matter and nutrient properties) between these paddocks. The paddocks to be included in the simulation are then selected in a simple way. To implement these changes, the layout of the 'Paddocks' component of the model has changed, but it should be quite straightforward to work with.

Take care when selecting different numbers of paddocks for simulations as this will alter the total farm area. For example, if all 30 paddocks are set to 1 ha then if all are used for a simulation the farm area will be 30 ha, whereas if only 20 are selected then the farm area is reduced to 20 ha.

Stock rotation

The stock rotation management options are:

- Fixed time
- Pasture dry weight
- Leaf stage and pasture dry weight (more commonly applied in dairy systems)

Although some of these were available in previous releases, they are described here in full owing to recent modifications.

'Fixed time' simply requires you to prescribe the number of days on the paddock.

The other two are similar to each other and involve rules to move stock off a paddock and to determine where to move them.

- For the 'Pasture dry weight' option, a paddock is eligible to be grazed if it exceeds the specified dry weight.
- For the 'Leaf stage and pasture dry weight option', a paddock is eligible to be grazed if either the leaf stage or pasture dry weight exceed a prescribed value.
- The pasture will not be grazed below the specified residual, default 1 t ha⁻¹.
- Stock are moved off when the pasture reaches a specified residual, default 2 t ha⁻¹.

If no paddocks are eligible for grazing then a secondary set of rules is applied involving:

- A critical dry weight, default 1.5 t ha⁻¹.
- A holding paddock.

If at least one paddock exceeds the critical dry weight then you have the option of doing one of the following:

- Move to the 'Holding paddock'
- Stay put
- Chase the feed, whereby the animals move to the paddock with the greatest dry weight. This may involve grazing a paddock that had previously been allocated for cutting.

If no paddocks exceed the critical dry weight then the options are simply to move to the holding paddock or stay put.

These refinements to the rotation grazing management rules should allow the model to reflect most grazing strategies used in Australian dairy systems.

Model version: 5.0.36, released 30 April, 2013

There have been a number of refinements and improvements to the model interface and data handling routines. The main ones are listed here. In addition, a few 'undocumented features' have been fixed.

I have made some changes to the soil organic matter routines and parameter values that are discussed below. These have arisen from discussions with Brendan Cullen, Rich Eckard, Peter Grace, Ramilan Thiagarajah, including Brendan and Ramilan's work with long-term soil carbon data at Hamilton, Vic. We are still looking at parameter values and so there may be minor modifications to these in the future.

Model structure and management

- Annual species are now included. I've only put in defaults for annual ryegrass and sub-clover which are identical to perennial ryegrass and white clover apart from being annual. Have a look at these and I'll incorporate any refinements as required.
- The soil organic matter dynamics component has been modified:
 - Transfer from the fast- to slow-turnover soil carbon pool now depends on soil clay fraction, and the default decay rate parameters for the fast- and slow-turnover pools have been revised, along with the rate of transfer from the fast- to slow-turnover pool. (Note that the dependence on soil clay fraction was in the previous version but not implemented correctly.)
 - The initial soil carbon values have been increased. The previous values were too low and more relevant to soils that had been under long-term cropping.
 - The soil nutrient module interface allows you to specify the soil bulk density. However, this is only for indicative purposes in this module and the actual soil bulk density for simulations is defined in the 'Water' module. Bulk density influences the conversion from percent or mg kg^{-1} (equivalent to ppm) to mass in the soil
- Nitrification and denitrification now depend on the fast-turnover soil carbon mass rather than the total of fast- and slow-turnover. This is to reflect soil microbial activity.
- Volatilization has been refined to be proportional to ET since ammonia is transported to the atmosphere with evaporation water. Note that volatilization losses come directly from urine deposition and also the NH_4 concentration in the top soil layer.
- The single paddock grazing rules have been developed to allow grazing at specific intervals which can be either days, weeks or months.

Interface and data handling

- Export routines have been extensively revised.
 - You can select the data to be exported and save this as an export profile. This avoids having to export large amounts of data that are not relevant to a particular study.
 - Soil profile data for water and inorganic N can be exported. Note that only one paddock, plus the whole farm, can be included in any one export file. This is

because of the possible size of the export file. However, if you want to look at data for more than one specific paddock, just repeat the export.

- Let me know if you'd like to have any other variables available for export.
- Note that the code for the export routines is quite complex. If you find any problems please let me know and I'll fix them.
- When simulation files are opened a message will indicate any module parameter sets that are not on your machine that have been imported. For example, if someone sends you a simulation file (.sgsx or .dmsx) that has a soil parameter set that you don't have, then you will see a message saying it has been imported.
- Milk production can be expressed as litres, or more precisely energy corrected litres, or milk solids. The milk composition is defined in the 'Stock' module. Click 'Options, Milk units...'
- The units for GHG emissions of NO₂ and CH₄ now use the convention of expressing NO₂ as N units but keeping CH₄ in CH₄ units (rather than C).
- A few additions have been made to the available graphs for plotting. Let me know if you'd like to see any others.