

Guide to using DairyMod and the SGS Pasture Model

Ian Johnson

This document is written by Ian Johnson and provides a basic introduction to using DairyMod and the SGS Pasture Model. It is supplied without restriction for use in those projects.

These models have been developed as part of various projects funded by Dairy Australia (DA) and Meat and Live Stock Australia (MLA).

© 2013, Ian Johnson, IMJ Consultants, Pty Ltd.

ian@imj.com.au. PO Box 182, Dorriggo, NSW, 2453, Australia

Last updated 16 August 2013

Contents

1	Introduction	3
2	Running a perennial ryegrass cut-trial simulation for Ellinbank.....	3
2.1	Load the climate file.....	3
2.2	Define the paddock characteristics.....	4
2.3	Management.....	4
2.4	Running the simulation.....	4
3	Simulation graphs	5
3.1	Annual sums.....	5
3.2	Monthly stats	5
3.3	Daily stats.....	5
3.4	Individual daily values	5
3.5	Individual daily values through the soil profile.....	5
3.6	More about the graphs	6
4	Defining multiple paddocks	7
5	Management.....	7
5.1	Stock: DairyMod.....	8
5.2	Stock: SGS Pasture Model	8
5.3	Supplement.....	9
5.4	Feed management	9
5.5	Single paddock management.....	10
5.6	Multiple paddock management.....	11
5.7	Nutrient removal.....	13
5.8	Nitrogen fertilizer.....	13
5.9	Irrigation.....	13
5.10	Nitrification inhibition.....	14
5.11	Fire	14
6	Biophysics.....	14
7	Initializing simulations.....	15
8	Running simulations.....	15
9	Exporting simulation output to Excel.....	15
10	Program options	16
10.1	Milk units.....	16
10.2	GHG coefficients	16
11	Final comments.....	16

1 Introduction

When you first run DairyMod or the SGS Pasture Model (referred to as the ‘program’ or ‘model’) it will go to the ‘Overview’ page which has a diagram of the basic program structure. This diagram links to the same places as the buttons along the top. The objective is to run simulations and do some analysis. This involves prescribing a climate data file, defining the paddocks in terms of pasture species and soil characteristics, and defining the stock management as well as any fertilizer or irrigation regimes.

The model has a collection of default parameter sets for pasture species, soil water characteristics, soil organic matter and nutrient characteristics, and stock. These can be defined by the user under the ‘Biophysics’ page. However, it is advised that you first work with system defaults to find your way around the program.

This document will lead you through doing a basic cut-trial simulation, which is the simplest of simulations that can be run with the model. A guide to the more general program options is then given that should provide you with sufficient information to run complex multi-paddock grazing simulations for sheep and cattle (SGS Pasture Model) and dairy (DairyMod) systems and explore the simulation output.

2 Running a perennial ryegrass cut-trial simulation for Ellinbank

As an introduction to the basic operations of the program, follow these instructions for running a simple cut-trial simulation. The Ellinbank SILO climate file has been distributed (with permission) at various model workshops but if you don’t have it, it can be obtained by clicking the link on the ‘Climate’ page in the program and following the prompts. The file I’ve been using is the ‘Data Drill’ for latitude -38.25 and longitude 145.9 (decimal degrees). I recommend you get the full range of data available, even though the program will only run from 1901. Once you have the SILO file, which is delivered as a .zip file, extract the .txt file and put it somewhere convenient on your machine. For example, on my machine it is ‘Ellinbank.txt’ and it is in ‘My Documents\SILO’.

2.1 Load the climate file

- Click ‘Climate’.
- The panel to the left shows various places you can navigate to. Stay at the top option (Climate data file) and click the ‘Load’ button in the right section of the screen. Navigate to Ellinbank.txt and open it.
- The model has now read the climate file and analyzed the climate data. You can look at this on the ‘Summary’ page which you can get to from the panel on the left. There is also information about the location on the ‘Location’ page – note that the latitude and elevation have been read from the SILO file. You can change these parameters to see how they influence daylength and solar radiation characteristics. The latitude and elevation will be reset to the values in the file each time you run the simulation.
- It is also possible to load Excel climate files, but I’m not covering that here. However, note that, unlike for the SILO .txt file, you must set the latitude and elevation yourself.
- At some time in the very near future, it will be possible to impose climate scenarios on the climate data – watch this space!

2.2 Define the paddock characteristics

Click the 'Paddocks' button

Up to 30 paddocks can be implemented. Paddocks are defined in terms of the plant species (up to 5), the soil hydraulic characteristics and the soil organic matter and nutrient characteristics. Again note that you navigate around the program using the panel on the left while the one on the right is where you make the various selections.

In this example, we are going to work with a single paddock and just select the plant species, so that soil options are set to the defaults.

2.2.1 Select the plant species

- Click the 'Edit' button (on the left) or the 'Plants' part of the diagram.
- Make sure 'Edit paddock' is set to paddock 1. This means that we are defining the plant and soil characteristics for paddock number 1.
- There are two lists of 5 options in the 'Plant species' box. On the left are system defaults which are characterized by '*' in front of the name. On the right are user-defined parameter sets which I'll not discuss for now.
- Click the first box for plant species which will show a drop-down list of various options. The first three are '*C3', '*C3 legume', '*C4' – these are generic sets used mainly when you start defining your own parameter sets.
- Select '*P ryegrass' – we'll stick to a single species for now.

The rest of the 'Paddock' options relate to the soil characteristics and setting up multiple paddocks, which will be discussed later. For now, just use the defaults which are '*Medium' for the soil hydraulic properties and '*Medium OM' for the soil organic matter and nutrients.

Now click the 'Select' button and check that the single paddock simulation is using paddock 1. (We'll look at multiple paddock simulations later.)

2.3 Management

Now that the climate file has been loaded and the paddock has been defined, the last thing to do before running the simulation is to define the management by clicking the 'Management' button.

As before, the panel on the left is for navigating and the one on the right for setting parameters. Also, the lower part of the left panel is for selecting between a single and multiple paddock simulation. This is how you set up a simple cutting trial:

- Under 'Select management', make sure 'Single paddock' is selected (it will be by default) and click 'Cut'.
- This is all you need to do, although the relevant parameter page will also be displayed – the default residual is 1 t/ha. Leave it at this for now.

2.4 Running the simulation

Now for the fun part! Since we're running a long-term cutting trial, nutrients can get complicated because all cut material is removed. In the first instance, it is best to run these simulations without implementing soil carbon and nitrogen. This means the simulation runs under the assumption of

non-limiting nitrogen and ignores soil carbon and nitrogen dynamics. We'll come to more realistic situations for grazing systems later, but this type of simulation gives a good insight into potential pasture growth as affected by climate alone.

- Click the 'Simulation' button.
- Un-check the 'Include soil C and N' box
- Ignore the 'Initialize' check box and 'Loops' value for now – they'll be discussed later
- Leave the dates at the default values
- Click the 'Run' button (the left of the 2 buttons above the dates).
- Wait a few seconds and graphs will appear once the simulation has run.

3 Simulation graphs

For all graphs, both the left and right mouse button are important. Stick to the left for now.

There are 5 types of graph available:

3.1 Annual sums

These are pretty straightforward. On the default graph layout there are 3 of them: 'Annual cut yield', 'Annual evapotranspiration', 'Annual drainage'. We'll see more options very soon.

3.2 Monthly stats

The top left graph on the default layout is the 'Monthly cut growth rate'. This is derived from the monthly growth rates throughout the simulation. Right-mouse-click the graph to see options to display various percentiles.

It is important to note that, while lines have been drawn through these percentiles, and the mean, the graphs should really be read vertically. That is, choose a month and then see the variation in potential growth rate for that month. A sequence of exceeding the 90th percentile for all months has a probability of 10^{-12} of happening! Pretty small. Even the probability of *not* having one month exceeding the 90th percentile is small, $0.9^{-12} = 0.28$. So, read these graphs with caution and, by doing so, they contain a great deal of information.

3.3 Daily stats

These are just like the monthly stats but, instead of using monthly values, work on individual days.

3.4 Individual daily values

For graphs like 'Daily drainage', the data are displayed for an individual year. The year is defined under 'Graph options' in the left-hand panel of the screen.

3.5 Individual daily values through the soil profile

The final graph type is for either soil water distribution through the soil profile or inorganic nitrogen distribution. Since this simulation does not have nitrogen implemented, just look at soil water distribution.

To do this use the left mouse. Go to any of the graphs and click the left mouse – this will bring up a menu with a range of options. There is no point in looking at the ‘Soil’, ‘Stock’ or ‘GHG dynamics’ until soil C and N are implemented. To show the soil water distribution, click ‘Water’, ‘Daily values’, ‘Soil water content’. This will now display the soil water content for the ‘Display year’ and ‘Day of year’ under ‘Graph options’ to the left of the screen.

An interesting way to look at soil water dynamics is to scroll through a year. Before doing this, go to another graph, left-mouse click and select ‘Climate’, ‘Rain’. This shows the rainfall from the climate file. Now go to ‘Day of year’ and type ‘1’. Then use the up arrow of your keyboard. You’ll see the soil water content change and, as it does so, note that it is responding to the rainfall. If you’ve still got ‘Daily drainage’ displayed, you’ll see how the three are connected.

3.6 More about the graphs

At this point, you should have a good idea about selecting the different types of graphs. Of course, it would be good to be able to have different screen layouts for different types of studies. The initial default layout is called ‘Cut trial’. Once you’ve got a layout you like, just click ‘Save’ at the bottom of the left-hand panel, and give it a name. Now, each time you run the program, that layout will be there for you.

You will have noticed that the right-mouse click can also copy the graph, copy the data, or make an individual graph full screen. These should be self-explanatory. Note that you can adjust the appearance of the graphs, either for screen or clipboard, by clicking ‘Options’ on the menu bar and going to ‘Graphs...’. Also, if a graph has been made ‘full screen’, the equivalent menu item becomes ‘Show all graphs’. The full screen option can be useful for looking at complex graphs with many lines.

If you’ve already worked through the cutting trial simulation, you should have an idea about navigating around the graphs. For full grazing simulations, it will be seen that multiple paddocks and stock can be implemented and, by implementing soil C and N, the full carbon and nitrogen cycle is simulated. The model also gives a complete analysis of greenhouse gas dynamics, including methane and nitrous oxide emissions. All of these components can be explored graphically, so keep clicking the left and right mouse over the graphs to explore the range of options available.

When exploring multiple paddocks, it is possible to look at the output for individual paddocks by scrolling the ‘Paddock’ number. Checking the ‘Whole farm’ box allows you to look at the results averaged over all paddocks. 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’ (see below), which may receive substantially greater dung and urine inputs than other paddocks as a result of the grazing management strategy.

Similarly, when multiple animals are implemented, you can look at the output for the individual animals. Not all cases allow averaging over the animals, since it doesn’t always make sense – for example if weaner stock are brought in at different times of year, their average weight is meaningless.

4 Defining multiple paddocks

The cutting trial mentioned above was for a single paddock. For grazing simulations, there is a range of options for single or multiple paddock management strategies. Before looking at these, let's first see how plant and soil characteristics are defined for multiple paddocks.

As an example, we'll implement 30 perennial ryegrass / white clover paddocks each of 1 ha, so that the total area is 30 ha.

- Click the 'Paddocks' button and then click the 'Edit' button.
- Make sure 'Edit paddock' is set to '1'. This means you're editing the characteristics for paddock number 1.
- Change the area to 1 ha.
- For the first species select '*Perennial ryegrass' and for the second '*White clover'.
- Change the area to 1 ha.
- Now, if you change the 'Edit paddock' from 1, you'll see that all the other paddocks still have default settings for area and plant species.
- So, change 'Edit paddock' back to 1.
- Under 'Copy paddock' make sure the boxes for 'Area', 'Plants', 'Soil hydraulic properties' and 'Soil OM and nutrients' are checked (the last 2 don't actually matter as we've not changed these).
- Click 'All paddocks' so that all paddocks are checked.
- Now click 'Copy'. This copies your selections to the paddocks you've chosen.

You will see a message telling you that the copy is complete – you can choose not to see this message again.

At this point, just scroll up 'Edit paddock' number and satisfy yourself that the area and plant species for all paddocks are the same as paddock 1. It should be clear how different aspects of different paddocks can easily be transferred to other paddocks.

Now click the 'Select' button at the top left of the left-hand panel. This is where you select which paddocks to include in the simulation. Since we are working with the maximum number of paddocks, ensure that all 30 are selected. You will also see the total area selected – this is important when choosing animal numbers since changing the total grazing area will alter stock density unless animal numbers are also adjusted.

Although we have set up and implemented 30 identical paddocks, it should be clear how individual plant, soil hydraulic, and soil organic matter and nutrient characteristics can be prescribed for different paddocks. Once a paddock has been defined, any of its 'Area', 'Plants', 'Soil hydraulic properties', or 'Soil OM and nutrients' characteristics can be copied to other paddocks.

5 Management

Management options can be accessed under the 'Management' page. There are options for defining and feeding stock; grazing and cutting paddocks in single and multiple-paddock simulations; applying nitrogen fertilizer, irrigation and nitrification inhibitors; as well as implementing fire in order to calculate methane and nitrous oxide emissions as a result of burning.

Again, the panel at the left is where different settings are selected, and various parameter values and options are defined on the right. Different stock selections are available in DairyMod and the SGS Pasture Model. Note that default and 'User defined' stock parameter sets can be implemented. Initially there will be no 'User defined' stock available, but we'll see how to set up your own parameter sets later.

5.1 Stock: DairyMod

Only dairy cows can be implemented in DairyMod. You can choose up to 12 sets of animals by defining:

- Number of animals
- Calving date
- Lactation length

Once these have been defined, you can then select which animals to implement. Note that each animal class is identified by its 'ID' number – this is used in the graphs for the simulation output and also if simulation data are exported to Excel.

Take care when choosing which sets of animals to implement as this will alter the total number of animals on the farm. For example, if there are 30 paddocks each of 1 ha and you want to run 3 cows ha⁻¹, then the total number of *implemented* animals must be 90. Suppose you want to consider the difference between single and split calving systems, it is a good idea to use animals with ID-1 for the single calving and those with ID-2 and ID-3 for the split system, just remembering to implement the correct set of animals for each simulation.

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 'Paddocks' where you can look at individual paddocks or the whole farm.

5.2 Stock: SGS Pasture Model

The SGS Pasture Model has either sheep or cattle. In both cases you can use the default animal or select a 'User defined' parameter set.

5.2.1 Mature wethers / steers

Mature wethers or steers are useful for simulations where the main aim is to focus on pasture processes and where the primary role of the animals in the simulation is to graze the pasture and return dung and urine for nutrient dynamics. You can also select whether to include animal growth in the simulation. If it is not included then daily animal energy requirements are fixed at their maintenance requirements at mature weight. If animal growth is included then animal weight can change in response to intake.

5.2.2 Weaners

It is possible to define up to 3 simultaneous systems for weaner stock. This is straightforward 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. It is not possible to average over all animals, as this has little meaning for this type of management strategy.

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.

5.3 Supplement

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.

5.4 Feed management

Feed management is quite flexible. Four animal metabolic stages are considered, although only those that are relevant to the stock selection are implemented. The stages are:

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

For each of these, 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 ensures that it is possible 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.

5.4.1 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.

5.5 Single paddock management

The single paddock management options are for cut or grazing simulations. The cut simulation was discussed earlier. Click on 'Graze' under 'Single paddock', which will show the following options:

- Set stocked
- Variable stock density
- Rotational grazing by pasture weight
- Rotational grazing at fixed time interval

These are considered in turn. Note that animal growth will only be implemented for the set stocked option and with the option to de-stock (see below) not selected. This is because there are times when the animals are removed from the simulation.

5.5.1 Set stocked

The set stocked option should be self-explanatory – the animal numbers prescribed in the ‘Stock’ section will graze the paddock each day.

There is also an option to de-stock at a prescribed pasture dry weight and then re-stock when the pasture recovers to another prescribed dry weight. As mentioned above, if this option is selected then animal growth is not included and only mature wethers will be implemented.

5.5.2 Variable stock density

Variable stock density allows you to vary the stock numbers in relation to available pasture dry weight. The interval for stock adjustment is defined, either in days or months. When stock are adjusted, the difference between actual pasture dry weight and target residual is used to estimate the pasture carrying capacity which defines the stock numbers until the next time of stock adjustment. There is also the option to prescribe a maximum stock density.

5.5.3 Rotational grazing by pasture dry weight

According to this scheme, stock remain on the pasture until it falls below a specified dry weight and are then returned to the pasture when it reaches another specified dry weight. Stock numbers remain fixed at the value defined for wethers or steers, depending on the stock choice of sheep or cattle.

5.5.4 Rotational grazing at fixed time interval

This is a simple approach for looking at a single paddock that is being grazed at regular intervals. The time between grazings is specified and then the stock spend one day on the paddock. The paddock will not be grazed below the prescribed residual.

5.6 Multiple paddock management

There are three rotational grazing strategies that can be implemented:

- Fixed time rotation
- Rotate in relation to pasture dry weight
- Rotate in relation to leaf stage and pasture dry weight

These are considered in turn. Note that the third of these is more widely used in dairy systems than for sheep or cattle.

5.6.1 Fixed time rotation

This is a simple rotation scheme that moves the stock around the paddocks, leaving them on the paddock being grazed for a specified number of days. There is the option to move them in sequence, in which case they rotate around the paddocks regardless of their dry weight. If this option is not selected, then the stock move to the paddock with the greatest dry weight.

5.6.2 Rotate in relation to pasture dry weight

According to this scheme, a paddock becomes eligible for grazing when it reaches a specified dry weight. Two residuals are defined for the paddock being grazed: the first is the minimum residual, so that the paddock won't be grazed below this value; and the second is the residual at which stock

will be moved. Thus, stock will remain on the paddock until it reaches the defined residual at which they will be moved. Having a residual that defines when stock will move that is different to the minimum residual at which the paddock will be grazed allows the option of moving stock before pasture availability becomes too low.

When stock move, the paddock that they move to is the one with the highest dry weight, provided it is eligible for grazing. If no paddock satisfies these criteria then a second set of rules apply, whereby a critical dry weight is defined, along with a holding paddock. If at least one paddock is above the critical dry weight then you can select between the following options:

- *Move to holding paddock.* In this case, the stock are moved to the specified holding paddock.
- *Stay put.* The stock are not moved and continue to graze the paddock they are already on.
- *Chase the feed.* They move to the paddock with the highest dry weight. Because at least one paddock exceeds the critical dry weight, they will therefore be moved to a paddock with at least this amount of pasture.

If no paddocks are above the defined critical dry weight, then the options are either to move to the holding paddock or stay put.

Thus, if no paddock is eligible for grazing, the options are either to move to the holding paddock or stay put, with the further option of chasing the feed if at least one paddock is above the critical dry weight.

5.6.3 Rotate in relation to leaf stage and pasture dry weight

The management strategy of moving stock in relation to leaf stage is quite widely used in dairy systems. It is similar to implement to 5.6.2 apart from the fact that paddocks are deemed eligible to be grazed if either the leaf stage or pasture dry weight exceed prescribed values. The rest of the rules are identical to the scheme for rotating in relation to pasture dry weight.

Note that for pastures with multiple species, leaf stage is defined as the weighted average in relation to pasture dry weight.

5.6.4 Cutting rules

For each of the rotational grazing strategies a set of cutting rules can also be implemented. The pasture dry weight at which to allocate the paddock to cutting is defined. The paddock is then removed from the rotation and subsequently cut either when it reaches a prescribed dry weight or after a defined number of days since it was allocated to be cut, whichever occurs first. We use number of days and not just a dry weight because, if growth slows for a reason such as lack of rainfall, then it is possible that the paddock will never reach the dry weight required for cutting. The cutting rules can be applied to any paddocks.

If paddocks have been allocated to be cut and there are no paddocks eligible to be grazed, they will be returned to the grazing cycle. If this is necessary, the paddocks that have been allocated to be cut with the *lowest* dry weight are returned to grazing first. This means that paddocks that have recently been removed from the grazing cycle are preferred over those that are almost ready to be cut.

5.7 Nutrient removal

Nutrient returns as dung and urine play an important role in system behaviour through their influence on nutrient dynamics and the corresponding plant response. In many practical situations, such as dairy enterprises, substantial amounts of nutrients may be removed from the paddock through dung and urine deposition in laneways and the milking shed. The model allows you to define a fixed proportion of dung and urine nutrient removal from paddocks.

5.8 Nitrogen fertilizer

Up to 4 nitrogen fertilizer application rules can be implemented, and these can be applied to any paddocks. The amount of nitrogen applied can be specified as nitrate, urea / ammonium, or a combination of both. If urea is applied, it is assumed to be immediately hydrolysed to ammonium.

- *Critical soil N (ppm)*. The nitrogen is applied when the soil N concentration in the top 15 cm falls below a prescribed value. (Note that ppm is equivalent to mg kg^{-1})
- *Plant N as % of optimum*. The nitrogen is applied when N concentration in live leaf material falls below a prescribed percentage of its optimum.
- *Rotation (cut or grazed)*. For rotationally grazed systems, or the single paddock cut simulation, nitrogen is applied after each grazing or cut regardless of soil or plant nitrogen status. For this strategy, it is also possible to implement fertilizer N as a daily equivalent. Thus, for example, if the fertilizer amount is defined as 1 kg N ha^{-1} and the regrowth period prior to grazing or cutting was 35 days, then 35 kg N will be applied following grazing or cutting.
- *Fixed date*. Fertilizer N is applied on a specified fixed date for each year.

Note that:

- For the first two strategies there is also a minimum number of days between applications (although this can be set to zero).
- For the first three strategies, fertilizer application can be restricted to a date range. This is useful, for example, to avoid application during hot dry summer periods in winter dominant rainfall regions such as WA or Victoria.

5.9 Irrigation

Up to 4 irrigation strategies can be implemented, and these can be applied to any paddocks. For each strategy, the amount of water as well as the start and end time are specified. The time and duration of application can affect evapotranspiration and possible runoff. In addition, irrigation can be limited to a prescribed date range.

- *Rainfall deficit*. The cumulative deficit between potential evapotranspiration (PET) evaluated according to the FAO56 method and rainfall is calculated each day. Irrigation is applied when this deficit reaches a specified value. If the deficit falls below zero, which will occur when there is significant rainfall, it is reset to zero.
- *Soil water status*. Plant available soil water is calculated in the root zone and irrigation is applied when this falls below a prescribed percentage of field capacity.
- *Plant water status*. Irrigation is applied when plant transpiration falls below a specified percentage of demand.

- *Fixed intervals.* Irrigation is applied at prescribed fixed daily intervals regardless of any other considerations.

5.10 Nitrification inhibition

Nitrification inhibition, that is, a reduction in the rate of nitrification of ammonium to nitrate, may help reduce denitrification, and is being explored as a possible greenhouse gas mitigation strategy.

Up to 4 nitrification inhibition strategies can be implemented, and these can be applied to any paddocks. For each strategy, an initial value, duration and a curvature coefficient are prescribed. The rate of nitrification is calculated in the model and then scaled in proportion to this function.

5.11 Fire

The model allows the implementation of burning the pasture. A burn date is defined to occur at set yearly intervals or randomly with a prescribed frequency. Burn efficiency defines the proportion of the paddock dry weight, including litter, that is burnt.

Emission factors for methane, carbon dioxide, carbon monoxide and other carbon gasses are prescribed, along with a factor for nitrous oxide.

Carbon not lost as gas is converted to ash. The C:N ratio of ash is defined along with the proportion of ash that is retained on the paddock. The C:N ratio of ash determines the N retained in ash, with the remainder being lost as gas. Ash that remains on the paddock is transferred to the inert soil organic matter pool in the top soil layers.

6 Biophysics

The 'Biophysics' button gives you access to the underlying biophysical parameters for each of the plant, soil water, soil organic matter and nutrients, and stock. Clicking any one of the buttons on the 'Biophysics' page will take you to the module for editing the biophysical parameter sets. Each of these modules has the same look-and-feel. There are system defaults and user defined parameter sets. You can start with any of the system defaults, make some changes to the parameters, and then either click 'Save' or 'Save as...' to save your changes. When you save a parameter set it is identified by its name and the Author, which is the username you entered when first running the program. The parameter sets also save information about the program (DairyMod or SGS Pasture Model) and version number used to generate them, as well as the date and time that they were saved. This information is used to help with sharing parameter sets with colleagues and other users.

To share parameter sets, click the 'Export' button. This generates a small file that you can then pass on to other users (eg by email). Clicking 'Import' allows you to import parameter sets that you have received from other users. When importing, if there is a user-defined parameter set with the same name, the program will give you the option of overwriting the existing set or renaming it.

All biophysical parameter sets are accessible on the main program interface. The plant, soil water and soil organic matter and nutrients can be selected on the 'Paddocks' page, while the stock can be accessed under 'Management'.

7 Initializing simulations

Simulation results are affected by the choice of initial conditions, although the effect is generally diminished through time. The initial pasture dry weight and soil water content are unlikely to have a significant effect on results beyond the first year of the simulation. However, the same cannot be said for the initial soil organic matter status, since turnover rates can be very slow. Depending on the choice of initial values, it is possible that the initial conditions may affect simulation results for decades or even centuries.

A common strategy for reducing the influence of initial conditions is to run simulations for a long period of time before generating the results to be analyzed. This is often referred to as 'spinning-up'. This option is directly available in the model by running for a number of 'Loops' as specified on the 'Simulation' page. If, for example, you select 2 loops then the simulation will run from the start to end dates as normal, but will then start again but without initializing any of the system variables. This process can be repeated by increasing the number of loops.

You can also run a simulation, change some management options and then run again without initializing the system variables – to do this, just un-check the 'Initialize' box.

8 Running simulations

As we saw earlier in section 2.4, running simulations is quite straightforward. That example was a single paddock cut trial without nutrients implemented. For more complex simulations, the process is the same so that, once the simulation has been setup, just click the 'Run' button. In most cases, you will want to make sure that 'Include soil C and N' is checked so that the full carbon and nitrogen cycles are implemented. Simulations with many paddocks will take longer to run, with the time depending on the power of your computer.

Once the simulation has run, you can explore the graphical output for each paddock or the whole farm, as well as each animal class. Also, for multiple calving simulations in DairyMod, or set stocked simulations, you can also look at average animal values by checking 'All animals'.

9 Exporting simulation output to Excel

Simulation data can be exported to Excel for further analysis. To do so, just click the 'Export data' button or 'Export simulation results...' under the 'File' menu item. For multi-paddock and multi-animal class simulations, you can select which paddocks and animals are exported. You can also select individual data items to be exported under groups for

- Whole farm GHG emissions
- Stock data
- Paddock data
- Soil profile data

Once you've selected which data you want to export, the selection can be saved and used again later. This is useful, for example, if you are focusing on soil water content and don't want too much animal detail.

Note that with many paddocks and animal classes, the export file can be very large and the export may take some time.

10 Program options

The 'Options' menu item allows you to change the milk units in DairyMod, CO₂ equivalent coefficients, and graph display

10.1 Milk units

Milk production in DairyMod can either be expressed as 'Energy corrected litres' or milk solids. These are related by the milk composition which is defined in the 'Stock' module.

10.2 GHG coefficients

GHG coefficients are used to convert methane and nitrous oxide emissions to carbon dioxide equivalent (CO₂e) units. If you change these values after running the simulation, GHG emissions will be updated accordingly. Furthermore, when the simulation is saved, the GHG coefficients are saved with the simulation.

11 Final comments

If you've followed these basic instructions, you should have a reasonable working knowledge of the program layout. There is much more in there than has been covered here, but I think it should be fairly straightforward to explore the program. The management routines are under regular review and revision. Keep clicking away and exploring the depths of the program.