SELECT YOUR NITROGEN

A decision tool for quantifying nitrogen availability and crop response in broadacre farming systems

Users Manual




Department of Agriculture
Government of Western Australia

SELECT YOUR NITROGEN

A decision tool for quantifying nitrogen availability and crop response in broadacre farming systems

Concept and Equations: Bill Bowden and Art Diggle.

Design: Anne Bennett, Felicity Flugge, Emma Kopke and Craig Scanlan.

Users Manual

Department of Agriculture, Western Australia
October 2002

Contents

Acknowledgments

Select Your Nitrogen (SYN) brings together the results of over 40 years work on nitrogen nutrition of crops in WA. The contribution of early workers such as Mel Mason can not be overestimated.

In recent years, the development of computer based, quantitative, nitrogen decision support systems which have culminated in SYN, is the result of co-operation at several levels:

- research colleagues from various Departments of Agriculture, CSIRO and the universities – all of whom have willingly, contributed information, ideas, data and technical expertise.

- many Western Australian consultants, advisers and farmers have provided valuable feedback on prototypes of SYN. Special thanks to Doug Sawkins for his invaluable criticisms and for the suggestion that we use a comparative delivery system.

Funding of various aspects of the components of SYN has come over the years from the WA Department of Agriculture, CLIMA and GRDC.

Disclaimer

1. Introduction

Nitrogen plays a crucial role in crop growth and development. As farmers strive to increase their yields and gain quality bonuses, they are becoming increasingly aware of the need to "get it right", when it comes to applying nitrogen fertiliser.

In a farming system, many factors affect how much nitrogen is available to, and required by, the crop. Understanding these factors and acting accordingly can help to optimise yield, quality and dollar returns while improving the efficiency of fertiliser use. The "Select Your Nitrogen" calculator, hereafter referred to as SYN, is aimed at improving the users' understanding of these factors.

What is it?

Available nitrogen is the nitrogen that is actually available to the crop for uptake – here defined as mineral nitrogen within the root zone through time. The amount of nitrogen available is affected by leaching rainfall, soil type, rooting depth, rate and duration of mineralisation of organic matter, immobilization by soil microbes and the nature of the nitrogen sources used.

SYN is the culmination of more than 40 years of research into nitrogen availability. It integrates the information from past nitrogen recommendation systems with our current understanding of the major nitrogen processes in the WA environment. The result is a comprehensive tool, which is designed to support management decision making and allow users to understand the effects of various factors on available nitrogen.

SYN is a weekly time step, simulation model which is designed to give the user a quantitative feel for how different components of the farming system impact on available nitrogen, grain yield and grain quality as well as the dollar returns. For example, SYN can be used to answer questions such as "how will summer rain affect the total nitrogen available", "what would be the effect of delaying the fertiliser application", "what effect will using a no tillage operation have on available nitrogen", and so forth.

The main purpose of SYN is not to recommend a fertiliser rate; rather it is to show the consequences of any possible nitrogen management strategy in any cropping situation. SYN's main strength is in the COMPARISONS which can be made between management and environmental situations, on the RELATIVE availability of nitrogen and its impact on yield, quality and dollars. For example you could enter your current situation and management procedures and compare the outcomes with those you get from entering any changes in management you are contemplating.

It should be noted that, as with all models, there are simplifying assumptions, so the numbers SYN produces should not be taken as gospel.

How does it work?

Potential yield is the nitrogen non-limiting yield of the crop. It is the result of all factors that affect crop growth, other than nitrogen.

The user specifies details about their scenario which contribute to current nitrogen availability such as soil type, leaching rainfall, past rotations, tillage and fertiliser applications. The user also specifies the potential yield of the current crop. Using this information SYN calculates the nitrogen available to the crop from stable organic nitrogen (SON), residual organic nitrogen (RON) and fertiliser sources. It then calculates actual yield and grain protein/oil based on the available nitrogen and the potential yield of the crop. Simple calculations of net return are also be made.

2. Getting Started

Installing on your PC

To use SYN you need at least a Pentium processor with 16 MB of RAM and a CD-ROM drive.

SYN is not a stand-alone package and requires Microsoft Excel version 97 or later to run.

Transfer the SYN file to your hard disk and create a new version using “Save As”. Archive the original version as a backup/reference.

Running SYN

On opening SYN, a dialog box will appear asking if you want to enable macros. Select the button “Enable Macros”. SYN requires macros enabled in order to function properly.

SYN is in the form of a Microsoft Excel workbook, made up of the following worksheets:

Start: Introduction to the model, allows you to alter some settings (screen size, year) and has an “about” SYN button.

Paddock History: Details about paddock rotations, yields and tillage for the previous four years. Also, soil type and rainfall data are stored here.

Current Management: Details about this year’s management – current crop type and price, potential yield, fertiliser strategy.

Roots: Graph showing root depth and wetting front at weeks relative to seeding date.

Forms: Graph showing amount of the various forms of nitrogen at all weeks relative to seeding date. Can be shown for any particular source or the total of all sources.

Profile: Graph showing root depth and nitrogen concentration at different depths for a specified week after seeding. Can be shown for any particular source or the total of all sources.

Sensitivity Analysis: A worksheet that allows you to conduct sensitivity analysis on any of: rate of fertiliser application, time of fertiliser application or potential yield.

Report: This worksheet is simply a summary of the input sheets (i.e. soil type, rainfall, paddock history, current paddock management) and the result sheets (i.e. nitrogen availability table, and the roots, forms and profile graphs), in a one page format.

The different worksheets are shown as tabs at the bottom of the screen. To move around the program click on the tab of the worksheet you want to go to.

On the Start page there is a drop down menu, which allows you to select the correct zoom for your monitor. You should select a magnification so that the square border on the Start page fits just inside your screen. This will ensure that all the other pages are at the correct size also.

Also on the Start page there are two small buttons titled One situation and Two situations. SYN is designed so that two scenarios may be analysed at once and compared side by side. Therefore the user is able to change any of the parameters in the model and compare the difference in results. This allows the user to obtain quantitative answers to their questions / sensitivity analysis. However, if you wish to only use one situation, click on the button labelled “One Situation”. To go back to two situations click on the button labelled “Two Situations”.

You should also select the year you want to analyse from the drop down menu. This adjusts the years of paddock history so that they are the preceding four years. The year you want to analyse may be the current year or you may be analysing a situation from a previous year, or estimating the outcome of a year in the future.

Saving SYN

SYN has been kept simple and easy to initialise and so has been designed with limited saving routines. You can use “save as” in the normal way to retain any version of the total spreadsheet (about 3 megabytes).

You can save many input scenarios for instant recall, within the soils, rainfall, crop and fertiliser menus (see below). For example, the special characters of the “dam paddock” soil could be saved on the soils menu under that name so that it does not have to be re-entered next year.

To keep a record of any runs you can print out a report or you can save them electronically to a new workbook by pulling down the workbook “file” menu and hitting the “Save Reports” item at the bottom. This will open a new workbook with all the inputs and outputs for situation A and situation B recorded on separate sheets. (Note: an error will occur if the options in Excel have been set to open new workbooks with only one worksheet).

3. Defining your situation

There are two worksheets of SYN where you need to specify details about your situation in order to use it correctly. These are the Paddock History and Current Management worksheets. The components of these worksheets and how to correctly input your details are explained in this chapter.

The top half of each of these input sheets has yellow cells where you can enter the specifics of your situation (these cells change to orange when situation A differs in that character from situation B). The bottom half of each sheet contains the outputs so that you can instantly see the effect of a changed value on yield quality and dollars (above the line) and nitrogen availability (below the line). At the bottom of the page is a summary of the input information from the other input page.

It is worthwhile spending some time initially setting up or calibrating the model for your farm and/or locality. The model is designed so that a number of different soil, rainfall and crop scenarios can be created and stored. Once you have created your own scenarios, you are able to quickly change between them to see how different soil types or rainfall events will affect the available nitrogen, or how different crop grades will give different net returns. In future years you will be able to refer back to these specifications without having to re-enter all of the information.

Paddock History worksheet

This worksheet is where you enter details about soil type, rainfall and past rotations on the paddock.

Rainfall

Rainfall inputs (mm/week) are required to allow the calculation of crop available nitrogen. Crop available nitrogen is affected by the leaching of nitrate and the mineralisation of unavailable organic forms of nitrogen in the soil. Increasing rainfall in SYN does not automatically adjust yield potentials for better seasons. You have to make those adjustments independently.

> **Note:** Rainfall entered here only affects the availability of nitrogen. SYN is NOT a crop growth simulation model and so the rainfall does NOT affect the yield. Yield can only be adjusted by the user when he/she changes the potential yield parameter (described in the Current Management section of this chapter.)

Rainfall will cause leaching of nitrogen that is present as nitrate, because nitrate does not bind to soil colloids. As the wetting front moves down through the soil, so too will nitrate nitrogen, and it can be leached below the root zone. This will cause a decrease in the nitrogen available to the crop.

Note: This is **leaching/infiltrating** rainfall NOT total (gauge) rainfall, i.e. the rainfall that is left to leach through the soil profile after run-off and evaporation are accounted for. Run-off depends on many factors including slope of the land, microrelief, surface cover, soil wettability, surface sealing and soil structure, as well as the intensity and duration of the rainfall events. No guidelines for the conversion of gauge rainfall to infiltrating rain are possible. It is left to the user to estimate what proportion of any rainfall has infiltrated. For long term average inputs it is probably appropriate to use about 90% of gauge rainfall. Subtraction of estimates of weekly pan evaporation from the gauge rainfall will overestimate the losses. However, rainfall events after 8-10 weeks beyond seeding should be heavily discounted, because evapotranspiration will have caused considerable drying of the surface soil (not allowed for in the model) with the effect of reducing movement of the wetting front and its effect on leaching.

If there is enough infiltrating rain to keep the surface soil moist enough for long enough, it allows the mineralisation of SON and RON to take place. A considerable amount of pre-seeding or summer rain will cause organic nitrogen to begin mineralisation, increasing the proportion of RON and SON which becomes available for uptake by the crop (and, when nitrified, susceptible to leaching). In SYN the amount of rain needed to begin mineralisation is 50 mm in one week, or 60 mm in two consecutive weeks or 70 mm in three consecutive weeks. The rainfall scenario covers a 30-week period, of which 15 weeks is before seeding and 15 weeks is after seeding. Significant periods of summer rain prior to the pre-seeding 15 weeks should be entered as one input in week 15 prior to seeding. If there is no summer rain, then this mineralisation is assumed to begin at 4 weeks before seeding. However, if mineralisation does begin earlier, then more RON and SON will become available.

SYN contains four predefined rainfall scenarios. At the top of the “Paddock History’ worksheet, there is a box (shown in Figure 1, below) that shows the name of the selected rainfall scenario, for example ‘Default rain – leaching’. By clicking on the arrow on the right hand side of the box, a drop down menu will allow you to select one of the predefined rainfall scenarios. Default SYN rainfall scenarios are shown in Table 1.

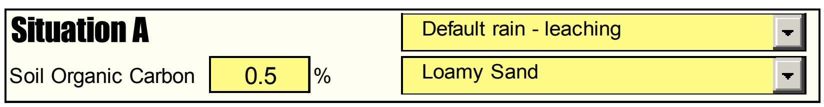

Figure 1: Rainfall scenario and soil type menu boxes

Table 1: Default rainfall scenarios in SYN

Weeks before seeding	**14**	**13**	**12**	**11**	**10**	**9**	**8**	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**0**
Default rainfall – leaching	0	0	0	0	0	0	0	0	0	10	0	3	3	3	3
Summer rainfall – leaching	100	0	0	0	0	0	0	0	0	10	0	3	3	3	3
Default rainfall – no leaching	0	0	0	0	0	0	0	0	0	10	0	3	3	3	3
Summer rainfall – no leaching	100	0	0	0	0	0	0	0	0	10	0	3	3	3	3
Weeks after seeding	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**
Default rainfall – leaching	10	20	75	20	5	10	10	0	10	0	5	0	0	0	0
Summer rainfall – leaching	10	20	75	20	5	10	10	0	10	0	5	0	0	0	0
Default rainfall – no leaching	10	20	15	20	5	10	10	0	10	0	5	0	0	0	0
Summer rainfall – no leaching	10	20	15	20	5	10	10	0	10	0	5	0	0	0	0

You can select one of these predefined rainfall scenarios or alternatively you can create a new scenario or modify the existing ones. To do this select ‘Edit Rainfall’ from the drop-down menu. This will bring up a window titled ‘Rainfall scenarios’ (shown in Figure 2, below). On the left hand side there is a list of the rainfall scenarios. The right hand side shows the millimetres of leaching rain for each week, for the scenario that is highlighted. To see the values of a particular scenario click on the ‘Next’ button until the one you want to look at is highlighted.

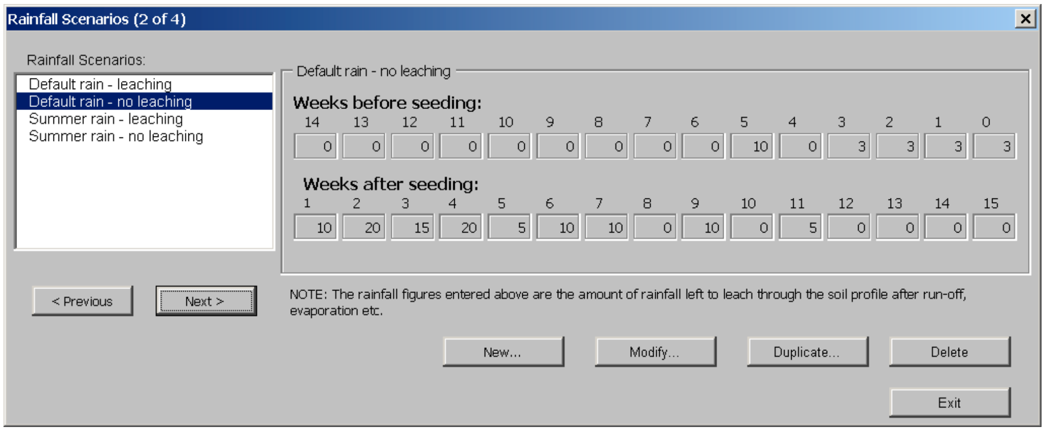

Figure 2: Rainfall scenarios window

At the bottom of the window there are buttons labelled ‘New’, ‘Modify’, ‘Duplicate’, ‘Delete’ and ‘Exit’. Clicking on the ‘New’ button will allow you to enter a new rainfall scenario from scratch. You must enter the leaching rainfall, in millimetres, for each week and a name for the scenario. Clicking on the ‘Modify’ button will allow you to overwrite any of the values for the selected scenario. You also have the option of giving the scenario a new name; though you may chose to leave the name as it was previously. The ‘Duplicate’ button will make a copy of the selected scenario, which you can then modify and rename (the duplicate option is useful if you want to change a scenario slightly, but also wish to retain the original scenario). Clicking on the ‘Delete’ button will delete the selected scenario.

Once you have modified or entered a new rainfall scenario, click on the ‘Exit’ button to return to the ‘Paddock History’ worksheet. You will then be able to select your new scenario from the drop-down menu.

<u>Note</u>: The default scenarios show in Table 1 are useful for comparisons of the impact of different rainfall events. However, they represent no particular location or rainfall sequence. It is recommended that the user spend some time setting up a menu of scenarios that are relevant to the location(s) of interest and the problems most likely to be addressed. Choices of current, average, median or representative years have to be made. If you use average or median rainfall data, then you will have to nominate the seeding date. A VERY simple rule of thumb for post seeding rainfall is to take 1/3 of May to October rain and divide it into 8 equal parts and enter this into the first 8 weeks after seeding (e.g. 240 mm at Merredin becomes 8 entries of 10 mm each). An even simpler approximation of this is to multiply annual rainfall by 3 and divide by 100 and then allocate that number to each of the first 8 weeks after seeding. Beware of averages as they are usually wrong! Use the defaults or some more extreme settings just to explore the impact of the rainfall by soil by N source interactions. It is also useful to construct a “current” file which gets updated as the season progresses and is used for addressing tactical nitrogen questions.

Soil Type

The properties of your soil will affect how much available nitrogen there is, firstly through the amount of stable organic nitrogen (SON) calculated from a soil organic carbon percentage (OC%) and secondly by the susceptibility of nitrate from any source to leaching.

Several soil properties — field capacity, wilting point, root hospitality, soil organic carbon and gravel content — need to be entered into SYN to determine available nitrogen.

Field capacity: This is the water holding capacity of the soil, expressed as ml of water per ml of soil, i.e. higher for clay soils, lower for sandy soils. This and the wilting point parameter represent the full depth of a soil profile, and are used to determine the depth of water penetration from any input of infiltrating rain. On most (e.g. gradational and duplex) soils, these parameters should be changed with depth, but SYN only allows one set of parameters to represent the whole profile. For duplex soils where the surface soil is less than 40-50 cm, use the characteristics of the subsoil. For deeper duplex soils, use the characteristics of the surface soil. These water storage characteristics are in reality, affected by the relative proportion of fine and larger particles (including rock and gravel) in the soil, and by changes in soil properties with depth.

Obviously such a soil characterisation will be approximate and should be chosen to represent the most common or averaged water infiltration characteristics of the soil. The choice of soil parameters lets any given infiltrating rain wet more or less deeply. With experience of how the outputs change with your choice of field capacity, you will settle on default soil types that suit you.

If you do not want to use the default soils, you can get your own numbers for your soils by taking profile samples a couple of days after significant cumulated rainfall (say July) and before the crop has had much of a drying effect. Weigh the samples wet and again after they have been dried. The water content (difference in weight) as a fraction of the dry weight and multiplied by the bulk density (when in doubt use 1.5 gm/cc) gives the volumetric water content used in SYN.

Wilting point: This is the water content of the soil below which plants do not extract any water. Expressed as ml of water per ml of soil. Infiltrating rain fills the difference between wilting point and field capacity and then the wetting front moves downwards.

Root Hospitality: The categories (ripped soil, acid subsoil and default soil) apply to sets of three parameters that control root growth (effective rooting depth as a function of time). These parameters are the maximum rate of root penetration (cm/week), the initial penetration rate modifier and a modifier for the steepness of transition from initial to final rate of root penetration. The first category, ripped soil, speeds up the initial rate of root penetration through the hard pan. Acid subsoil reduces both the initial and maximum rates of root penetration. The default setting represents the average rates of root penetration from a range of soils.

Soil Organic Carbon: Using an assumed C:N ratio of soil organic matter, soil bulk density and soil depth. The measured 0 -10 cm OC% allows us to estimate the amount of SON in the soil. Soil OC% varies markedly, but default levels for eastern, central and western wheatbelt could be 0.5, 0.7 and 1.2, respectively. Soil OC% is relatively stable on most cropped soils but should be measured about every five years.

Gravel content: Gravel consists of rock fragments and lateritic gravels that are over 2 mm in size. Gravel content %, with the OC% measured on the <2 mm soil fraction, is used to estimate the amount of SON. Standard soil testing services sieve out the rock and gravel before doing soil analyses. The higher the gravel content the lower is the amount of soil per hectare containing organic matter and therefore the lower is the amount of SON.

Table 2: Default soil types in SYN

Soil Type	Field Capacity (ml/ml)	Wilting Point (ml/ml)	Root Hospitality	Gravel Content (%)
Clay	0.35	0.16	Normal	0
Clay Loam	0.28	0.12	Normal	0
Loam	0.2	0.09	Normal	0
Sandy Loam	0.14	0.07	Normal	0
Loamy Sand	0.12	0.06	Normal	0
Loamy Sand ripped	0.12	0.06	Ripped	0
Loamy Sand 60% gravel	0.11	0.05	Normal	60
Sand	0.1	0.05	Normal	0

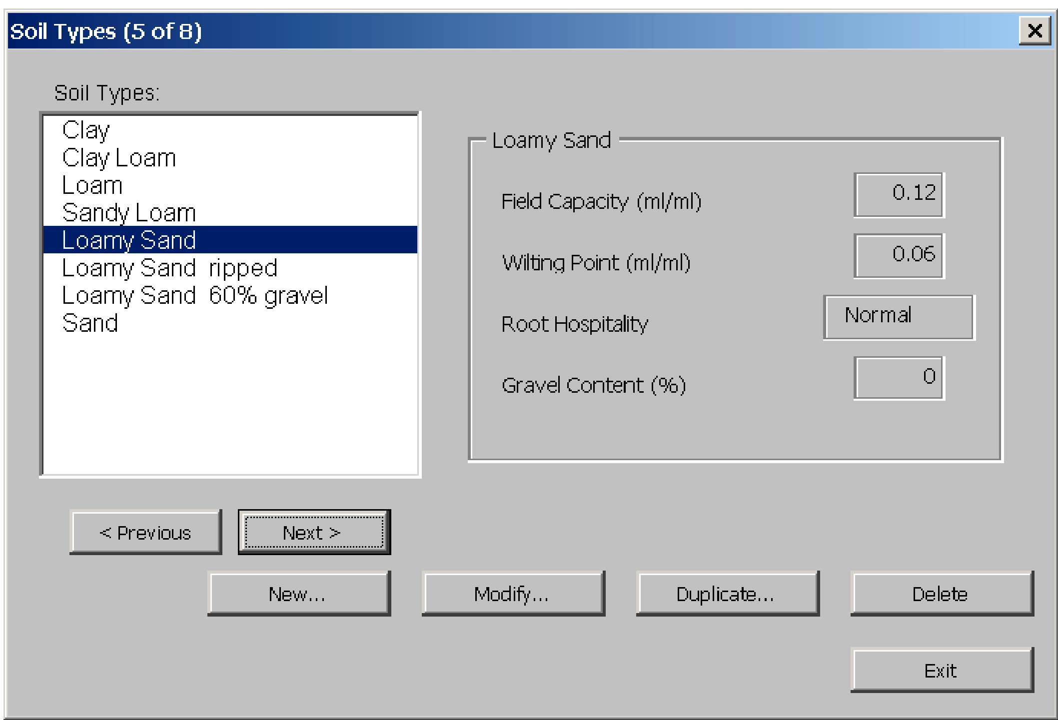

Figure 3: Soil Types window

SYN contains eight default soil types. Below the menu box showing the selected rainfall scenario, is a menu box showing the soil type (Figure 1). By clicking on the arrow to the right of the button, a drop-down menu will be displayed. From this, you may select the default soil type that applies to your paddock. Each of the soil types has appropriate values for the soil properties described above, except soil organic carbon, which must be entered separately on the Paddock History sheet (Figure 1). Table 2 shows the default soil types in SYN and their properties.

SYN allows you to modify any of these soil types to better suit your situation or create a completely new soil type from scratch. To do this, select the “Edit soils” option from the drop-down menu. This will bring up a window titled ‘Soil types’ (Figure 3).

This window works the same as the ‘Rainfall scenarios’ window. The parameter values of the soil type selected on the left-hand side are displayed on the right hand side of the window. Details of other soil types can be displayed by clicking the ‘Next’ button. As for rainfall, you are able to modify an existing soil type, create a new pattern, or copy an existing soil type and modify it, using the ‘Modify’, ‘New’ and ‘Duplicate’ buttons at the bottom of the window. You can name your soil types in any way you choose. For example, you can store your soil information under paddock names for ready reference in the future.

The ‘Delete’ button will delete the selected soil type and the ‘Exit’ button will take you back to the ‘Paddock History’ worksheet. Any new soil types created can now be selected from the drop-down menu.

Cropping History

This section is where the model calculates the residual organic nitrogen (RON) that is potentially available for use by this year’s crop. The amount of RON will depend on the previous paddock use and rotations, the yield and harvest index of legume crops and the yield and legume content of pasture. The value of RON (the amount of “available” N from this residue source) also depends on the method of seeding (i.e. till or no till), the duration of mineralisation and the leaching factors.

In this section, you must specify the paddock use for the previous four years (Figure 4). From the pull down menu, you can select legume crop, non-legume crop, green manure or pasture. Where a ‘No till?” box is provided, click to get a tick for ‘no till’ or click it off to get a blank, which indicates full soil disturbance has occurred either at, or prior to seeding.

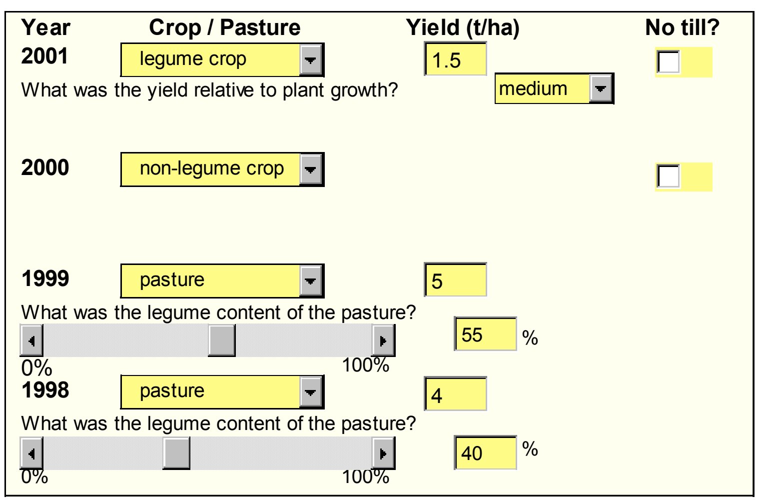

Figure 4: Cropping history section of the Paddock History worksheet

A note on tillage:

Using a tillage operation in previous years will decrease the amount of RON available in the current year. Tillage, or cultivation, causes soil disturbance, which increases the rate of mineralisation of organic matter. The carryover of organic matter into the next year will then be less. No till reduces the rate of mineralisation so that there is more organic nitrogen carried into the following year.

Legume crop: For a legume crop you need to specify the harvested yield in tonnes per hectare, the yield relative to plant growth and whether no till was used.

A legume crop will add RON to the soil because of its nitrogen fixing and/or saving, capabilities. The higher the yield, the more RON that will be added. Additionally, the lower the harvest index (yield relative to plant growth or tops) the more RON added. For example, a 1 t/ha crop at very low yield relative to tops will supply the same amount of RON as a 7 t/ha crop at very high yield relative to tops. This is because the nitrogen in the legume seed is removed from the system. If seed production is high, relative to plant growth, then more nitrogen will be removed leaving less available to crops in following years. When in doubt about harvested yield relative to plant growth, choose the medium option. Use the 'harvested' grain yield because legume grain which spills on the ground contributes nitrogen to following crops when it germinates and is killed, or when it has passed through a grazing animal.

Non-legume crop: For a non-legume crop you need to specify only whether no till was used. As distinct from a non-legume pasture, a non-legume crop will not add any RON to the soil because most of the N is transported off in the grain leaving only high C:N residues which release nitrogen very slowly and in insignificant amounts for following crops. These residues add nitrogen to the much larger SON pool.

Pasture: For pasture inputs, you need to specify the dry matter production of the pasture and the percentage legume content. A guideline to estimating pasture production is shown below.

Pasture density	Pasture production
Poor	10 kg/ha per mm of growing season rain
Average	15 kg/ha per mm of growing season rain
Good	20 kg/ha per mm of growing season rain

Example: A pasture with average density in a 300 mm growing season rainfall season, would grow approximately 4.5 t/ha. Note that this is pasture grown, not forage on offer at the end of the season. Grazing returns nitrogen to the soil. If you are harvesting pasture (hay or silage or transporting it in animals to a night paddock), then you need to estimate that removal and reduce the pasture production accordingly.

A pasture phase adds RON to the soil. The higher the yield of the pasture, the more RON that is added. Additionally the higher the legume content of the pasture, the more RON that will be added. For example 4 t/ha at 100% legume content gives approximately the same RON as 7 t/ha at 0% legume content. When in doubt about the legume content or the pasture density, choose medium values.

Green manure: For a green manure crop or pasture, you need to specify the dry matter yield and the legume content. As for pasture, the higher the yield and legume content of the green manure, the more RON will be added to the soil. For **brown manure**, use the pasture item, albeit, with green manure yield and composition inputs. In both cases (green and brown manure) the yield should be reduced because of the shortened growing season.

Current Management worksheet

In this worksheet you specify details about the current year's management. SYN uses this information to determine how much nitrogen the crop will need, and how much it is getting from fertiliser. Figure 5 shows the section of the worksheet where you enter this information.

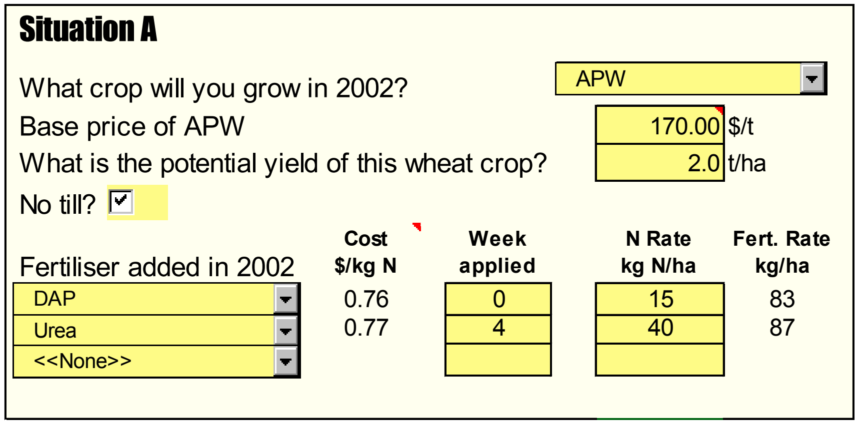

Figure 5: A section of the Current Management worksheet.

Crop Information

In SYN crops can be differentiated in two ways. Firstly by differences in yield and quality responses to nitrogen and secondly by the price which can vary with quality, depending on segregation.

The yield response to nitrogen in cereals is assumed to be identical for the same potential yield. The protein responses vary with species and segregation. Protein in oats is approximately 1% higher than standard wheat while protein in barley varies up to 1.5% higher than standard wheat. Hard wheat varieties tend to give higher proteins than ASW and or noodle varieties. On the other hand soft wheat varieties tend to give lower proteins than ASW. SYN accounts for this by increasing final protein by 0.5% for hard or durum wheat and decreasing final protein by 1% for soft wheat, relative to standard protein. Canola differs from cereals in both yield and quality response to nitrogen.

You have two options when selecting your current crop. You can select just the species of crop (wheat, barley, oats or canola) or you select a particular grade. If you select just the species, then there is no change in price in response to protein/oil. The price is constant and is whatever you enter into the "Base Price" box (see below).

The second option is to choose a specific grade. The default grades in SYN are shown in Table 3, below. These grades each have a protein (or oil) premium and discount price schedule attached. The premium or discount appropriate for the protein result is added to or subtracted from the base price that you enter, which is then used to calculate net return. The premiums and discounts for each grade can be viewed by selecting "Edit Grades" from the drop down menu. From here, the premiums and discounts for each grade can be updated and new grades can be created. Use the "Modify" "New" and "Duplicate" buttons to do this. When creating a new grade remember to select what species it is at the top of the form i.e. wheat, barley, oats or canola. If you don't do this the model will default to wheat.

<u>Note</u>: If you select wheat as the crop type when creating a new grade, you also have to specify which category of wheat it falls into, i.e. hard or durum, soft or other. This is because hard and durum wheat give higher proteins and soft wheat gives lower proteins, as explained above. Wheat types that are not classified as hard, durum or soft (for example ASW, APW and noodle) come under the "other" classification and protein is not adjusted. If you don't select the wheat type the model will default to "other".

Table 3. Default grades included in SYN

Grades in SYN	Comments*
ASW	Premiums above 10% protein, discounts below 10% protein.
APW	Premiums above 10% protein, discounts below 10% protein.
AHW	Premiums above 11.5% protein, discounts below 11.5% protein.
Durum	Durum 1 if above 13% protein, Durum 2 if between 11.5% and 12.9% protein, Durum 3 if between 10% and 11.4% protein.
Noodle Wheat	Discounts above 11% protein and below 10.5%.
Soft Wheat	Discounts above 8.5% protein
Malting Barley	Discounts above 11.5% protein and below 9.5% protein.
Canola (Oil)	Premiums above 40% oil and discounts below 40% oil.

* See the model for actual premiums and discounts. These were accurate at time of writing (July 2002), but change frequently. Please check websites of the relevant authority for updates.

When modifying or creating new grades, you do not need to use all the protein and price boxes. You can enter as few protein increments as you like. However the results will be more accurate the more you enter. Updated protein discounts and premiums for wheat grades can be found on the AWB website, under Grain Marketing ➤ Golden Rewards. Barley and canola premiums and discounts can be found in the Harvest Handbook issued by the Grain Pool or on their website, under Grower Tools ➤ Documents and Forms ➤ Harvest Handbook.

In SYN, screenings may increase with protein levels above 10.7% ASW, 11.2% hard and durum, 10.2% soft and 12.2% barley (because these protein levels characterise the point on the response curve where higher nitrogen supplies reduce cereal yields in SYN). Users could adjust prices down the protein/screenings diagonal on the Golden Rewards matrix above those critical protein levels, if they needed a screenings effect which is not provided automatically by SYN.

Base Price: The value entered here should be the base price for the grain, i.e. the price without any premium or discount for quality, minus the delivery and freight costs and state levies. i.e. farm-gate price at base level of protein or oil.

Potential yield: SYN needs to know the potential yield of the crop you are growing. The potential yield is the yield that would be possible if nitrogen were in non-limiting supply. The potential yield encompasses all other factors that affect yield, which are not dealt with specifically in the model. For example, time of sowing, cultivar, crop-water relations, soil fertility, crop disease, pests and weeds. Therefore, potential yield will vary with management as well as from season to season and soil to soil. For example, in a good year when you have an early start to the growing season and a good finish with no disease problems then your potential wheat yield may be 4 t/ha. However in another year when you have a late break or a dry finish your potential yield would be below 2 t/ha.

As you do not know what the end of the season will be like, what the total amount of rainfall you will get is, or what disease problems there may be, you should use a realistic, attainable yield as the potential yield. It is possible to simulate the effects of different seasons by doing a sensitivity analysis on the potential yield. Conducting sensitivity analyses is explained in Chapter 5.

<u>Note:</u> Potential yield is NOT a target yield. The yield SYN gives for any scenario will always be less than the potential yield you enter here, except when nitrogen is not limiting production. Economics should dictate the level to which you fertilise and (depending on costs and prices) the economic optimum (profit maximising) yield normally falls in the range from 90% to 100% of potential yield. So, if you want to fertilise for a target yield, either ignore the economic outcomes or inflate your target yield by 5-10% and enter this number as the potential yield.

Tillage: As on the 'Paddock history' worksheet, SYN asks if no till is used in the current year. Using no till in the current year will give you relatively less available RON, than using tillage. This is because tillage increases the rate of mineralisation of RON through its incorporation into, and the disturbance of, the soil.

Fertilisers

The model allows you to select up to three fertilisers to apply to the crop and the fertiliser may be applied at any week after seeding. Your strategy does not have to be three different fertilisers, you may apply the same fertiliser but at different times, or you may use just one or two fertiliser applications. Select <<None>> from the drop down menu where you are not using a fertiliser.

Delaying the application by around 4 weeks can increase the availability of nitrogen from that source, by reducing leaching losses. By four weeks the plant has established a root system and so can take nitrogen from deeper in the soil profile. The availability of nitrogen from any source is averaged over the period of time from 4 to 15 weeks after seeding. This is the time period in which the crop has most demand for nitrogen. Applying fertiliser more than four weeks after seeding can decrease the availability of nitrogen because it is not present for part of the time over which the availability is averaged.

SYN contains the most commonly used fertilisers. However, it is possible to add new ones when a particular one you wish to use is not listed. To do this, click on 'Edit fertilisers' at the bottom of the list on the drop down menu. This will open a window similar to 'Soil properties' and 'Rainfall scenarios'. In this window, you are able to enter in a new fertiliser or modify any of the values of an existing fertiliser. Click on the 'Exit' button once you have finished to get back to the 'Current paddock management' worksheet. You can then select your fertiliser from the drop-down menu.

To enter a new fertiliser you must know some of its properties. The properties SYN requires are urea content, NH_4^+ - N, NO_3^- - N, ammonification rate, nitrification rate, fertiliser cost and fraction attributable to N.

Urea content: This is the fraction of nitrogen in the fertiliser that is present as urea and/or any other organic form.

NH_4^+ - N: This is the fraction of nitrogen in the fertiliser that is in the form of ammonium, NH_4^+.

NO_3^- - N: This is the fraction of nitrogen in the fertiliser that is in the form of nitrate, NO_3^-.

Ammonification Rate: This is the fraction of organic nitrogen that is transformed (mineralised) to ammonium nitrogen each week. For urea, this is the hydrolysis rate, which is usually very high.

Nitrification Rate: This is the fraction of ammonium nitrogen that is transformed to nitrate each week.

Fertiliser Cost: This is the cost of fertiliser in dollars per tonne. This is used in the net return calculation.

Fraction attributable to N: This is the fraction of the fertiliser cost that is nitrogen. This is to account for fertilisers that provide benefits other than nitrogen, i.e. if the fertiliser is solely nitrogen then this fraction will be one but if it provides any other benefits such as phosphorous then the fraction will be less than one. Default values have been calculated according to the fractional composition of the fertiliser and the cost per unit of the cheapest fertiliser that provides only one nutrient.

4. Output

The output of SYN is presented in a results table and in three different graphical formats titled Forms, Roots and Profile.

Results table

The results table (Figure 6) is displayed on both the ‘Paddock History’ and ‘Current Paddock Management’ worksheets so that you can instantly see the results of any adjustments you have made.

Results - Situation A					
Actual yield: (t/ha)	2.81	% Protein:	9.07	Net return: ($/ha)	401.43

Nitrogen Source	Nitrogen Availability (kg N/ha)	Fraction of N Avail. %
Soil Organic Nitrogen	28	2
Residue Organic Nitrogen	26	25
DAP	8	52
Urea	36	89
TOTAL	98	

Figure 6: Results table.

The table shows the actual yield, protein/oil % and basic net return that would be attained from the scenario you have entered. The actual yield and protein/oil is calculated from the amount of nitrogen available to the crop and given the potential yield that is possible. The net return per hectare (returns minus costs) is calculated from: -

(farm gate price of grain +/- protein or oil adjustment if applicable * yield) –
(cost of fertiliser * rate of fertiliser used)

The table shows the amount of nitrogen that is available from SON, RON and each fertiliser source in common (“availability”) units. This is the averaged amount of nitrogen available for crop uptake that is in a mineral form within the crop root zone from weeks 4 to 15 after seeding. The total at the bottom of the column is the total available nitrogen (kg N/ha) from all sources. Alongside this is a column, Fraction of N Avail., which shows the available nitrogen as a percentage of the total nitrogen from that source. These numbers are excellent for comparing the effect of soils, rainfall, root depth etc. on the ‘averaged unit availability’ of the different sources of nitrogen and different times of application. Dividing this number into the adjacent kg N/ha value and multiplying by 100 should give the total amount of nitrogen provided by that particular source.

Forms graph

This graph shows the amount of the various forms of nitrogen at weeks relative to seeding. It demonstrates the changing amounts of nitrogen in the various forms over time. You can select, from the drop-down menu above the chart, which source of nitrogen you would like to look at or you can look at the total nitrogen from all sources.

Available nitrogen, ammonium, total nitrate, nitrate in the root zone, leached nitrate and immobilised nitrogen (all in units of kg N/ha) are graphed. You can select which forms you wish to show on the graph by clicking on the small boxes to the right of the screen.

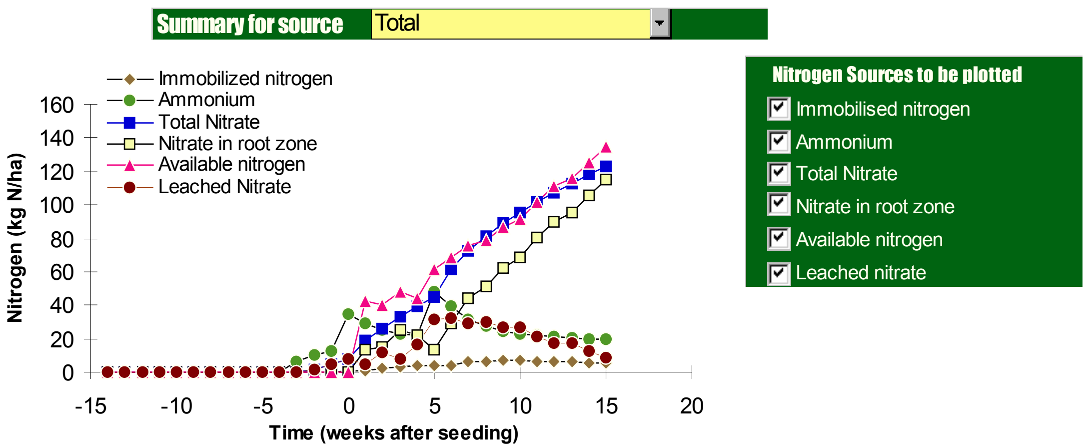

Figure 7: Forms graph – showing forms of nitrogen over time

Available nitrogen: This is nitrate (NO_3^-) and ammonium (NH_4^+) that is in the root zone (above the root depth at that time) and thus available for uptake by the plant.

Note: Only inorganic nitrogen; i.e. nitrate or ammonium, is available to plants. Organic nitrogen must be mineralized to ammonium (and then nitrate) before it can be used.

Ammonium: Ammonium nitrogen comes directly from fertiliser inputs or from the mineralisation of the organic nitrogen sources (SON, RON, and urea). Ammonium is assumed not to leach beyond the root depth and so is always available to the plant.

Total nitrate: This is the cumulated nitrate in the system and is the sum of the nitrate in the root zone and the leached nitrate. This is either a direct fertiliser input or comes from the conversion (nitrification) of ammonium from any source.

Nitrate in the root zone: This nitrate is above the root depth and so is available to the plant.

Leached nitrate: This is the nitrate below the root zone and so is unavailable for use by the plant. Prior to seeding, when no roots are present, this equals the total nitrate nitrogen.

Immobilised nitrogen: This is nitrogen that is immobilised through capture by microbes and so is not plant available or leachable.

Roots graph

This graph shows the rooting depth and the depth of the wetting front through time in weeks relative to seeding (Figure 8). If the wetting front is below the root zone then much of the nitrate may be unavailable to the plant. Nitrogen is only available to the plant if it is in the root zone. <u>Note:</u> the root zone is the area from the surface of the soil to the root depth.

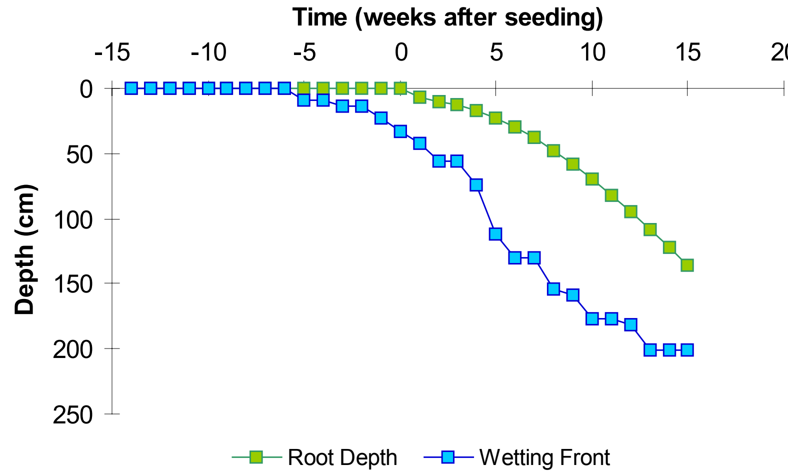

Figure 8: Roots graph – showing rooting depth and wetting front over time.

Profile graph

This graph shows the mineral (ammonium plus nitrate) nitrogen concentration (mgN/l) at different soil depths for a specified week after seeding (Figure 9). Mineral nitrogen that is above the root depth is available for uptake by the crop. The units (mg N per litre of soil) are unusual, but allow you to convert to kg/ha for any depth increment, without knowing soil bulk density or water content: 10 mg N/l is 10kgN/ha for each 10 cm of depth of soil.

For any nominated week after seeding, the mineral nitrogen concentration can be shown for any particular source or the total of all sources. You can animate the Figure to show leaching and root depth through time by moving the week slide from left to right.

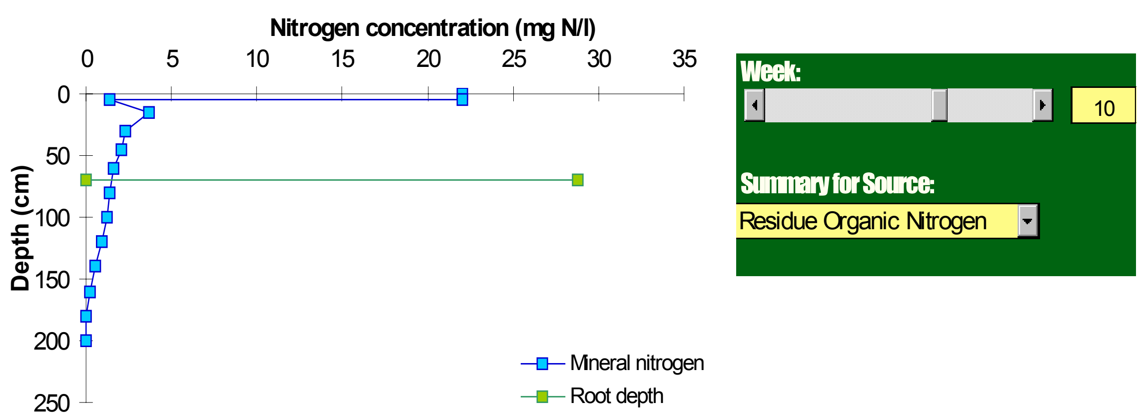

Figure 9: Profile graph – showing nitrogen concentration in soil profile

5. Sensitivity Analysis

SYN contains a worksheet called “Sensitivity Analysis” which allows you to carry out sensitivity analyses on three variables. These are rate of fertiliser applied, week that fertiliser is applied and potential yield. Results are shown for actual yield, protein, price received and net return. In addition to the table of results, results are also shown in graphical format. Summary statements of the input choices are shown to the left of the graph. If you leave the sensitivity analysis worksheet to change an input, you will need to re-run the analysis.

The sensitivity analysis component allows you to look at results for a range of values, without having to manually put each value in. This is particularly useful for investigating the effects of changes in these variables and looking at trends. Note that the sensitivity analyses are done with all other factors held constant. Thus the response to time of application may be marginal if the background nitrogen status is high or the rate of application of the fertiliser is low.

To conduct a sensitivity analysis, choose the variable you want to perform a sensitivity analysis on, from the drop down menu on the top right-hand side of the screen and click on the Run Sensitivity Analysis button. After you have conducted the sensitivity analysis, you can look at graphs of the results. Select which graph you want to look at (actual yield, protein/oil, price received and net return) using the buttons on the lower right hand side of the screen. To print out a report of the sensitivity analysis, click the Print Sensitivity Analysis button. The report shows the results and the four graphs.

Rate of fertiliser applied

This sensitivity analysis varies the rate of fertiliser applied between an upper and lower limit, which you specify. To change these upper and lower limits click on the “Change” button and then type new values into the form. SYN selects nine interval values in between this upper and lower limit and results are calculated for each of the eleven values. The program will calculate a sensitivity analysis for each of the fertilisers being used. You can look at the results of any one of them by selecting it from the drop down menu on the left side of the screen.

Week applied

This sensitivity analysis looks at varying the week at which the fertiliser is applied. You do not need to select an upper and lower limit; the program will automatically calculate results for each of the 14 weeks after seeding. As above, the program will calculate a sensitivity analysis for each of the fertilisers being used. You can look at the results of any one of them by selecting it from the drop down menu on the left side of the screen.

Potential Yield

This sensitivity analysis varies the potential yield between a range advised by the user. You need to select an upper and lower potential yield (click on the “Change” button to enter new values). The program will then select nine values in between the extremes and results will be calculated for each of the eleven potential yield values.

6. Technical Notes and Further Information

Nitrogen sources, cycling and availability

The following notes are abstracted from the “Estimating soil nitrogen status – ready reckoners” technote and the “NAVAIL spreadsheet” publication.

Nitrogen sources in SYN are residue organic nitrogen (RON), soil organic nitrogen (SON, also known as stable organic nitrogen) and fertilizer sources which comprise organic (urea), ammonium and nitrate forms of nitrogen (Figure 10). Organic sources are mineralized to ammonium (ammonification) according to source specific ammonification rates. Ammonium is then transformed to nitrate (nitrification). Note that denitrification (on water-logged soils, and de-ammonification (high pH moist soil surface conditions) are not modelled in SYN. Crops can only utilise nitrogen when it is in mineral form in the soil, that is, in the form of ammonium or nitrate.

Once nitrogen is in the form of nitrate, it becomes mobile in the soil and therefore is potentially able to be leached (Figure 10). In addition to mineralisation, nitrification and leaching, there is one other form of nitrogen cycling. Microbial organisms present in the soil can immobilise mineral nitrogen (Figure 10).

The mineralization rate of organic nitrogen to ammonium will vary from source to source. Residue organic nitrogen mineralizes relatively rapidly while soil organic nitrogen mineralizes slowly. Fertiliser nitrogen can be added in the form of urea, ammonium or nitrate. Urea hydrolyses quite rapidly to ammonium.

The nitrogen available to the crop from any particular source is the product of the availability index of that source and the amount originally present. Where the availability index is the mean of the weekly quantities of mineral nitrogen from that source which is residing in the root depth (expressed as a fraction of the total amount of that source).

Nitrate nitrogen is soil mobile and thus can be leached from the root zone. The degree of leaching depends on the downward movement of infiltrating rainfall which in turn, depends on the water holding characteristics of the soil type and the amount of that infiltrating rain. Thus the availability of nitrogen from any source in any week is highly dependent on the amount of nitrogen in the nitrate form as well as the rooting depth of the crop. Nitrogen availability can increase with time as roots grow down into previously leached nitrate

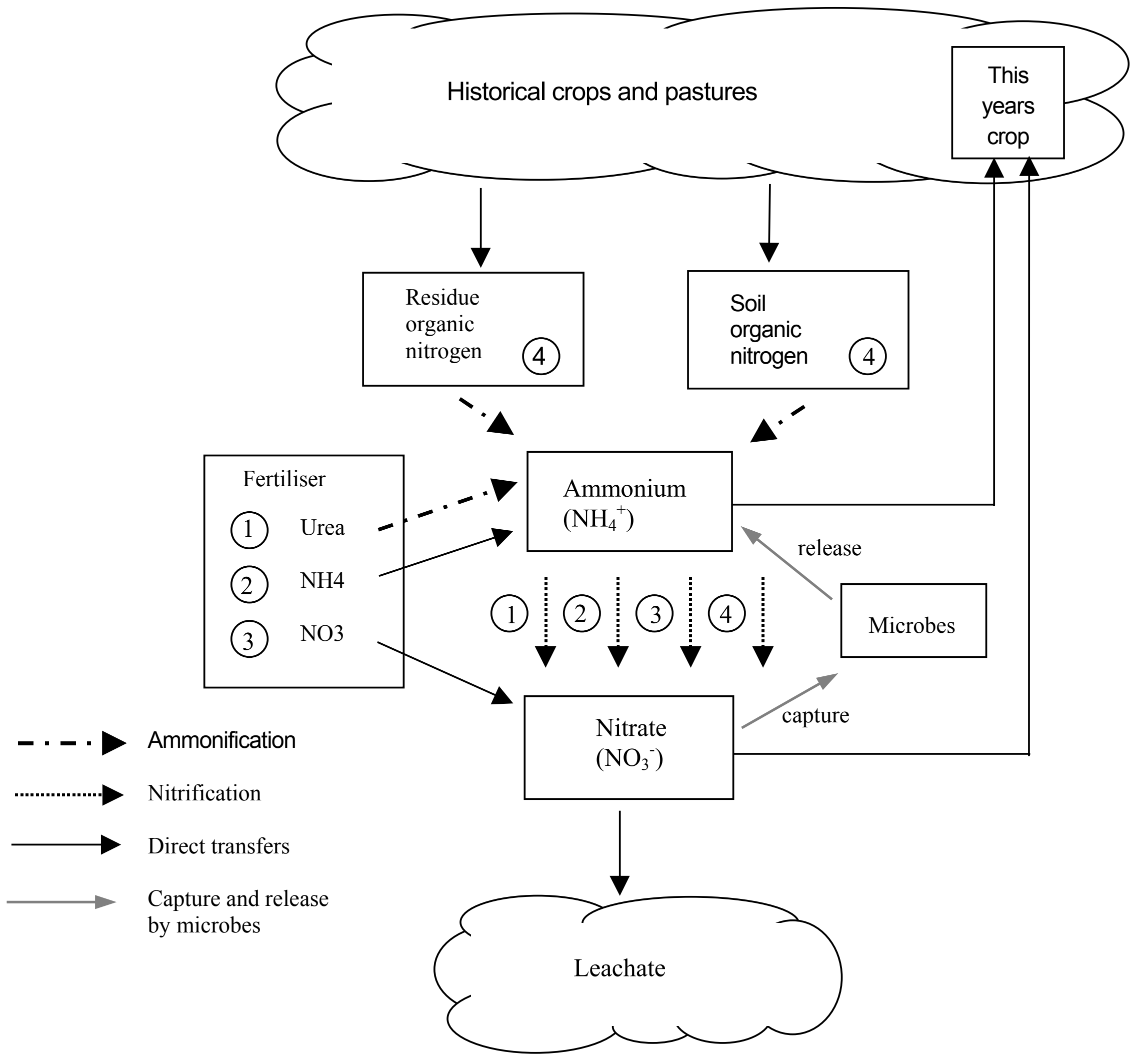

Figure 10: Soil and fertiliser nitrogen transformation processes

SYN calculations for grain yield, protein% and oil%

The model can be summarised by the following equations:

Grain yield = GY = A*(2*Nupt/(A*G) - (Nupt/(A*G))^2) (1)

where the constant 'G' = 0.04 for cereals and 0.07 for canola, when A is the nitrogen non-limited yield and has units of kg/ha and Nupt is the nitrogen uptake by the tops in kgN/ha

Nupt = A*z*tanh(Navail/(A*z)) (2)

where the constant 'z' = 0.06 for cereals and 0.07 for canola, when A has units of kg/ha. 'A*z' gives the maximum possible nitrogen uptake by the crop. In a less constrained version of the model, z could take values between 0.04 and 0.08 for cereals. Navail is the crop available nitrogen (kgN/ha) and is given by:

Navail = sum (K_{Ni}*Ni) (3)

where KNi is the scaled unit “availability” of nitrogen from source “i” and Ni are the kg N/ha of that source (see NAVAIL notes).

The protein% is a conversion of grain nitrogen (GN in kgN/ha) which is calculated from Nupt using a non-linear scalar to adjust a maximum nitrogen harvest index, here set equal to 0.9, downwards with increasing Nupt.

GN = Nupt*0.9*(A*K_{nhi}/(A*K_{nhi}+Nupt)) (4)

Protein% =pf*GN/GY (5)

where pf is the conversion factor for oven dry nitrogen to protein% on the basis of the appropriate moisture% in the grain.

Oil% in canola is derived from the calculated protein%

Oil% = 62 – protein% (6)

Where 62 is a parameter reflecting the average of hundreds of protein and oil data. The data range from 60 to 67.

References

NAVAIL Spreadsheet. (1992) S. J. Burgess, A. J. Diggle, J. W. Bowden and I. R. Fillery. Department of Agriculture, Western Australia, Miscellaneous publication 27/92

The Nitrogen Calculator (wheel). (1996). Department of Agriculture, Western Australia, CLIMA, GRDC and TopCrop West.

Estimating soil nitrogen status – ready reckoners (1993) Bill Bowden and Steve Burgess. Department of Agriculture, Western Australia, Technote No. 6/93

Summer Rain, Nitrogen and Your Crop (2001). Mark Chmielewski and Bill Bowden, Department of Agriculture, Western Australia, Farmnote 16/2001