A summary of four Australian bio-economic models for mixed grain farming systems

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Abstract

This report describes four models used to analyse Australian broadacre mixed-grain farm systems. The models that are included in this report are: IMAGINE, STEP, LUSO and APSfarm. For each model, we include a brief description of how they work, their data requirements and model outputs. IMAGINE is a bio-economic model that focuses on the impacts of tree belts on crop yields. The model accounts for the interactions between herbaceous and woody crops in terms of water and nutrient competition. Its financial analysis includes cash flow reporting. The STEP model simulates the transition from one farm system to another (mainly land-use sequence), and gives a full financial analysis of the change. LUSO simulates the impact of diseases, weeds and break crops on crop yields. LUSO reports discounted cash flows for different management strategies. The APSFarm model focuses on operational decisions. It simulates how the allocation of production and factor inputs affect farm business performance and the environment.

Key words: Bio-economic modeling, Farm systems modelling Grains, Mixed crop-livestock farming,

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Contents

1. IMAGINE

Aim/use	**Provides financial analysis of alternative land uses**
Objective	Simulation and sensitivity analysis
Time	Dynamic
Scale	Paddock/field
Used by	Researchers
Software	Matlab, Microsoft Access
Developers	Cooper and Abadi
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1.1 Introduction

IMAGINE is a bio-economic simulation model for evaluating alternative agricultural land use systems and land use sequences (LUSs). (Abadi and Cooper 2004). The purpose of IMAGINE is to fill the modeling and analytical gap that exists between crop growth simulation models such as APSIM and whole-farm optimisation models such as MIDAS (Farquharson et al., 2013). IMAGINE is designed to be flexible, allowing it to be adapted to different soil and climatic conditions on an adjustable field or paddock level. Regarding economic analysis it is able to analyse the impact on cash flow (e.g. NPV and AER) over time associated with seasonal and climatic conditions, using a rainfall module. The model allows for long term analysis, from one up to 50 years and operates on a monthly step for crop growth and cash flow. It accounts for variability in climate and prices. Its analysis can include both herbaceous and woody crops. Land-use activities which can be included are annual and perennial crops and pastures as well as tree crops. Perennial plants or crops may be in short or long rotation with annual crops. The model allows for spatial and temporal interactions between land-use activities within a field. The spatial interactions allow different spatial crop, pasture and tree crop configurations to be analysed, for example the integration of mallees belts into crops and pastures. Temporal interactions allow the user to analyse the sequence of a crop with other crops or pasture, for example the effect of a legume crop on a subsequent cereal crop (Abadi and Cooper, 2004). Regarding trees, the model also takes into account tree products other than timber, for example biomass, carbon sequestration, oil, fruit and forage.

IMAGINE includes a sensitivity analysis routine, allowing the user to identify economically important parameters.

1.2 How IMAGINE works

A range of subsequent land-use activities can be specified for a single or a block of fields or paddocks (see Figure 1). Land-use activities that can be included in the analysis are a range of annual and perennial crops and pastures and tree crops.

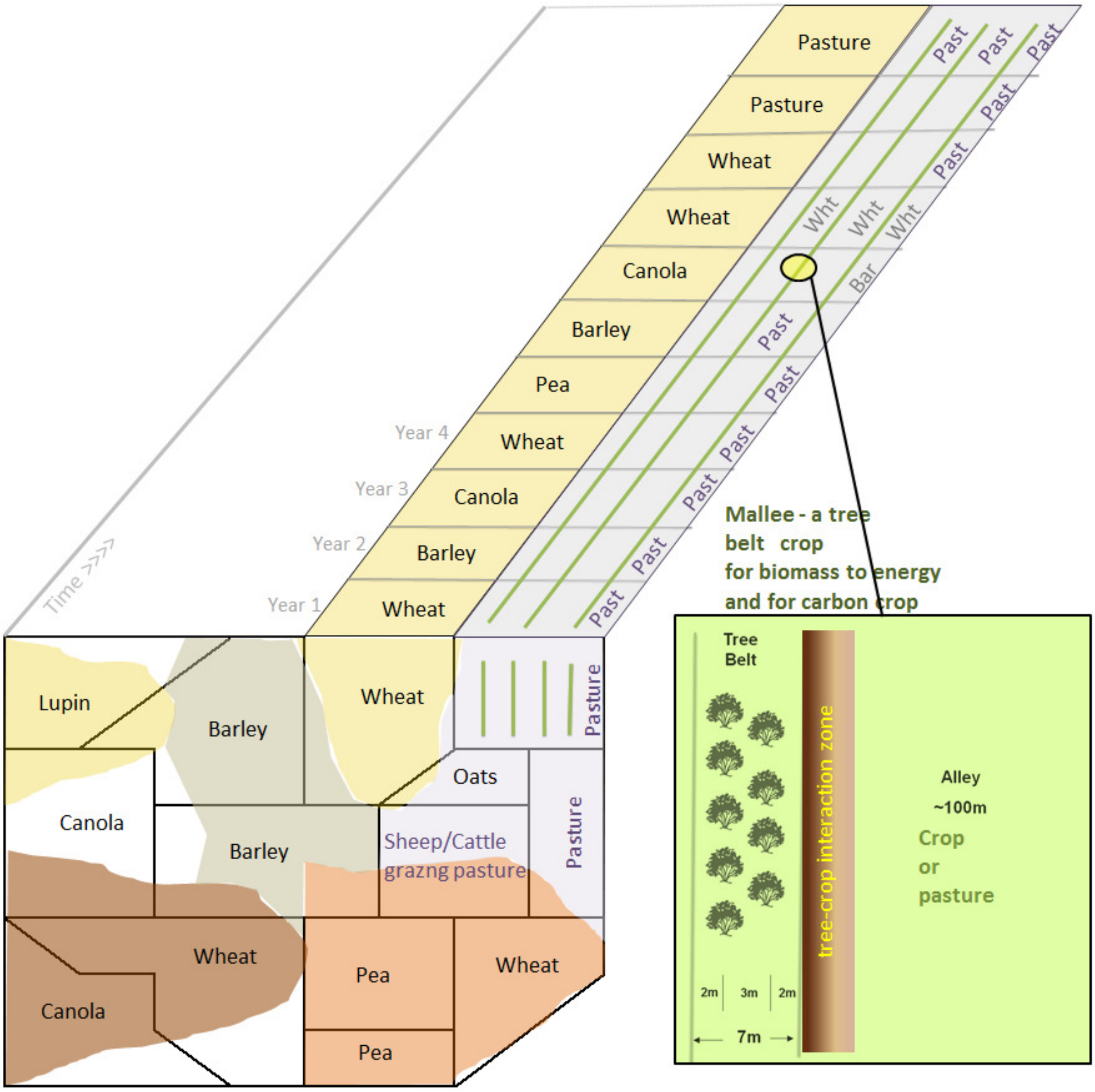

Figure 1.1 Modeling mixed land-use sequences (source: Abadi, 2013)

IMAGINE's analysis includes interaction between crops and trees, taking into account the competition for light, water and nutrients (see Figure 2). Moreover, including trees in paddocks would result in indirect benefits for crops (i.e. improving yields due to moisture storage and providing shelter). Crops and trees compete for water during dryer periods. However, when rainfall is at certain levels the trees store the moisture, keeping water available for future crop growth.

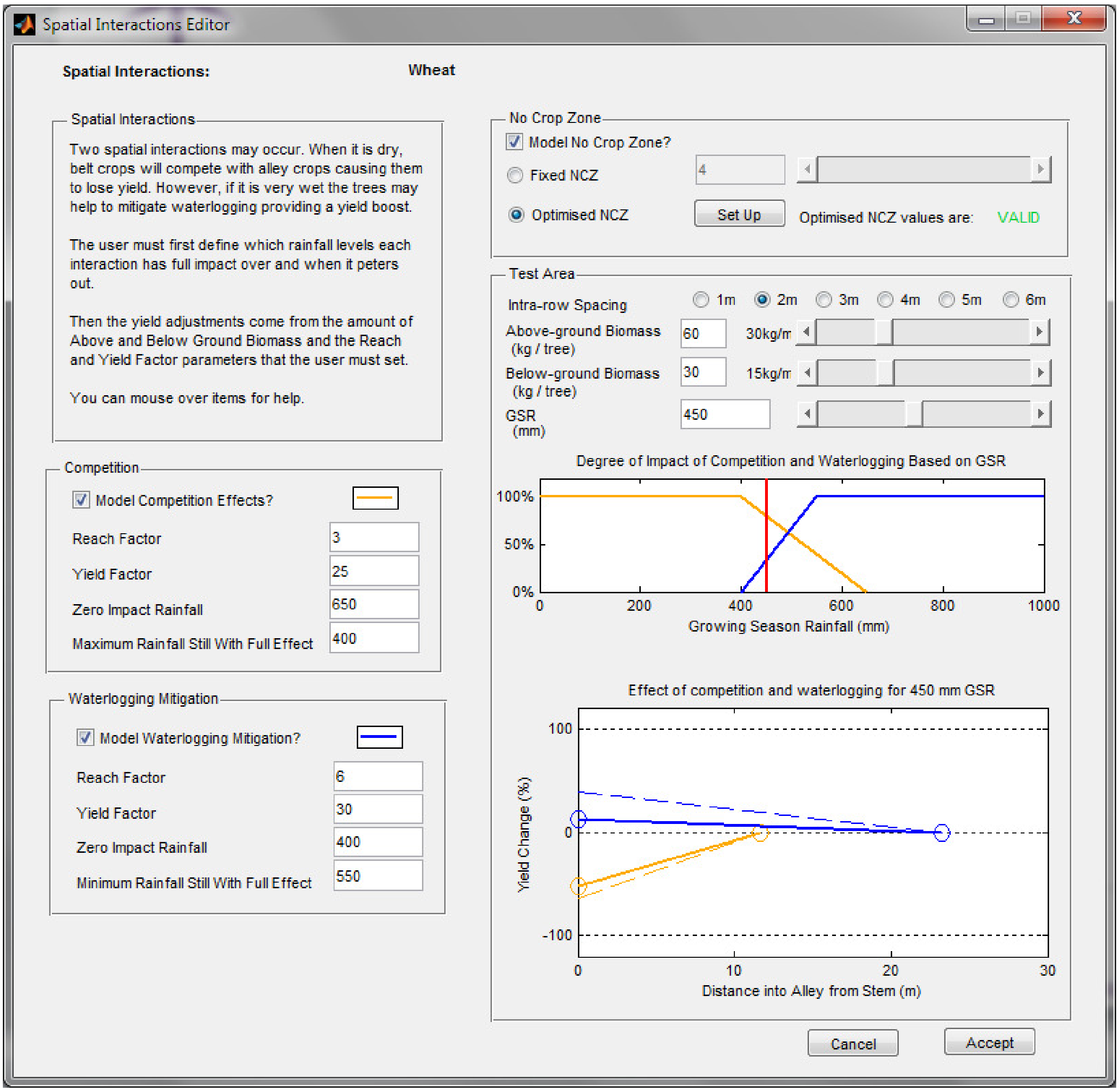

Figure 1.2 Spatial interactions set-up in IMAGINE

Figure 3 depicts the benefits and losses resulting from so called “alley farming”, where trees are planted in rows and crops grown in-between.

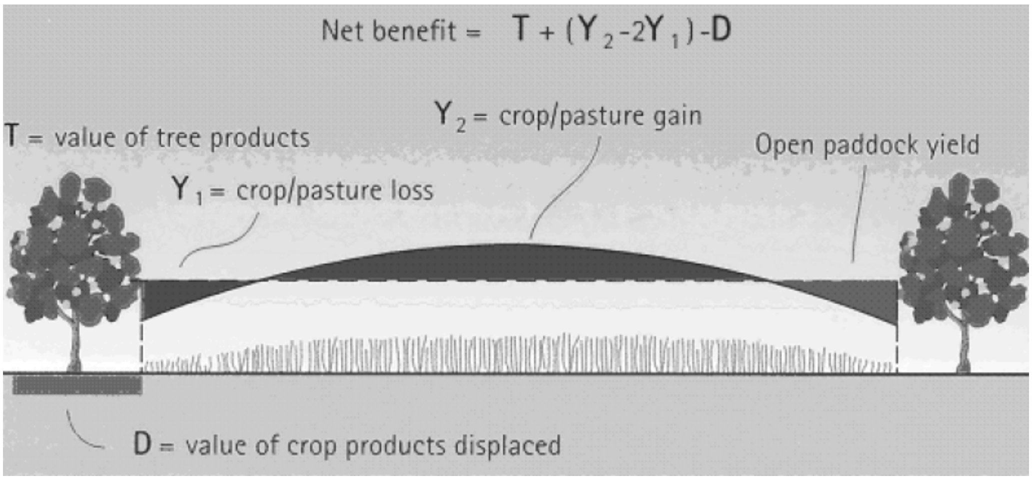

Figure 1.3 Net benefit of tree belts (source**:** Abadi and Cooper, 2004)

The net benefit of integrating tree belts with crops is a combination of the value of the tree product plus yield enhancement due to shelter, less the area of land displaced and the crop lost to competition.

Crop set-up

In the crop set-up sheet the user defines the number and types of different land-use activities and its sequence on the field area (see Figure 4). Numbers one to 50 represent simulation years. In this section the user defines the spatial layout of the field area, as can be seen in the coloured boxes. In this example a mallee belt is integrated in an annual crop regime (which is wheat in the first year).

The user can define the spatial tree layout in any configuration as desired, for example belts, alley systems or blocks (see Figure 5). This allows the user to test the performance of the different spatial layout configurations and temporal interactions for a field area over a predefined period of time.

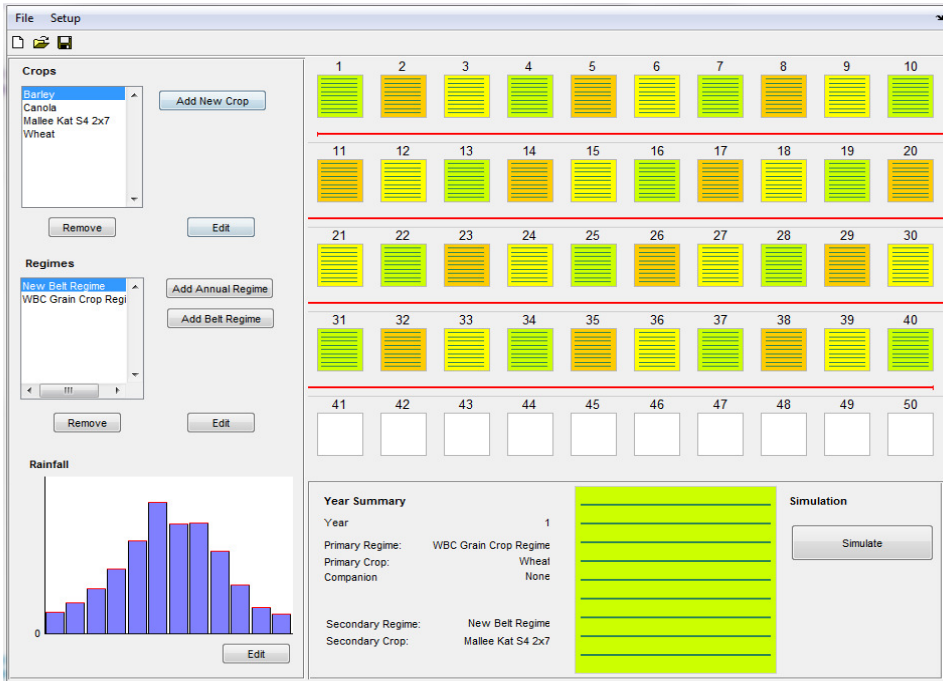

Figure 1.4 IMAGINE's crop set-up sheet

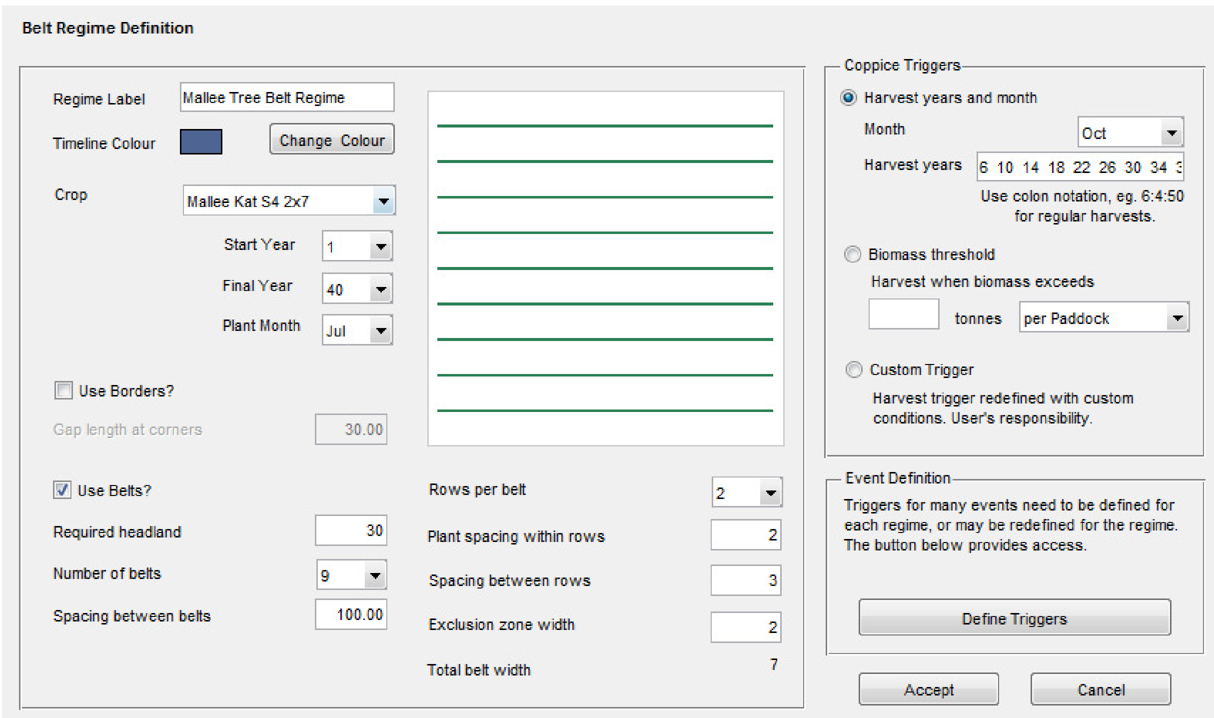

Figure 1.5 Belt regime spatial configuration

In the belt regime sheet the user enters the type of tree, year and month of planting and the final year. Several parameters regarding the tree configuration can be adjusted: number of belts, space between belts, space between rows, exclusion zone (space between trees and crops), etc. Harvesting can take place at a predefined month and harvest years. Another option is to implement a biomass threshold, triggering harvest when trees reach a user defined quantity of biomass.

Rainfall module

From the crop set-up sheet the user enters the Rainfall module. Here the user enters the amount and standard deviation of rainfall for each month throughout the year (see Figure 6). It is also possible to use historical weather data as input or to define a probabilistic distribution of variables, using mean values and standard deviation.

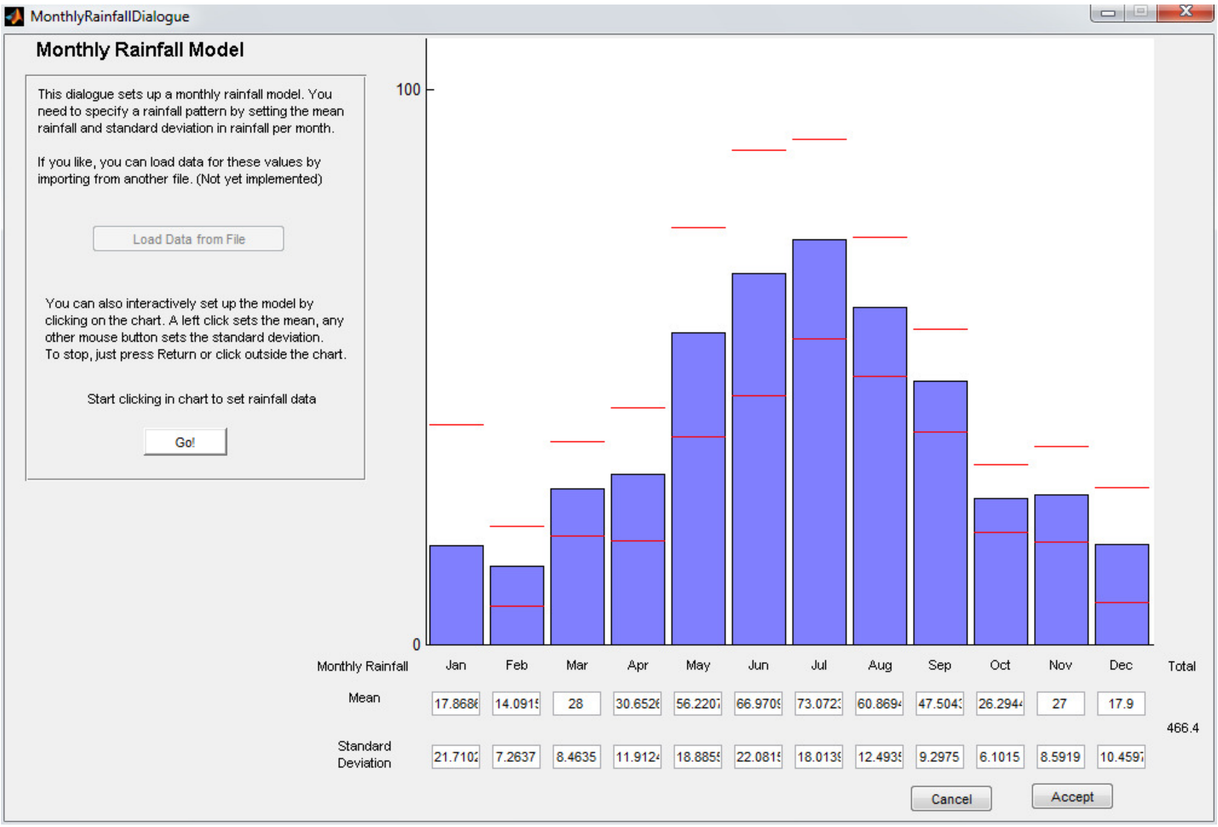

Figure 1.6 IMAGINE's rainfall module

Grain crop growth module

In the grain crop growth module (see Figure 7) the user defines yields, temporal interactions between crops (the effect a crop has on the yield of the subsequent crop) and spatial interactions between crops and trees (competition and yield benefits).

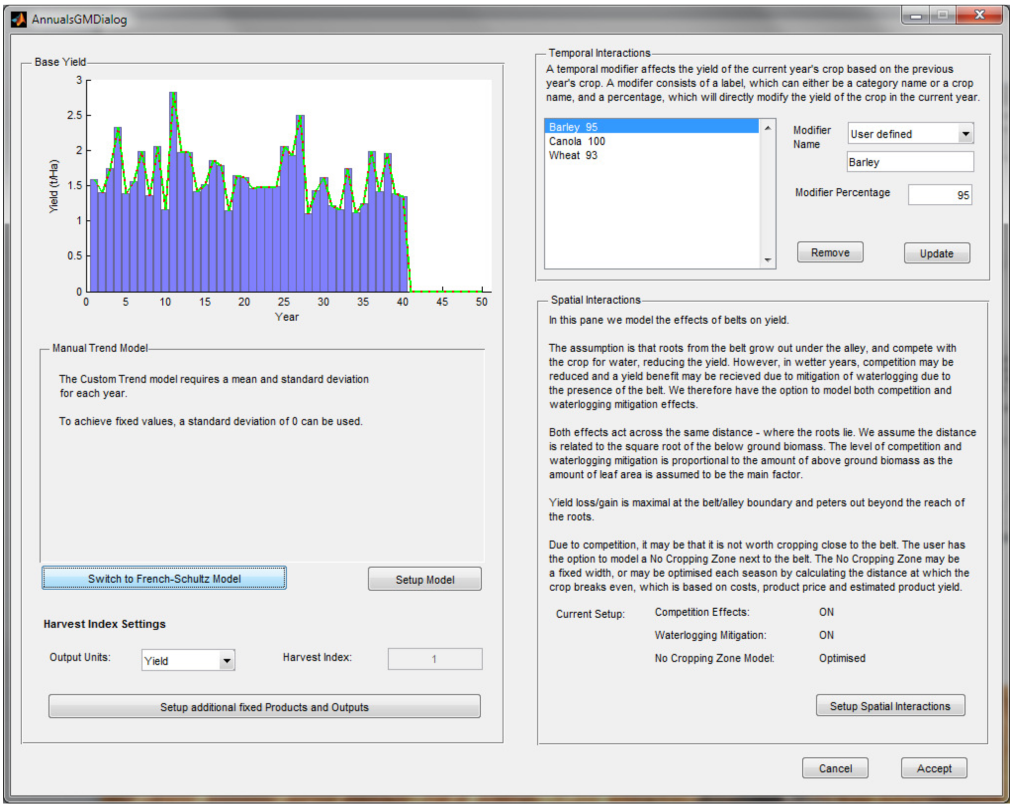

Figure 1.7 Grain crop growth module

Pasture and livestock module

In the livestock module the user enters prices and costs for wool and sheep. IMAGINE includes the possibility to import pasture growth data from GrassGro.

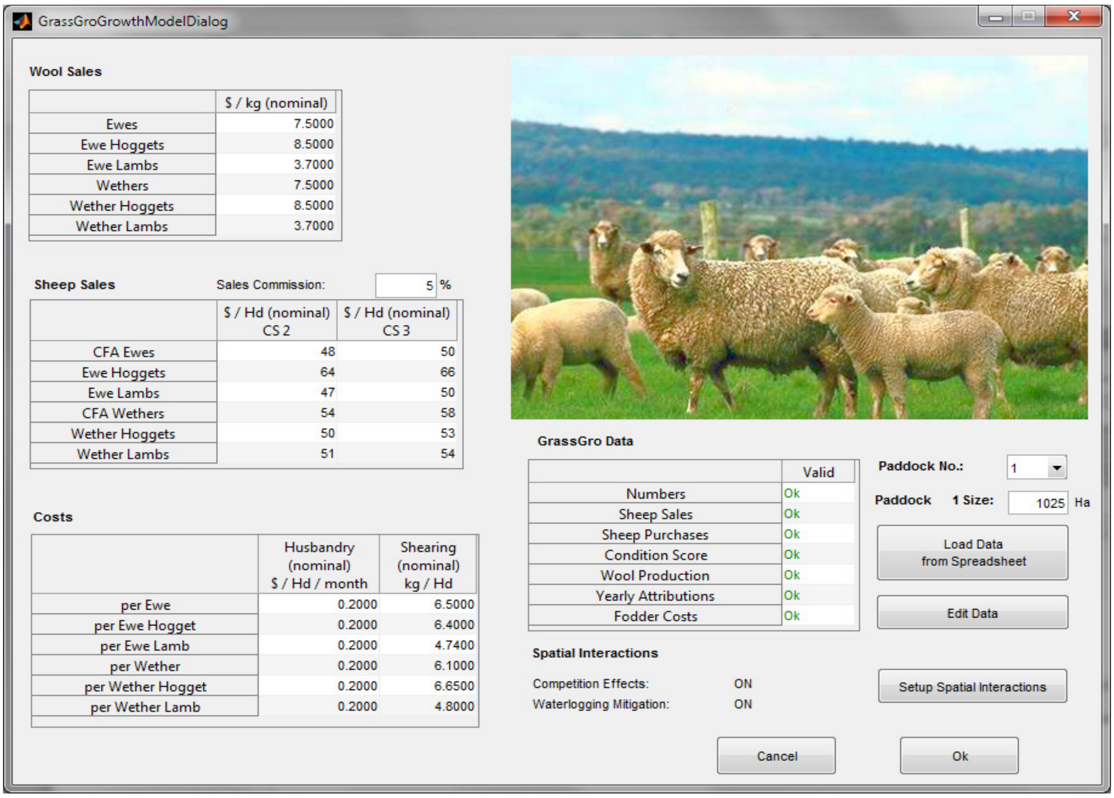

Figure 1.8 Livestock module

1.3 Model Inputs

IMAGINE allows the user to enter data such as rainfall, prices and costs from different sources. One option is to define a probabilistic distribution of variables, using mean values and standard deviation. This option also includes the possibility of defining a trend in the variable distribution, allowing for growth and decay in variables over time. Another option for the user is to enter historical data as input values. It is also possible to import (manually) yield and growth data from third party software as APSIM and GrassGro.

Model input parameters include yields, prices, costs, crop growth, rainfall, paddock dimensions, layout of belts, operating expenditure (establishment and maintenance, harvest, transport and cleanup), regimes for land use, harvest and other crops. Repeat bonuses/penalties (e.g. wheat after wheat), ravages of time (inflation, decline in yield, etc.) and interactions in space and time (competition and shelter, see parameter list below).

Parameters related to the interactions between crops/pasture and trees:

- Competition width
- Competition factor
- Shelter width
- Shelter factor
- Yield penalty for a cereal crop immediately following a cereal crop of the same species
- Yield penalty for a cereal crop immediately following a cereal crop of a different species
- Maximum yield penalty for a cereal crop following another crop – sets a ceiling
- Yield penalty for a lupin crop immediately following another lupin crop
- Yield penalty for a lupin crop immediately following another pulse crop - different species
- Maximum yield penalty for a lupin crop after a lupin or pulse crop – sets a ceiling

1.4 Model Output

IMAGINE reports outputs as tables and charts (see Figure 9). Moreover, there is a possibility to export outputs to Microsoft Access for further analysis.

IMAGINE's outputs include financial/economic data as well as physical and biological data such as rainfall and yield of crops. Its outputs can be used to compare profitability and cash flow of the alternative land use systems. The economic analysis results include net present value (NPV), annual equivalent value (AEV), minimum and maximum values of a cash flow over a period of time, and the standard deviation and coefficient of variation (see Figure 10). The NPV is used to calculate discounted cash flows of receipts. The AEV is useful to compare discounted receipts from projects with a different length, which overcomes the common difficulty of comparing an agroforestry projects with agricultural rotations. Variations in cash flow and prices can also be calculated using the standard devitiation and coefficient of variation of the income streams.

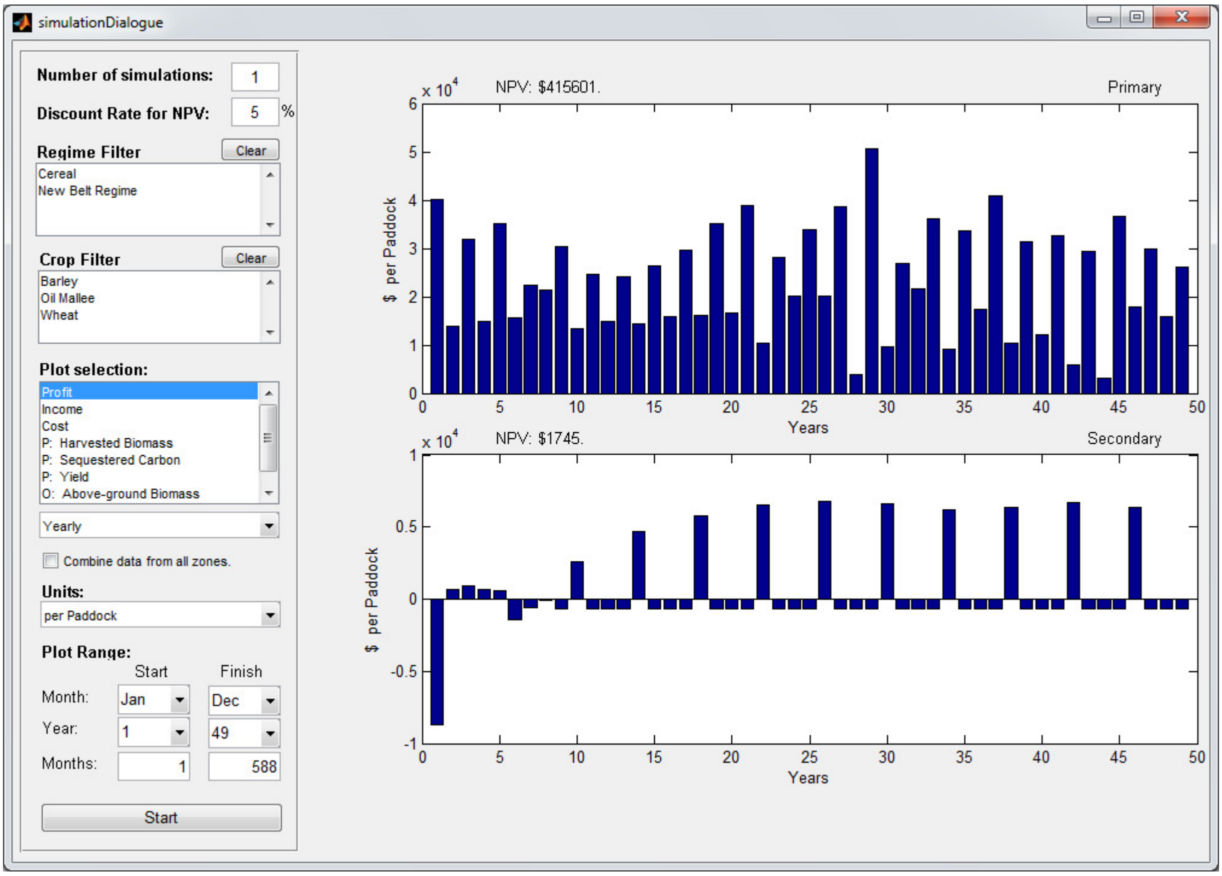

Figure 1.9 Simulation and output sheet

Wheat-barley-canola rotation on sandy loams (LMU 5) in Katanning		
Period	1972-2011	2012-2051
NPV ($/ha)	3379	3776
AEV ($/ha/annum)	253	283
Min ($/ha)	-48	-13
Max ($/ha)	894	656
Std Dev (%/ha)	233	213
cv: Stdev/AEV	92%	75%

Figure 1.10 IMAGINE's output data (source: Everfarm data from Farquharson et al 2013, NCCARF report)

2. STEP

Aim/use	Simulate costs of farming system transition
Objective	Simulation
Time	Dynamic
Scale	Whole farm
Used by	Consultants, farmers and researchers
Software	Excel, Visual interface: MS Visual Basic
Developers	Peek, Bennett, Herbert and Rogers
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2.1 Introduction

STEP (Simulated Transitional Economic Planning) is a tool to simulate whole-farm financial consequences of changing from one farm system to another. With STEP it is possible to compare different production possibilities and different enterprise options to get a strong indication of the viability of a new system compared to the old. The tool assists farm managers in assessing the risk of transition strategies as well as comparing rotations, integrating paddock management and whole-farm management decisions. The tool has been created in response to farmer demand. With increasing economic and environmental pressures farmers are considering changing their farming systems more than ever and need a tool to financially evaluate proposed changes.

STEP fills the gap between generating information from conventional financial tools such as gross margins, partial budgets and cost benefit information and practical implementation of a new system. After entering a few parameter values STEP automatically generates information over a number of years. Given the data links within the spreadsheet, sensitivity analysis of variables is easy and increases the user's overall understanding of the new system.

2.2 How STEP works

STEP is an Excel workbook consisting of a setup, land management unit (LMU), livestock tracking, budget, farm summary and a graph sheet (see Figure 1). A farm is represented by a series of land management units (LMU's), which is a grouping of land with the same production characteristics and rotation sequence. A LMU could be a group of paddocks or a single paddock. STEP's analysis only considers land that is used for production.

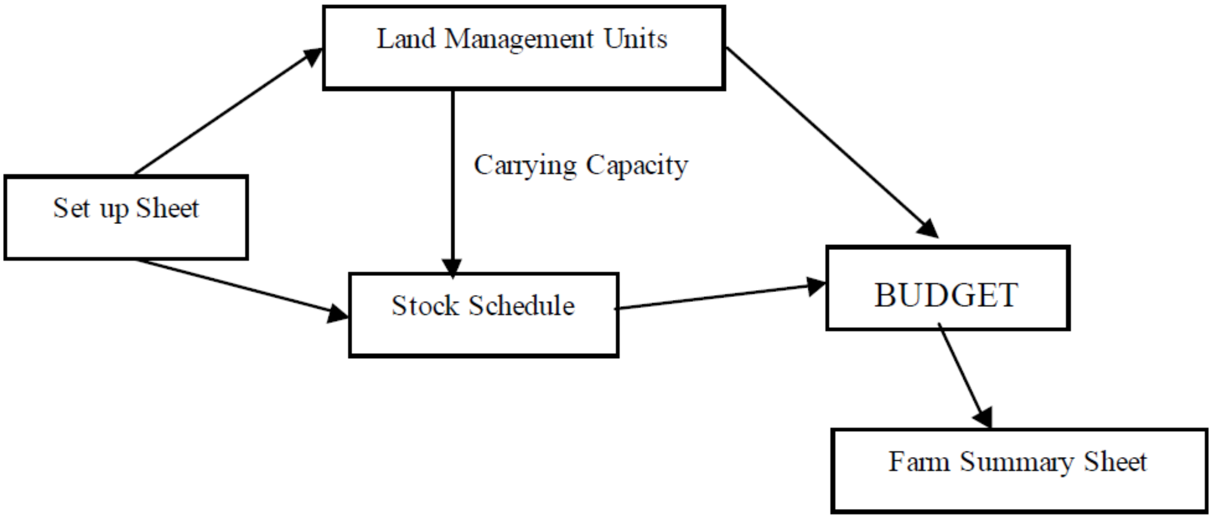


Figure 2.1 Conceptual representation of the STEP model (source: Bennett et al., 2003)

Setup sheet

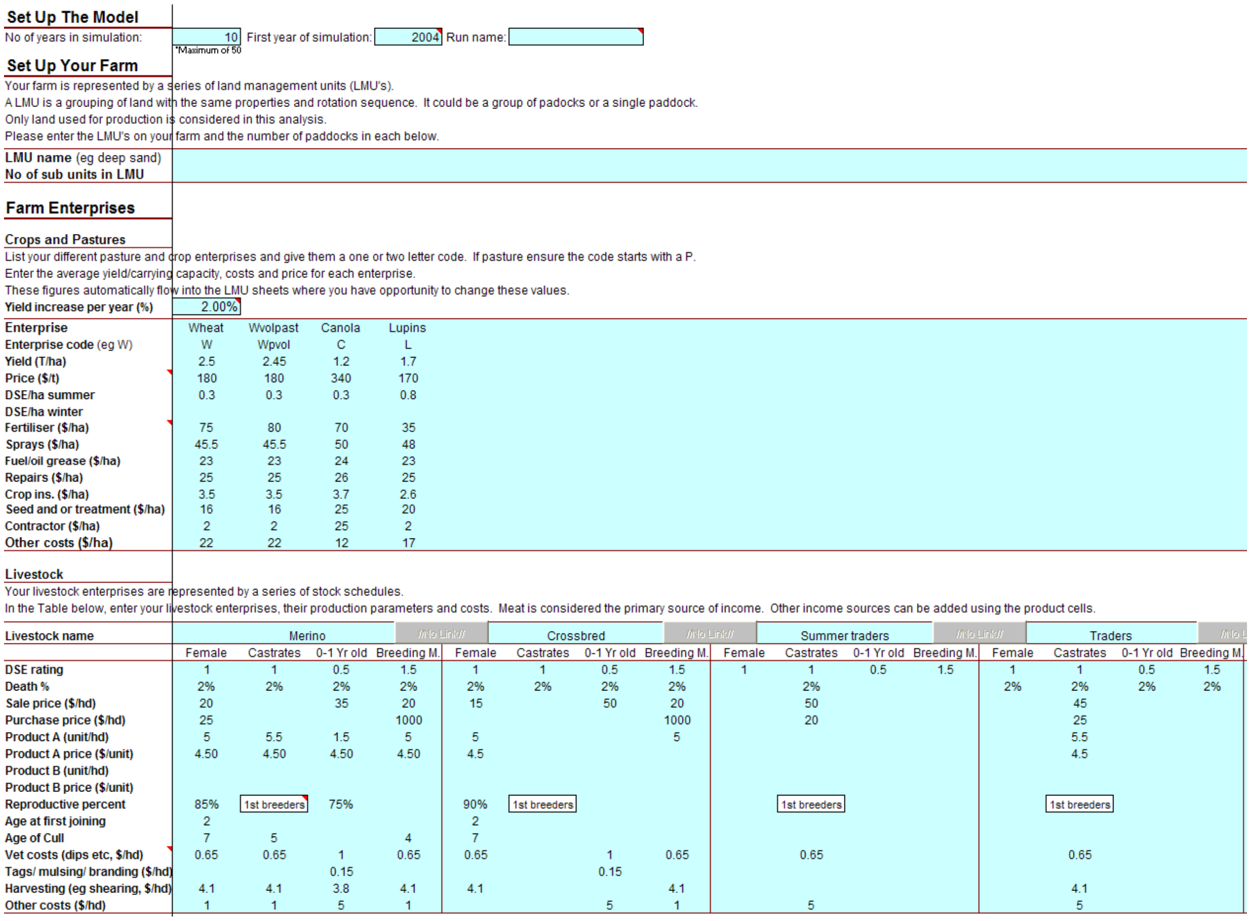
In the set up sheet the user enters the number of years in simulation (between 4 and 50), and determines the starting year of the simulation (see Figure 2).

In the farm set up section of the Set Up sheet the user determines the number of LMU's and the number of paddocks in each LMU. LMU labels that reflect the soil type or production system are most useful (e.g. deep sand).

In the crop and pasture section the user defines the number and types of different pasture and crop enterprises that are currently used on the farm or that will be used in the future. Crops and pastures that behave differently in terms of for example inputs or yields can be classified as a different enterprise (e.g. you could have wheat, wheat after lupins, and wheat on light land or pasture and pasture establishment). For each enterprise the user enters its production details (yields/ha, prices received and different types of costs/ha). For each enterprise a DSE (Dry Sheep Equivalent) summer and winter rating is required, which is used to calculate carrying capacity in the Livestock Sheet. This gives the user an indication of feed availability for livestock in winter and summer.

In the livestock section the user enters the names of the different livestock enterprises, production parameters (DSE rating, death percentage, reproductive percent, prices, etc) and costs.

After all the data is inserted in the Set Up sheet, the user enters the so called "transitional model". After this, additional LMU and livestock schedule workbooks are created according to the different crop and livestock enterprises defined in the Set Up sheet.



Set Up The Model

No of years in simulation: 10 *Maximum of 50 First year of simulation: 2004 Run name:

Set Up Your Farm

Your farm is represented by a series of land management units (LMU's).
A LMU is a grouping of land with the same properties and rotation sequence. It could be a group of padocks or a single paddock.
Only land used for production is considered in this analysis.
Please enter the LMU's on your farm and the number of paddocks in each below.

LMU name (eg deep sand)
No of sub units in LMU

Farm Enterprises

Crops and Pastures

List your different pasture and crop enterprises and give them a one or two letter code. If pasture ensure the code starts with a P.
Enter the average yield/carrying capacity, costs and price for each enterprise.
These figures automatically flow into the LMU sheets where you have opportunity to change these values.

Yield increase per year (%) 2.00%

Enterprise	Wheat	Wvolpast	Canola	Lupins
Enterprise code (eg W)	W	Wpvol	C	L
Yield (T/ha)	2.5	2.45	1.2	1.7
Price ($/t)	180	180	340	170
DSE/ha summer	0.3	0.3	0.3	0.8
DSE/ha winter				
Fertiliser ($/ha)	75	80	70	35
Sprays ($/ha)	45.5	45.5	50	48
Fuel/oil grease ($/ha)	23	23	24	23
Repairs ($/ha)	25	25	26	25
Crop ins. ($/ha)	3.5	3.5	3.7	2.6
Seed and or treatment ($/ha)	16	16	25	20
Contractor ($/ha)	2	2	25	2
Other costs ($/ha)	22	22	12	17

Livestock

Your livestock enterprises are represented by a series of stock schedules.
In the Table below, enter your livestock enterprises, their production parameters and costs. Meat is considered the primary source of income. Other income sources can be added using the product cells.

Livestock name	Merino			//No Link//	Crossbred			//No Link//
	Female	Castrates	0-1 Yr old	Breeding M.	Female	Castrates	0-1 Yr old	Breeding M.
DSE rating	1	1	0.5	1.5	1	1	0.5	1.5
Death %	2%	2%	2%	2%	2%	2%	2%	2%
Sale price ($/hd)	20		35	20	15		50	20
Purchase price ($/hd)	25			1000				1000
Product A (unit/hd)	5	5.5	1.5	5	5			5
Product A price ($/unit)	4.50	4.50	4.50	4.50	4.5			
Product B (unit/hd)								
Product B price ($/unit)								
Reproductive percent	85%	1st breeders	75%		90%	1st breeders		
Age at first joining	2				2			
Age of Cull	7	5		4	7			
Vet costs (dips etc, $/hd)	0.65	0.65	1	0.65	0.65		1	0.65
Tags/ mulsing/ branding ($/hd)			0.15				0.15	
Harvesting (eg shearing, $/hd)	4.1	4.1	3.8	4.1	4.1			4.1
Other costs ($/hd)	1	1	5	1			5	1

Livestock name	Summer traders			//No Link//	Traders			//No L
	Female	Castrates	0-1 Yr old	Breeding M.	Female	Castrates	0-1 Yr old	Breeding M.
DSE rating	1	1	0.5	1.5	1	1	0.5	1.5
Death %		2%			2%	2%	2%	2%
Sale price ($/hd)		50				45		
Purchase price ($/hd)		20				25		
Product A (unit/hd)						5.5		
Product A price ($/unit)						4.5		
Product B (unit/hd)								
Product B price ($/unit)								
Reproductive percent		1st breeders				1st breeders		
Age at first joining								
Age of Cull								
Vet costs (dips etc, $/hd)		0.65				0.65		
Tags/ mulsing/ branding ($/hd)								
Harvesting (eg shearing, $/hd)						4.1		
Other costs ($/hd)		5				5		

Figure 2.2 STEP's Set Up sheet

LMU sheet

In the Rotation In formation section of the LMU sheet the user enters the current and future rotation (in case rotation changes) (see Figure 3). There is a possibility to include transition years. Transition years are years between the current and future rotation, these are typically enterprises that will not be repeated in the old or new rotation. For example, a transition year may be an extra year of pasture to reduce weed levels before moving into a new rotation.

In the Sub Unit Information section the user enters the size of the paddocks in the LMU and specifies the corresponding sequence year which the paddocks are in. For each paddock it is possible to include transition years.

After all the data is entered in the LMU Sheet, de simulation can be run by clicking on the “Run simulation” button on the top of the sheet. After the simulation is run, each of the paddock rotations can be expanded to show the costs and benefits that have been imported from the Set Up Sheet. Changes made manually in the rotation section to yields and costs will also be shown here. It is possible to alter these costs and benefits for each stage of the rotation in this table.

deep sand Land Management Unit. Run Simulation

Rotation Information

Enterprise Letter Code Reminder.

Enterprise	Wheat	Wvolpas	Canola	Lupins
Enterprise code (eg W)	W	Wpvol	C	L

Current Rotation. Choose the rotation using the enterprise codes listed above. The rotation cell background will turn dark blue if a letter that does not represent an enterprise is used.

Sequence Year	1	2	3
Enterprise	C	W	L

Future Rotation. Are you changing to a new rotation? If yes, fill in the future rotation.

Sequence Year	1	2	3
Enterprise	Wpvol	C	W

Transition Years. Are there a number of expensive years of transition moving into the future rotation? If yes, fill in the transition years.

Sequence Year	
Enterprise	

Sub Unit Information

Total Farm Ha	100
Total LMU Ha	100

Sub Unit Names	ha	Sequence yr in current rot.	Transition yr (eg 2002)	Include transition yrs? 1=yes
Paddock 1	100	2		

Simulation

Rotation Simulation	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
Paddock 1	W	L	C	W	L	C	W	L	C	W
Yield (T/ha)	2.5	1.7	1.2	2.5	1.7	1.2	2.5	1.7	1.2	2.5
Price ($/t)	180	170	340	180	170	340	180	170	340	180
DSE/ha summer	0.3	0.8	0.3	0.3	0.8	0.3	0.3	0.8	0.3	0.3
DSE/ha winter	0	0	0	0	0	0	0	0	0	0
Fertiliser ($/ha)	75	35	70	75	35	70	75	35	70	75
Sprays ($/ha)	45.5	48	50	45.5	48	50	45.5	48	50	45.5
Fuel/oil grease ($/ha)	23	23	24	23	23	24	23	23	24	23
Repairs ($/ha)	25	25	26	25	25	26	25	25	26	25
Crop ins. ($/ha)	3.5	2.6	3.7	3.5	2.6	3.7	3.5	2.6	3.7	3.5
Seed and or treatment	16	20	25	16	20	25	16	20	25	16
Contractor ($/ha)	2	2	25	2	2	25	2	2	25	2
Other costs ($/ha)	22	17	12	22	17	12	22	17	12	22

Figure 2.3 STEP’s land management unit (LMU) sheet

Stock Schedule sheet

In the Stock Schedule the user enters the number of livestock present on the farm. According to production parameters entered in the Livestock Section of the Set Up sheet, the number of births, deaths, sales, purchases and transfers will automatically be calculated. It is the user's responsibility to ensure the total farm dry sheep equivalents (DSE) does not exceed the carrying capacity of the farm.

Livestock Tracking

Year		2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Carry cap. summer (DSE)		5700	3950	4800	4450	5300	5900	6200	6200	6200	6200
Carry cap. winter (DSE)		7200	5850	8050	8500	10700	11700	12200	12200	12200	12200
Max Merino DSE		7111	5947	4584	1	0	0	0	0	0	0
Max Cattle DSE		0	0	3200	6400	8000	8800	9600	9600	9600	9600
End Merino DSE		4832	3703	1	0	0	0	0	0	0	0
End Cattle DSE		0	0	0	0	0	0	0	0	0	0
Total Farm Max DSE		7111	5947	7784	6401	8000	8800	9600	9600	9600	9600
Class		Merino									
Start numbers	No.	8172	7007	5452	1	0	0	0	0	0	0
(includes 0-1 y.o.)	DSE	7084	5929	4584	1	0	0	0	0	0	0
Deaths	No.	161	136	106	1	0	0	0	0	0	0
	DSE	139	115	89	1	0	0	0	0	0	0
Purchases	No.	18	12	0	0	0	0	0	0	0	0
	DSE	27	18	0	0	0	0	0	0	0	0
Transfers In	No.	0	0	0	0	0	0	0	0	0	0
	DSE	0	0	0	0	0	0	0	0	0	0
Transfers Out	No.	0	0	0	0	0	0	0	0	0	0
	DSE	0	0	0	0	0	0	0	0	0	0
Sales	No.	3216	3193	5345	0	0	0	0	0	0	0
	DSE	2140	2129	4494	0	0	0	0	0	0	0
End numbers	No.	4813	3690	1	0	0	0	0	0	0	0
	DSE	4832	3703	1	0	0	0	0	0	0	0
Product A		34501	28441	21851	5	0	0	0	0	0	0
Product B		0	0	0	0	0	0	0	0	0	0
Excess summer grazing available DSE											
Summer DSE - Tot. End DSE		868.	247.	4799.	4450.	5300.	5900.	6200.	6200.	6200.	6200.
Costs and returns summary											
Returns											
Merino Product A		155254.5	127984.5	98327.25	22.5	.					
Merino Product B		.	.	.	.	.	.	.	.	.	.
Merino Sales		175015.	173700.	228385.	.	.	.	.	.	.	.
Costs							.	.	.	.	.
Vet costs (dips etc, $/hd)		6098.4	5330.25	4160.5	.65	.					
Tags/ mulsing/ branding ($/hd)		332.1	329.1	264.3	.	.	.	.	.	.	.
Harvesting (eg shearing, $/hd)		32685.2	27914.7	21718.	4.1	.	.	.	.	.	.
Other costs ($/hd)		17046.	15795.	12500.	1.	.	.	.	.	.	.
Purchases		9000.	6000.	.	.	.	.	.	.	.	.

Figure 2.4 STEP's Livestock Tracking sheet

Budget

The budget sheet gives an overview of all the income and costs on the farm for the different simulation years (see Figure 5), which is mainly calculated from data entered in the Set Up, LMU and Livestock Sheet. The user is able to enter a range of variable and fixed costs (labour, machinery, education, etc). It is also possible to add additional income and costs in the Budget Sheet. The Budget sheet also requires the user to enter tax and interest information.

Transition Tracking Budget

Item	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	
Income	$330,270	$301,685	$606,712	$560,023	$700,000	$770,000	$840,000	$840,000	$840,000	$840,000	
Income per ha	$236	$215	$433	$400	$500	$550	$600	$600	$600	$600	
+ Crops:	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	
+ Livestock:	$330,270	$301,685	$606,712	$560,023	$700,000	$770,000	$840,000	$840,000	$840,000	$840,000	
+ Other:	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	
Expenditure	$272,872	$285,724	$406,961	$520,646	$602,176	$625,628	$663,432	$663,432	$667,592	$663,432	
+ Crops:	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	
+ Livestock:	$109,262	$121,619	$238,193	$347,506	$425,900	$448,450	$484,800	$484,800	$488,800	$484,800	
+ Other variable costs:	$14,000	$14,000	$14,000	$14,000	$14,000	$14,000	$14,000	$14,000	$14,000	$14,000	
+ Fixed costs:	$29,500	$29,500	$29,500	$29,500	$29,500	$29,500	$29,500	$29,500	$29,500	$29,500	
Operating costs	$152,762	$165,119	$281,693	$391,006	$469,400	$491,950	$528,300	$528,300	$532,300	$528,300	
Operating costs/ha	$109	$118	$201	$279	$335	$351	$377	$377	$380	$377	
+ Capital and other:	$120,110	$120,605	$125,268	$129,640	$132,776	$133,678	$135,132	$135,132	$135,292	$135,132	
Taxation	$15,386	$15,386	$9,096	$24,913	$20,465	$21,115	$25,519	$34,284	$32,301	$39,944	
Surplus/Deficit	$42,011	$575	$190,655	$14,464	$77,359	$123,257	$151,049	$142,284	$140,107	$136,624	
Starting balance	$0										
Cumulative position (before inte	$42,011	$42,586	$233,241	$247,705	$325,064	$448,322	$599,371	$741,655	$881,762	$1,018,386	
Interest @ (-ve,+ve surplus/defi	10%	8%									
Interest paid (-ve as outgoing)	$3,361	$3,407	$18,659	$19,816	$26,005	$35,866	$47,950	$59,332	$70,541	$81,471	
Cumulative position (after interest and tax)	$45,372	$49,354	$258,668	$292,949	$396,313	$555,436	$754,435	$956,051	$1,166,699	$1,384,794	
Operating surplus (= Income minus variable costs minus fixed costs (excludes all interest))											
Operating surplus	$177,508	$136,565	$325,019	$169,017	$230,600	$278,050	$311,700	$311,700	$307,700	$311,700	
Operating Surplus/ha	$127	$98	$232	$121	$165	$199	$223	$223	$220	$223	
Taxation Calculator	This allows the user to estimate tax paid, but his will need to be manually entered into the taxation line										
Taxable income	$51,287	$9,356	$188,484	$23,736	$79,048	$124,694	$155,436	$155,436	$151,116	$155,436	$0
Percent tax paid	30%	30%	30%	30%	30%	30%	30%	30%	30%	30%	
Tax paid (5 yr average)	$15,386.06	$15,386.06	$9,096.42	$24,912.68	$20,464.73	$21,114.67	$25,519.09	$34,283.90	$32,301.02	$39,943.80	$0.00

Figure 2.5 STEP’s Budget sheet

Farm Summary sheet

The Farm Summary Sheet provides an overall summary of the simulation analysis. It gives financial and production summary information (see Figure 6).

1	**Summary of Operations**	WLWcz hcz hcz			Save Run							
2	**Terms of trade**											
3	Percent increase in returns	2%										
4	Percent increase in costs	3%										
5	Discount rate	7%										
6	**Net Present Value**	-$323,487										
7												
8	**Financial Information Sum**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	
9	Cumulative position (after intere	-$61,887	-$91,293	-$146,060	-$200,928	-$242,300	-$294,836	-$301,065	-$338,851	-$383,368	-$418,083	
10	Operating surplus	$177,003	$215,584	$198,297	$201,777	$219,779	$213,660	$275,455	$252,580	$255,725	$276,564	
11	Operating surplus per ha	$51	$62	$57	$58	$63	$61	$79	$72	$73	$79	
12	Gross Income from Crops	$660,972	$738,201	$718,060	$734,965	$770,473	$775,053	$894,939	$869,027	$888,014	$929,429	
13	Gross Income from crops per h	$343	$365	$371	$391	$412	$416	$443	$449	$472	$497	
14	Gross Income from Livestock	$242,077	$246,897	$251,835	$256,872	$262,009	$267,250	$272,595	$278,046	$283,607	$289,280	
15	Gross income from stock per h	$154	$167	$161	$159	$161	$163	$184	$178	$175	$177	
16	Gross Income	$903,049	$985,099	$969,896	$991,837	$1,032,482	$1,042,302	$1,167,534	$1,147,074	$1,171,622	$1,218,709	
17	Gross Income per ha	$258	$281	$277	$283	$295	$298	$334	$328	$335	$348	
18	Crop Variable Costs per ha	$224	$233	$237	$247	$255	$258	$270	$275	$286	$295	
19	Livestock Variable Costs per ha	$127	$135	$135	$136	$140	$144	$156	$156	$158	$162	
20	Total Variable Costs per ha	$190	$202	$202	$207	$213	$217	$234	$234	$240	$247	
21	Fixed Costs per ha	$17	$18	$18	$19	$19	$20	$20	$21	$22	$22	
22	Capital costs	$197,858	$203,116	$204,877	$207,341	$210,813	$214,495	$221,490	$223,802	$226,834	$230,891	
23	Capital costs per ha	$57	$58	$59	$59	$60	$61	$63	$64	$65	$66	
24	Total Costs	$952,946	$1,002,515	$1,005,567	$1,026,323	$1,052,399	$1,071,729	$1,143,452	$1,147,388	$1,171,652	$1,201,919	
25	Total Costs per ha	$272	$286	$287	$293	$301	$306	$327	$328	$335	$343	
26	Annual Surplus/Deficit	-$61,887	-$29,406	-$54,767	-$54,868	-$41,372	-$52,535	-$6,230	-$37,786	-$44,517	-$34,716	
27	**Production Information Summary**											
28	Enterprise hectares (total)	**3500**	**3500**	**3500**	**3500**	**3500**	**3500**	**3500**	**3500**	**3500**	**3500**	
29	Crop hectares	1925	2020	1935	1880	1870	1865	2020	1935	1880	1870	**1920**
30	Pasture hectares	1575	1480	1565	1620	1630	1635	1480	1565	1620	1630	**1580**
31	Wheat	150	150	150	150	150	150	150	150	150	150	**150**
32	Wpvol	0	0	0	0	0	0	0	0	0	0	
33	Canola	0	0	0	0	0	0	0	0	0	0	
34	Lupins	650	560	660	565	505	650	560	660	565	505	**588**
35	volpasture	0	0	0	0	0	0	0	0	0	0	
36	Cadiz	0	0	0	0	0	0	0	0	0	0	
37	Wcadiz	560	660	565	505	650	560	660	565	505	650	
38	Hsserra	1525	1430	1515	1570	1580	1585	1430	1515	1570	1580	**1530**
39	Biserrula	0	0	0	0	0	0	0	0	0	0	
40	Subclover	0	0	0	0	0	0	0	0	0	0	
41	Wheat 2yr	0	0	0	0	0	0	0	0	0	0	
42	Wheat (-dr)	0	0	0	0	0	0	0	0	0	0	
43	Sub dr	0	0	0	0	0	0	0	0	0	0	

Figure 2.6 STEP's Farm Summary sheet

2.3 Model inputs

Set Up sheet

- Number of years of the simulation and the starting year

Land management units (LMU's)

- Name of the LMU
- Number of paddocks (or sub units) in each LMU

Crop and pastures

- Yield increase per year
- Enterprise name and code
- Yield (T/ha)
- Price ($/t)
- DSE/ha summer
- DSE/ha winter
- Fertiliser ($/ha)
- Sprays ($/ha)
- Fuel/oil grease ($/ha)
- Repairs ($/ha)
- Crop ins. ($/ha)
- Seed and or treatment ($/ha)
- Contractor ($/ha)
- Other costs ($ / ha)

Livestock

- DSE rating
- Death %
- Sale price ($/hd)
- Purchase price ($/hd)
- Product A (unit/hd)
- Product A price ($/unit)
- Product B (unit/hd)
- Product B price ($/unit)
- Reproductive percent
- Age at first joining
- Age of Cull

- Vet costs (dips etc, $/hd)
- Tags/ mulsing/ branding ($/hd)
- Harvesting (eg shearing, $/hd)
- Other costs ($/hd)

LMU Sheet

- Current rotation
- Future rotation
- Transition years
- Sizes of paddocks in the LMU
- Sequence year in current rotation per paddock
- Transition year per paddock

Stock schedule sheet

- Female numbers per age category
- Castrate numbers per age category
- Female numbers transferred in per age category
- Castrate numbers transferred in per age category
- Female numbers transferred out per age category
- Castrate numbers transferred out per age category
- Breeding males sales

Budget sheet

- Other income sources (if applicable)
- Freight expenditure (crops)
- Repairs and maintenance expenditure (livestock)
- Fuel, oil and grease expenditure (livestock)
- Wool Packs expenditure (livestock)
- Freight expenditure (livestock)
- Other variable costs (Lime, Other, Labour and Training)
- Annual depreciation
- Capital development (crops)
- Capital development (stock)
- Principal repayment on loans
- Personal drawings/education
- Overdraft interest rate

- Taxation
- Starting balance
- Interest rate if deficit
- Interest rate if surplus
- Percent increase in returns (term of trade)
- Percent increase in costs (terms of trade)
- Discount rate (terms of trade)

If desired, income and costs can be altered to the user's specific needs

2.4 Model outputs

All output is calculated for the number of simulation years the user enters in the Set Up sheet.

Budget sheet

Income

- Total income
- Income per hectare
- Total crop income
- Income generated per crop enterprise
- Total livestock income
- Income generated per livestock enterprise

Expenditure

- Total expenditure

Crop expenditure

- Total crop expenditure
- Fertiliser ($/ha)
- Sprays ($/ha)
- Fuel/oil grease ($/ha)
- Repairs ($/ha)
- Crop ins. ($/ha)

- Seed and or treatment ($/ha)
- Contractor ($/ha)
- Other costs ($/ha)
- Freight

Livestock expenditure

- Total livestock expenditure
- Vet costs (dips etc, $/hd)
- Tags/ mulsing/ branding ($/hd)
- Harvesting (eg shearing, $/hd)
- Other costs ($/hd)
- Purchases
- Pasture est. & maint. Costs
- Repairs & maint.
- Fuel,oil and grease
- Wool Packs
- Freight
- Fodder

Other variable costs

- Total other variable costs
- Lime
- Other
- Labour
- Training
- Total fixed costs
- Overheads/fixed costs

Operating costs

- Operating costs
- Operating costs/ha

Capital and other

- Capital and other expenditure

- Machinery
- Average annual loan repayments
- Capital development –crops
- Capital development –stock
- Education
- Personal drawings

Tax and interest

- Surplus/Deficit
- Cumulative position (before interest)
- Interest paid (-ve as outgoing)
- Cumulative position (after
- Interest and tax)

Operating surplus

- Operating surplus
- Operating Surplus/ha

Farm Summary sheet

- Net Present Value

Financial information summary

- Cumulative position (after interest & tax)
- Operating surplus
- Operating surplus per ha
- Gross Income from Crops
- Gross Income from crops per ha
- Gross Income from Livestock
- Gross income from stock per ha
- Gross Income
- Gross Income per ha
- Crop Variable Costs per ha
- Livestock Variable Costs per ha

- Total Variable Costs per ha
- Fixed Costs per ha
- Capital costs
- Capital costs per ha
- Total Costs
- Total Costs per ha
- Annual Surplus/Deficit

Production information summary

- Enterprise hectares (total)
- Total crop hectares
- Total pasture hectares
- Hectares per enterprise
- Total enterprise production (total tonnes)
- Production per enterprise (tonnes)
- Carrying capacity (summer)
- Carrying capacity (winter)
- Stock DSE at End
- DSE per livestock enterprise

2.5 Model Limitations

As with all tools there are a number of limitations to using the STEP model. Some of these are listed below.

- The user is required to be knowledgeable about the farming system being tested. No prices or biological interactions are preset in the model. Lack of familiarity with the system interactions can result in incorrect and misleading results. Or said another way – rubbish in, rubbish out.
- Making changes to the STEP framework will require some knowledge of Excel and depending on the extent of the changes, possibly Microsoft Visual Basic.
- Planning of what is going to be tested is essential before starting the analysis. If a farm is represented incorrectly in the model it can inhibit extensive analysis. Consequently time spent planning how the analysis is undertaken is time worth spending.

- STEP does not link into other farm management tools that are currently on the market such as PAM ▯and Pinpoint or APSIM. This means that information existing in other computer programs needs to be re-entered into STEP.
- STEP is a simulation not an optimisation model.
- Climatic risk and inter-year price variation assessment is not easily accommodated by the model due to the complexity of relationships. However if this is desired, all figures can be altered on a yearly basis.

3. LUSO

Aim/use	To analyse strategic break crop decisions
Objective	Simulation, optimisation , sensitivity analysis
Time	Dynamic
Scale	Paddock
Used by	
Software	Python, Excel
Developers	Michael Renton and Roger Lawes
Contact info	michael.renton@uwa.edu.au or roger.lawes@csiro.au

3.1 Introduction

LUSO (Land Use Sequence Optimiser) is a tool for finding optimal land use sequences, with a particular focus on analysing the role of break crops within these optimal sequences. It is a simulation model for analyzing tactical and strategic decisions in agricultural rotations (Renton and Lawes, 2009). Break crops are crops included in the system which aren't primarily grown because of their own profitability, but rather because they can improve the overall land-use sequence profitability. For example, in southern Australian farming systems, wheat is generally the most profitable crop. In this case "break crops" are considered to be crops other than wheat and which are included in the system because of their overall "system benefits".

A southern Australian agricultural system is represented by the model, with one crop or pasture option possible each winter and a summer fallow (Renton, 2012). The model operates on a single land-use area (i.e. paddock) and simulates how the state of this land-use area changes from year to year according to different land-uses. Due to the complexity of possible seasonal variation and unpredictability of seasonal factors, LUSO assumes every year to be an "average year" throughout the sequence (Lawes and Renton, 2010). Its latest version (LUSOvar, which is still under development), however, does take into account seasonal variability in its analysis. LUSOvar allows the user to 1) simulate a single given sequence of land uses over a given sequence of season types, 2) find the optimal sequence of land uses for a given sequence of season types, 3) simulate a single given sequence of land uses over a large number of randomly selected sequences of season types, to predict the range of possible outcomes for that land use sequence (LUSOvar Instructions). LUSO incorporates weed population dynamics, plant disease loads and soil nitrogen levels which have an effect on yield and profit. These biophysical elements are used to predict the production and cost of the land use, and provide an over-all long-term value for the land-use sequence (Renton and Lawes, 2009).

Optimisation and sensitivity analysis

LUSO's optimization routines can be used to find answers to long term strategic questions and short-term tactical questions. With the long-term strategic routines it would, for example, be possible to analyse the optimal long-term sequence of crops to grow. For short-term tactical questions, LUSO would for example be able to analyse whether to harvest the crop that is currently being grown or not, depending on the crop status.

With the sensitivity routines built into LUSO it is possible to analyse how sensitive the model outcomes are to various model parameters, which in turn allows an analysis of what factors are most important in choosing between strategic and tactical options (Renton and Lawes, 2009).

3.2 How LUSO works

The objective of the model is to maximize, over time, economic return (i.e. profit) from a sequence of crops in response to weed disease and nitrogen status. The economic return for each crop is influenced by the weed population, disease population and nitrogen status at the time of planting. Furthermore, the current crop influences weeds, diseases and nitrogen levels for the subsequent crop. The model is built around the notion that diseases and weeds have a negative effect on yields. This is translated into the model with a yield damage function with weed and disease components. Moreover, crops have a nitrogen requirement, which can either be supplied externally by a cost or supplied partly by a crop previously planted on the paddock such as legume crops or pasture (Lawes and Renton, 2010). The dynamic weed and disease populations allow the model to estimate the performance of the subsequent crop. Therefore, the current land use choice indirectly influences future economic return from this land-use area or paddock. Depending on the weed, disease and soil nitrogen status, the subsequent crop could be a break crop. Although this break crop might not be beneficial in terms of economic return in this specific year, it reduces weeds and diseases and has a positive impact on soil nitrogen status leading to higher overall economic return. LUSO does its calculations in Python. It accesses input data from Excel, and exports its results to Excel.

The following section describes how nitrogen, weed, disease and economics are modeled in LUSO.

Nitrogen in LUSO

The objective of the nitrogen module in LUSO is to capture and represent the nitrogen contribution a legume crop makes to the following crop as a fertiliser equivalent (Lawes and Renton, 2010). Each crop has a certain nitrogen requirement (indicated with "Nreq" in the model), which can be supplied by the previous land-use activity ("NboostperTonne") or externally by a cost as a fertiliser ("Ncost"). The model assumes cereal and oilseed crops use all the nitrogen that is available to them. This means when cereal or oilseed crops are grown on the same paddock for two subsequent years, all nitrogen requirements in the second year must be supplied as a fertiliser. Lupins and pasture do not require nitrogen fertilizer, but rather leave nitrogen available for the subsequent crop (see Figure 5), reducing nitrogen fertiliser costs if the following crop grown is a cereal or oilseed crop.

Weed in LUSO

The weed module in LUSO is based on the RIM model of annual ryegrass seedbank dynamics (Pannell et al., 2004). A paddock or land-use area is assumed to start with a certain inactive weed seedbank ("seedbank0" parameter in the input file, see Figure 2). A fixed proportion of the seeds will germinate ("weedgermination" parameter) and, depending on the land-use what proportion, germinating weeds will set seed ("weedsurvival" parameter, Figure 1). Weeds that didn't set seed will, depending on the land-use what proportion, return to the weed seedbank and will be "available" for the subsequent land-use ("weedseedreturn" parameter, Figure 1). A maximum of seeds in the seedbank is set by the "weedmaxseedset" parameter (30.000 by default, Figure 2). The effect of weed on crops is calculated using a crop competitiveness index ("compindex", Figure 1), weed competitiveness ("weedcompindex", Figure 2), weed density and crop density ("sowdensity", Figure 1). Crop competitiveness and crop density are assumed to depend on the land-use.

Disease in LUSO

The effect of a disease is simulated in the model with a disease damage function (*ddf*), which depends on the disease level and the crop's resilience to disease. The model assumes only cereal crops can be affected by disease. Non-cereal crops and legumes or pastures are believed to have a positive impact on cereal disease when planted subsequent to cereal crops. There are two main variables that represent disease in the LUSO model: disease incidence (DI) and disease damage (DD). Disease incidence is a representation of the amount of the disease-causing organisms early in the growing season. It is affected by: the disease incidence of the previous year, the previous crop, the season and a random factor (everything for which isn't an explanation). The disease damage is the proportion of yield lost due to disease. It is affected by: the current incidence, the current crop, the season and again a random factor.

Economics in LUSO

The economics part of LUSO consists of a yield function and a profit function.

The yield function reads:

$$y_a = y_p \times (1 - ddf) \times (1 - wcf)$$

Where y_p represents the potential yield, which is affected by disease and weed damage. *ddf* is the disease damage function and *wcf* is the weed damage function. Both functions are scaled between 0 and 1, where 0 is no damage and 1 is full damage. The by weed and disease affected potential yield results in the actual yield (y_a), which is used in the profit function to calculate profits. Note that nitrogen requirement is not constraining yields, and is therefore not included in the yield function. The model assumes all nitrogen requirement by crops is met trough either nitrogen available in the soil (left by the previous crop) or as a nitrogen fertiliser.

The profit function, as the net present value of a land-use sequence, reads:

$$\sum_{n=0}^{y}((y_a P_{i_n} - Cf - Cv_{i_n} - Ncost(Nr_{i_n} - Ns_{i_n}))(1 - dis)^{n-1}) - WScost \times sb_Y$$

Where *y* represents yield, *n* is the year in the sequence and *I* the land-use.

The first part between brackets indicates income minus costs. $y_a P_{i_n}$ is the income, calculated as the actual yield of the crop times its price minus the fixed costs (*Cf)*, variable cost (excl. nitrogen costs) per hectare for the land use (Cv_{i_n}) and the nitrogen fertiliser cost per unit ((*Ncost*) times the additional required nitrogen (total required nitrogen minus nitrogen available in the soil, $Nr_{i_n} - Ns_{i_n}$). Subsequently, the income is discounted using discount rate *dis*, after which the costs of the remaining seeds in the seedbank is subtracted.

3.3 Model inputs

The model must be provided with a list of possible land-uses, each defined by a set of parameter values ("_LUSdetails_used.csv" excel File), and another set of 'general' parameter values that are not specific to a particular land-use ("parameters_used.csv" Excel File).

'_LUSdetails_used.csv': all land-use-specific information for an average season (see Figure 1).

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q
1	name	yield	price	cost	costCont	Nreq	IEprevcrop	DEcrop	NboostperTonne	weedsurvival	compindex	sowdensity	weedseedreturn	watermult	label	hide	extracostperextrayield
2	hi wheat	3	350	250	250	160	2	0.1	0	0.05	0.091	150	1	1	HW	n	0
3	wheat	2.2	350	200	200	120	2	0.1	0	0.05	0.091	100	1	1	W	n	0
4	lupins harvested	1.5	250	200	200	0	0	0	50	0.03	0.08	40	1	1	LH	n	0
5	sprayed pasture	3	0	80	80	0	0	0	25	0.03	0.08	50	0.1	1	SP	n	0
6	canola	1.4	550	250	250	120	0	0	0	0.03	0.08	100	1	1	C	n	0
7	lupins manured	1.5	0	150	150	0	0	0	70	0.03	0.08	40	0.1	1	LM	n	0
8	extra hi wheat	3	350	350	350	160	2	0.1	0	0.03	0.091	180	1	1	HW!	y	0
9	ppasture	3	90	100	0	0	0	0	25	0.03	0.08	50	0.1	1	PP	y	0

Figure 3.1 LUSO's land-use parameters input sheet

In this sheet the user enters all the land-use (crop and/or pasture) specific parameters. In the first column the user enters the land-use (crop or pasture and its specification). Yields are per hectare, price per tonne and (variable) costs per hectare. "Nreq" is nitrogen requirement per hectare for the specific crop. "IEprevcrop" stands for "incidence effect previous crop" and is a land-use specific parameter that controls the effect of the previous land-use. "DE crop" represents the "average" damage effect on a specific crop. "NboostperTonne" represents the nitrogen provided for the following crop per hectare per tonne of yield. The weedsurvival parameter represents the proportion of weeds that survive harvest and other farmer practices (i.e. herbicides). Weedseedreturn is the proportion of the weed seed set that is returned to the seedbank for following years. By answering "Hide" with "y" or "n" the user can include or exclude certain land-uses from the analysis.

'_parameters_used.csv': all non-land-use-specific information for an average season (see Figure 2).

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R
1	nyears	seedbank0	weedgermination	weedcompindex	weedmaxseedset	Ncost	N0	DI0	DImin	IEprevinc	IErandom	DEinc	DErandom	fixedcosts	nsols	discountrate	costperweedseed	season
2	10	50	0.8	0.02	30000	2	0.05	0.2	0.1	0.5	0.02	0.5	0.02	150	5	0.05	0.1	1

Figure 3.2 LUSO's non-land-use parameter input sheet

In this sheet the user enters parameters other than land-use specific parameters. “nyears” is the number of years for the simulation to run, “seendbank0” is the size of the initial seedbank, “weedgermination” the propotion of weeds that germinate, “weedcompindex” is the weed competitiveness index (used for calculating the effect of weed on crops), “weedmaxseedset” is the maximum amount of seeds in the seedbank, Ncost is the cost if nitrogen fertiliser (variable cost), N0 the initial amount of nitrogen available for the land-use, DI0 the initial disease incidence,

'**_stochasticParameters_used.csv**': all information on how parameters vary in other-than-average seasons – this is NOT needed to run the basic LUSO analyses, but is needed to run LUSOvar analyses (see Figure 3).

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
1	season	label	IEseason	DEseason	weedSeed	weedComp	NReq	Nlost	wheat	hi wheat	lupins har	sprayed pasture	canola	lupins manured	ppasture
2	1	0.05	0.55	1.45	0.5065439	1	1	0	0.342059	0.424301	0.013088	0.342058549	0	0.013087824	0.917757
3	2	0.1	0.6	1.4	0.6155345	1	1	0	0.487379	0.551457	0.231069	0.487379374	0	0.231069061	0.935922
4	3	0.15	0.65	1.35	0.68907	1	1	0	0.585427	0.637248	0.37814	0.585426644	0.170853	0.378139966	0.948178
5	4	0.2	0.7	1.3	0.7475136	1	1	0	0.663352	0.705433	0.495027	0.663351507	0.326703	0.49502726	0.957919
6	5	0.25	0.75	1.25	0.7976531	1	1	0	0.730204	0.763929	0.595306	0.7302041	0.460408	0.59530615	0.966276
7	6	0.3	0.8	1.2	0.8426798	1	1	0	0.79024	0.81646	0.68536	0.790239795	0.58048	0.685359692	0.97378
8	7	0.35	0.85	1.15	0.8844039	1	1	0	0.845872	0.865138	0.768808	0.845871813	0.691744	0.76880772	0.980734
9	8	0.4	0.9	1.1	0.9239959	1	1	0	0.898661	0.911329	0.847992	0.898661159	0.797322	0.847991738	0.987333
10	9	0.45	0.95	1.05	0.9623016	1	1	0	0.949735	0.956019	0.924603	0.949735461	0.899471	0.924603192	0.993717
11	10	0.5	1	1	1	1	1	0	1	1	1	1	1	1	1
12	11	0.55	1.05	0.95	1.0376984	1	1	0	1	1.043981	1	1	1.125661	1	1
13	12	0.6	1.1	0.9	1.0760041	1	1	0	1	1.088671	1	1	1.253347	1	1
14	13	0.65	1.15	0.85	1.1155961	1	1	0	1	1.134862	1	1	1.38532	1	1
15	14	0.7	1.2	0.8	1.1573202	1	1	0	1	1.18354	1	1	1.524401	1	1
16	15	0.75	1.25	0.75	1.2023469	1	1	0	1	1.236071	1	1	1.67449	1	1
17	16	0.8	1.3	0.7	1.2524864	1	1	0	1	1.294567	1	1	1.841621	1	1
18	17	0.85	1.35	0.65	1.31093	1	1	0	1	1.362752	1	1	2.036433	1	1
19	18	0.9	1.4	0.6	1.3844655	1	1	0	1	1.448543	1	1	2.281552	1	1
20	19	0.95	1.45	0.55	1.4934561	1	1	0	1	1.575699	1	1	2.644854	1	1

Figure 3.3 Stochastic parameters input sheet for LUSOvar

Additionally, small changes in Python files may be required, for example to define land-use sequence (crop/pasture rotation), in the top line of the document (see Figure 1.4). Numbers 1 and 4 correspond with a predefined crop or pasture type.

```
cropRotation=[1,4,1,4,1,4,1,4,1,4]

import sys
sys.path.append('files')
from random import *
from readers import *
from csv import *
from lusofuncs import *


lulist=readinLUlist('_LUSdetails_used.csv')
parameters=readinparams('_parameters_used.csv')
optionalparams=readoptionalparams(lulist,'_disallowed_combinations.csv')

print '##############################################################################'
print('these land uses available:')
nlus=len(lulist)
i=1
for lu in lulist:
    print i-1,lu['name']
    i=i+1

print '##############################################################################'
print 'evaluating:'
print [lulist[b]['name'] for b in cropRotation]

print '##############################################################################'
##[details1,p1] = profit(cropRotation,parameters,lulist,getDetails='both',optionalparams=optionalparams,annualise=False)
##[details2,p2] = profit(cropRotation,parameters,lulist,getDetails='both',optionalparams=optionalparams,annualise=False)
##detailsToCSV(details1,'singlerun_details1.csv')
##detailsToCSV(details2,'singlerun_details2.csv')

print 'overall profit:',profit(cropRotation,parameters,lulist,getDetails=False,optionalparams=optionalparams,annualise=False)
print 'annualised profit:',profit(cropRotation,parameters,lulist,getDetails=False,optionalparams=optionalparams,annualise=True)


print '##############################################################################'
print 'more information in output files'
details=profit(cropRotation,parameters,lulist,getDetails=True,optionalparams=optionalparams)
#print(details)
plotDetails(details,stufftoplot=['cost','profit','disease','newseedbank','weedpenalty','newN'],lus=cropRotation,lulist=lulist)
savefig('outputs/singlerun_details.png')
detailsToCSV(details,'singlerun_details.csv')
show()
```

Figure 3.4 LUSO in Python

3.4 Model outputs

LUSO mainly reports its results in Excel (in the “Output” folder). LUSO’s output data consists of the optimal rotation sequence (when using the optimiser routin), economic data (profit, income and costs) and disease and weed information (see Figure 5). Column B represents the simulation years (as defined in the non-land-use parameter sheet, see Figure 2). Column C represents the optimal land-use sequence given the input data.

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R
1	iden	year	name	undiscountedprofit	profit	cumprofit	discount	cumdiscount	income	yield	price	cost	Ncost	disease	diseaseImpact	weedpenalty	newN	newseedbank
2		0	hi wheat	204.4129949	204.413	204.41299	0.95	0.95	924.31	2.641	350	400	319.9	0.2	0.052631579	0.07079646	0	91.68822328
3		1	hi wheat	156.1083241	148.303	352.7159	0.9025	1.8525	876.11	2.503	350	400	320	0.5	0.1	0.072901244	0	167.7952934
4		2	sprayed pasture	-230	-207.58	145.1409	0.857375	2.709875	0	2.362	0	230	0	0.66667	1.00E-05	0.212682386	59.048	81.11800707
5		3	hi wheat	337.3233844	289.213	434.35354	0.814506	3.52438125	939.23	2.684	350	400	201.9	0.1	0.035714286	0.072368471	0	148.5271108
6		4	hi wheat	169.7379054	138.253	572.60612	0.773781	4.298162188	889.74	2.542	350	400	320	0.4	0.083175965	0.07575565	0	271.0686625
7		5	sprayed pasture	-230	-177.97	394.63651	0.735092	5.033254078	0	2.339	0	230	0	0.6202	1.00E-05	0.220290073	58.478	130.3015062
8		6	hi wheat	333.6775005	245.284	639.92013	0.698337	5.731591374	936.72	2.676	350	400	203	0.1	0.035714286	0.07484229	0	238.015366
9		7	hi wheat	165.4457825	115.537	755.45709	0.66342	6.395011806	885.45	2.53	350	400	320	0.4	0.083175965	0.080214233	0	432.5228901
10		8	sprayed pasture	-230	-152.59	602.87039	0.630249	7.025261215	0	2.304	0	230	0	0.6202	1.00E-05	0.231893471	57.607	206.1050941
11		9	hi wheat	328.1026534	206.787	809.6569	0.598737	7.623998154	932.89	2.665	350	400	204.8	0.1	0.035714286	0.078629307	0	375.1097104

Figure 3.5 LUSO’s Excel output data

At the end of the model run Python states a short summary, including the optimal rotation (or land-use sequence) and overall and annualized profit (see Figure 6).

```
Python Shell
File  Edit  Debug  Options  Windows  Help
#############################################################################
finished - the best land use sequence found was
['hi wheat', 'hi wheat', 'sprayed pasture', 'hi wheat', 'hi wheat', 'sprayed pas
ture', 'hi wheat', 'hi wheat', 'sprayed pasture', 'hi wheat']
#############################################################################
overall profit: 772.145927066
annualised profit: 101.278346534
#############################################################################
more information in output files
>>>
Ln: 77 Col: 4
```

Figure 3.6 LUSO output in Python

Additionally, it is possible for Phyton to produce output graphs (see Figure 7) when typing “show()” at the end in the Python shell.

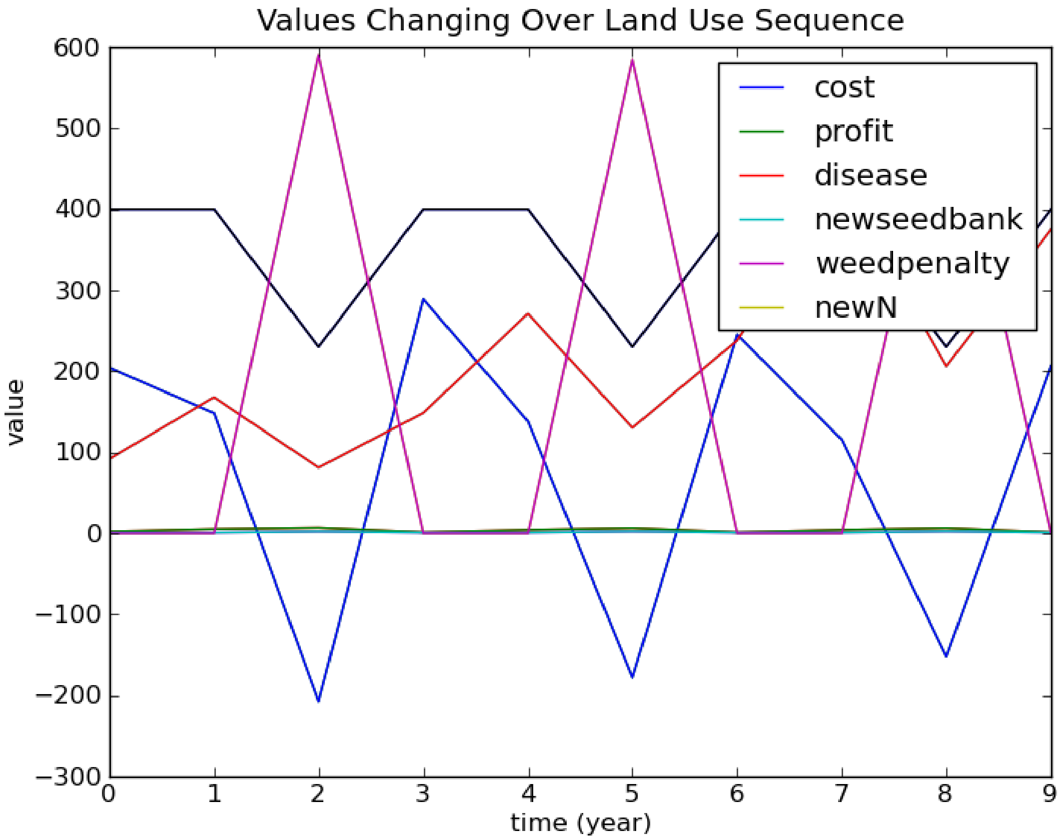


Figure 3.7 LUSO output graph

4. APSFarm

Aim/use	To simulate the opportunistic cropping system based on farm and paddock level criteria
Objective	Simulation
Time	Dynamic
Scale	Whole-farm / multi-paddock
Used by	Researchers
Software	APSIM
Developers	Agri-Science Queensland
Contact info	Daniel Rodriguez (University of Queensland)
	d.rodriguez@uq.edu.au

4.1 Introduction

APSFarm is a dynamic simulation model that uses the APSIM model to simulate the allocation of land, labour, time, irrigation water, livestock, machinery and other finance resources at the whole-farm level (Rodriguez et al., 2007). It was developed to improve the economic and environmental performance of farm businesses. It helps farmers make decisions by simulating how changes to their management practices will affect farm business performance and profits, and what the environmental impacts might be. It also provides information how the farm can adapt to change in climate, markets and government polivies. APSFarm simulates a multi-field, a collection of fields or management units, configuration where each field can have different size, soil characteristics, cropping history or management (Power et al., 2011).

Farm level management is controlled in a “farm level manager” that includes tactical and strategic decisions. Tactical decisions are considered short term seasonal decisions that are specific to particular fields (e.g. fertiliser rates, sowing densities and irrigation management). Strategic decisions relate to operations affecting, or being informed, by the availability of resources at the whole farm level (e.g. implementing crop rotations and setting priorities for irrigating alternative crops) (Power et al., 2011). Farm management is modeled as a set of state and transition networks. Each field has a current state (i.e. the current crop or pasture), the transition from one state to another (i.e. crop/pasture rotation) is bound to rules or constraints which represent the capacity. These rules can be physical constraints such as availability of machinery, land, labour and rainfall, but also agronomic and technical skills and farmer preferences such as farm business strategies and risk attitude. These rules are usually expressed as a Boolean value (true for feasible, false otherwise), but can also be given a real value where higher values represent the desirability of a particular management action. The model examines daily all paths leading away from the current state to another state, and chooses the highest ranked path. The process repeats until nothing more can be done for that day (Rodriguez, 2011).

The use of APSFarm involves interviews and discussions with farmers, consultants, agronomists and agribusinesses, to identify relevant rules, decision making processes, quantify model parameters and validate model outputs. Once the model outputs are accepted as realistic by the participating farmers, scenario analyses are developed - based on participants interests - to explore opportunities for improvement or to adapt to present drivers for change e.g. climate, markets, regulatory.

4.2 How APSFarm works

Rotations

Figure 1 is the rotation set-up sheet of APSFarm. The circles represent the state (crop or fallow) of each field on the farm, the arrows connecting the circles represent the rules and actions required for any transition between states. The model evaluates the rules each day for each paddock, and when they are met the transition is made. Rules for transition from fallow to wheat could for example be (see also Figure 2): sowing date window, minimum water availability in the soil, minimum/maximum number of days since the last harvest, machinery availability, etc. When one of these rules is not met, the next state of the paddock will still be fallow.

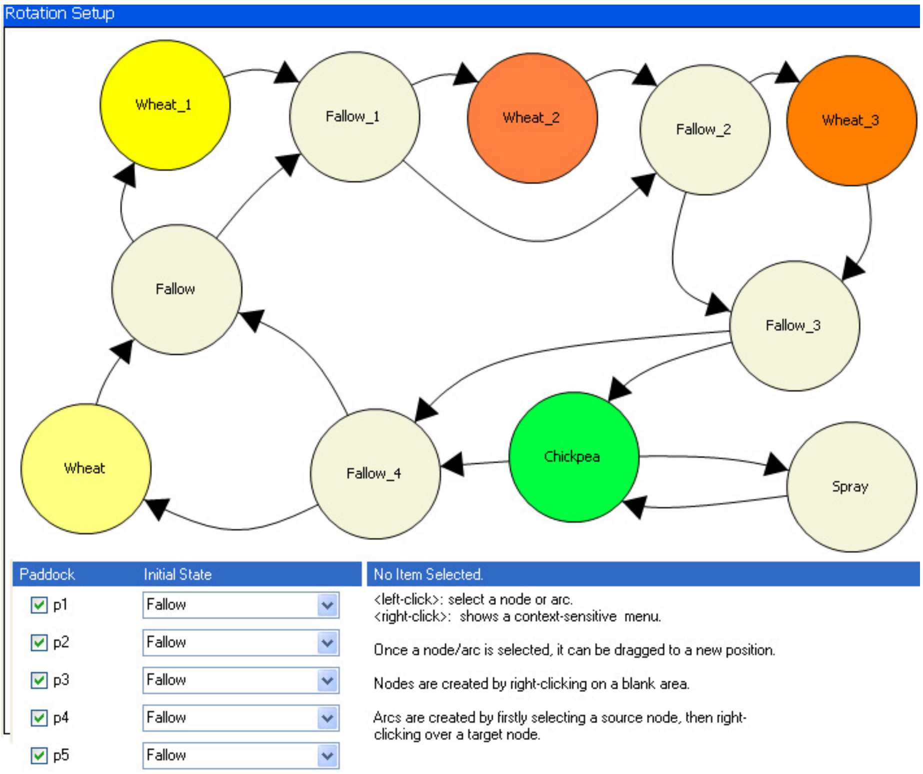


Figure 4.1 APSFarm's rotation sheet

Transition from Fallow to Wheat_1
Rules
[dayWithin 129 152]
[getEsw $paddock] > 183
[getMSeek2 $paddock] > 0.65
$daysSinceLastHarvest($paddock) > 30
[machineryAvailable tractor1_planter]
[areaPlanted wheat] <=1
[getEsw $paddock]

Figure 4.2 Transition rules in APSIM

Livestock

Figure 3 below depicts how groups of animals (called "mobs" in the model), are moved around the farm based on the feed availability.

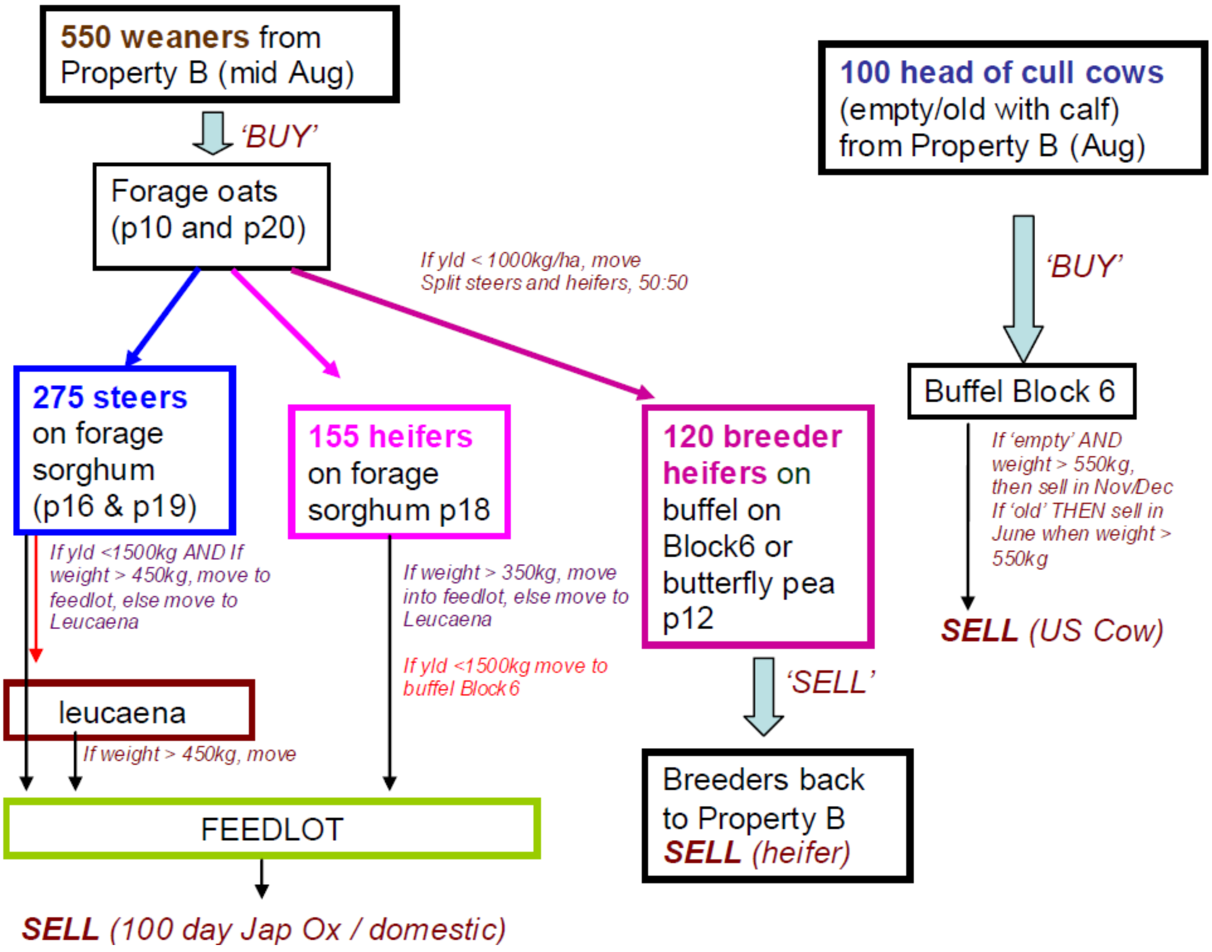


Figure 4.3 Flow diagram of how groups of animals are moved around the farm based on feed availability (source: Owens et al., 2009)

4.3 Model input

Economic input parameters

Description	Value
Initial Capital Assets	
Loan Value of Initial Investment ($)	1
Loan repayment rate (% pa)	6.0
Loan duration (years)	50
Cash Journal	
Initial cash balance ($)	42000
Cash Journal	
Produce Cashbook	yes
Produce Cash Summaries	yes
Prices	
Wheat price ($/tonne)	180.0
Wheat protein (%)	12.0
Sorghum price ($/tonne)	140.0
Chickpea price ($/tonne)	350.0
Weed price ($/tonne)	0.0
Maize price ($/tonne)	0.0
Overheads	
Accountant/Consultancy fees ($)	5000.0
Administration ($)	500.0
Bank Charges other than interest ($)	500.0
Electricity - Farm ($)	2000.0
Freight & Cartage (sundry) ($)	0.0
Fuel & Oil (other than farming) ($)	10000.0
Insurance - Farm ($)	6000.0
Motor Vehicle Expenses - Farm ($)	5000.0
Rates and Rents - Farm ($)	3500.0
Repairs & Maintenance (extra) ($)	20000.0
Subscriptions ($)	1000.0
Telephone - Farm ($)	2500.0
Wages (other than casual included in activity budgets) ($)	50000.0
Other Overhead Expenses ($)	0.0
Operators labour and management ($)	30000.0
Costs	
Cost of fuel ($/litre net)	1.0
Fertiliser Costs	
MAP (starterphos - 10n;21.9p;1.5s) ($/kg)	0.56
starter z ($/kg)	0.62
Urea ($/kg)	0.6
NO3 N ($/kg)	1.0
Herbicide Costs	
Roundup POWERMAX (glyphosate MEA salt) ($/kg)	7.64
MCPA LVE (MCPA ester) ($/kg)	5.0
Ally (metsulfuron) ($/kg)	0.2
Amicide 625 ($/kg)	5.5
Simazine 900DF ($/kg)	5.5
Insecticide Costs	
Larvin LV ($/kg)	27.97
Steward (indoxacarb) ($/kg)	85.36
Seed Costs	
Barley (Tallon) ($/kg)	0.78
Chickpea (Amethyst) ($/kg)	1.1
Cotton ($/kg)	5.6
Forage Sorghum (Jumbo) ($/kg)	3.96
Lucerne (sequel) ($/kg)	5.45
Maize ($/kg)	8.4
Millet (White frend) ($/kg)	8.4
Mungbean (Emerald) ($/kg)	
Sorghum (Buster) ($/kg)	5.8
Wheat (Kennedy) ($/kg)	0.9
Contractor Costs	
Harvesting ($/ha)	250.0

Machinery input parameters

Tractor	
Apsim name	tractor1
New price ($)	100000.0
Trade In Value (% of new)	15
Life of Equipment (hrs)	3000
Insurance cost ($/$1000 insured)	6.2
Repairs & Maintenance (% of new value over lifetime)	30
Oil & Tyre costs (%age of fuel costs)	10
Loan Interest Rate (%)	7
Loan Duration (years)	50
Age at start of simulation (hrs)	2
Implement 1	
Name	sprayrig
Fuel Rate (lts/hour)	30.0
Work Rate (ha/hour)	20.0
Daily Hours (hours)	16
Implement 2	
Name	planter
Fuel Rate (lts/hour)	40.0
Work Rate (ha/hour)	8.12
Daily Hours (hours)	16

4.4 Model Outputs

Economic activity

	A	B	C	D	E	F	G	H	I	J	K	L	M
1	event	paddock	area	year	date	days since	crop	yield (kg/l	biomass (l	protein(%	type	amount	weight
2	sell	livestock		1980	28/02/1980	58					steers	100	451
3	buy	livestock		1980	28/02/1980	0					steers	100	250
4	sell	livestock		1980	28/02/1980	0					steers	100	451
5	buy	livestock		1980	28/02/1980	0					steers	100	250
6	sell	livestock		1980	28/05/1980	90					steers	100	450
7	buy	livestock		1980	28/05/1980	0					steers	100	250
8	sell	livestock		1980	28/05/1980	0					steers	100	450
9	buy	livestock		1980	28/05/1980	0					steers	100	250
10	spray	CropPadd	200	1980	16/06/1980	167					roundup	1.5	
11	spray	CropPadd	200	1980	16/06/1980	167					roundup	1.5	
12	spray	CropPadd	200	1980	16/06/1980	167					roundup	1.5	
13	spray	CropPadd	200	1980	16/06/1980	167					roundup	1.5	
14	spray	CropPadd	200	1980	16/06/1980	167					roundup	1.5	
15	sell	livestock		1980	27/06/1980	30					steers	100	450
16	buy	livestock		1980	27/06/1980	0					steers	100	250
17	sell	livestock		1980	7/7/1980	10					steers	100	450
18	buy	livestock		1980	7/7/1980	0					steers	100	250
19	sell	livestock		1980	5/8/1980	29					steers	100	450
20	buy	livestock		1980	5/8/1980	0					steers	100	250
21	sell	livestock		1980	29/08/1980	24					steers	100	450
22	buy	livestock		1980	29/08/1980	0					steers	100	250
23	spray	CropPadd	200	1980	30/10/1980	136					roundup	1.5	
24	spray	CropPadd	200	1980	30/10/1980	136					roundup	1.5	
25	spray	CropPadd	200	1980	30/10/1980	136					roundup	1.5	
26	spray	CropPadd	200	1980	30/10/1980	136					roundup	1.5	
27	spray	CropPadd	200	1980	30/10/1980	136					roundup	1.5	
28	spray	CropPadd	200	1980	16/12/1980	47					roundup	1.5	
29	spray	CropPadd	200	1980	16/12/1980	47					roundup	1.5	
30	spray	CropPadd	200	1980	16/12/1980	47					roundup	1.5	
31	spray	CropPadd	200	1980	16/12/1980	47					roundup	1.5	
32	spray	CropPadd	200	1980	16/12/1980	47					roundup	1.5	
33	sell	livestock		1980	24/12/1980	117					steers	100	451
34	buy	livestock		1980	24/12/1980	0					steers	100	250
35	spray	CropPadd	200	1981	10/1/1981	25					roundup	1.5	
36	spray	CropPadd	200	1981	10/1/1981	25					roundup	1.5	
37	spray	CropPadd	200	1981	10/1/1981	25					roundup	1.5	
38	spray	CropPadd	200	1981	10/1/1981	25					roundup	1.5	

CQ Mixed GG.economics

Cropping events and soil and climate data

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U
1	event	paddock	year	date	days since last event	crop	yield (kg/l	biomass (l	protein(%)	Ep (mm)	esw (mm	no3 (kg/h	incroprain	fallowrain	soil evap (mm)	runoff (mm)	drainage (mm)	soil loss (t/ha)	surface OM (kg)	cover (%)	n_minerali
2	sow	CropPadd	1982	9/5/1982	859	wheat				0	219.832	249.3688			829.343689	127.583664	171.741455	89.311234	0.449532	0.00023	222.7358
3	sow	CropPadd	1982	10/5/1982	860	wheat				0	219.5326	249.5688			829.640381	127.583664	171.744217	89.311234	0.442926	0.000225	222.9311
4	sow	CropPadd	1982	11/5/1982	861	wheat				0	219.2418	249.7643			829.929016	127.583664	171.746353	89.311234	0.439399	0.000221	223.1123
5	sow	CropPadd	1982	12/5/1982	862	wheat				0	218.9589	249.9565			830.210266	127.583664	171.748001	89.311234	0.437999	0.00022	223.2869
6	sow	CropPadd	1982	15/05/1982	865	chickpea				0	218.1515	250.5047			831.014709	127.583664	171.750961	89.311234	0.437999	0.000219	223.7616
7	harvest	CropPadd	1982	7/10/1982	151	wheat	1490.821	5430.125	16.749298	92.40977	134.6481	174.0938	84		76.761848	0.000461	0.013011	0.000285	0.085417	0.728746	8.916596
8	harvest	CropPadd	1982	8/10/1982	151	wheat	1520.883	5305.229	16.688807	90.8135	135.7895	174.2231	84		76.918716	0.001967	0.010262	0.001242	0.087253	0.735823	8.993003
9	harvest	CropPadd	1982	8/10/1982	150	wheat	1526.425	5297.255	16.69175	90.92266	135.6862	174.2828	84		76.621956	0.00415	0.008131	0.002666	0.087	0.73749	8.946808
10	harvest	CropPadd	1982	9/10/1982	150	wheat	1540.065	5271.011	16.7124	90.88194	135.3378	174.3463	84.2		76.727356	0.006604	0.0065	0.004305	0.087356	0.73665	8.932055
11	harvest	CropPadd	1982	19/10/1982	157	chickpea	1359.771	3227.365	20.555998	100.3075	159.2985	202.5148	130.6		89.108482	0.034868	0.003731	0.024953	0.090799	0.605647	14.5831
12	sow	CropPadd	1983	9/5/1983	213	wheat				0	261.6014	143.3686		589.5	263.06897	59.969963	140.546585	19.322161	391.445068	0.180233	34.13282
13	sow	CropPadd	1983	14/05/1983	207	wheat				0	241.5184	208.9695		542.9	269.002686	85.025459	106.652847	59.76897	8.967457	0.001792	61.28956
14	sow	CropPadd	1983	15/05/1983	218	wheat				0	238.4068	137.1851		589.3	266.014252	60.317215	160.100479	19.735435	379.558563	0.172858	36.03082
15	sow	CropPadd	1983	16/05/1983	220	chickpea				0	235.6293	135.6566		590.9	266.287262	59.951756	163.421875	19.315489	387.197052	0.176011	35.9035
16	sow	CropPadd	1983	17/05/1983	222	wheat				0	233.1485	132.3036		590.9	267.01651	58.213833	167.170105	17.340485	426.772858	0.192156	33.85489
17	harvest	CropPadd	1983	3/10/1983	147	wheat	1010.145	2299.129	7.078008	35.18972	215.8354	86.91321	303.1		124.67067	30.837023	157.368393	10.670425	97.00605	0.29259	21.60622
18	harvest	CropPadd	1983	7/10/1983	146	wheat	1795.131	4968.239	7.25512	78.202	212.8977	138.0186	313.1		120.429352	34.887138	108.202576	20.386372	0.194769	0.444641	18.90006
19	harvest	CropPadd	1983	7/10/1983	145	wheat	985.1866	2288.906	7.419469	36.09792	220.9632	88.46993	313.1		126.596222	31.767059	136.082275	11.856092	94.013382	0.29457	21.35521
20	harvest	CropPadd	1983	9/10/1983	145	wheat	855.2823	2066.984	7.940352	32.93786	217.6649	86.79578	311.7		128.266785	31.593517	134.385376	11.450125	104.353188	0.274491	21.60505
21	harvest	CropPadd	1983	16/10/1983	153	chickpea	1639.459	4303.29	20.555998	128.8982	172.3176	83.38188	349.9		126.863861	30.462389	124.187317	13.299234	54.16354	0.759454	20.00856

Livestock allocation

	A	B	C	D	E	F
1	date	mob	number	from	to	weight
2	1/1/1980	mob1	100	.	BuffelPad	250
3	1/1/1980	mob2	100	.	BuffelPad	250
4	1/1/1980	mob3	100	.	BuffelPad	300
5	1/1/1980	mob4	100	.	BuffelPad	300
6	1/1/1980	mob5	100	.	BuffelPad	325
7	1/1/1980	mob6	100	.	BuffelPad	325
8	1/1/1980	mob7	100	.	BuffelPad	350
9	1/1/1980	mob8	100	.	BuffelPad	350
10	1/1/1980	mob9	100	.	BuffelPad	400
11	1/1/1980	mob10	100	.	BuffelPad	400
12	28/02/198	mob9	100	BuffelPaddock.buffel	out	451
13	28/02/198	mob9	100	.	BuffelPad	250
14	28/02/198	mob10	100	BuffelPaddock.buffel	out	451
15	28/02/198	mob10	100	.	BuffelPad	250
16	16/04/198	mob7	100	BuffelPaddock.buffel	OatsPadd	422.7668

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