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Bio-economic evaluation of pasture-cropping, a novel system of integrating perennial pastures and crops on crop-livestock farms

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Abstract

Pasture-cropping is a novel approach to increase the area of perennial crops in mixed sheep and cropping systems. It involves planting annual cereals directly into a living perennial pasture. There is interest in subtropical grasses as they are winter dormant and their growth profile is potentially well suited to pasture-cropping. However, a wide range of factors can affect the uptake of such systems. This paper assesses the relative importance of factors that can influence decisions to introduce pasture-cropping. In this paper the research question is: what factors predispose a farm to take up a new technology such as (1) subtropical grass and (2) subtropical grass that is pasture-cropped. The analysis uses the MIDAS model of a central wheatbelt farm in Western Australia. The results suggest the adoption of subtropical grasses is likely to be strongly influenced by soil mix; feed quality; and whether the farm is predominantly grazing or cropping and by the presence of meat versus wool producing animals. The same factors are relevant for subtropical grass that is pasture-cropped but in addition yield penalties due to competition between the host perennial and the companion cereal become important. The results suggest the level of forage production by subtropical grass is less important but this factor is likely to become more important if feed quality can be improved.

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Introduction

The increased use of deep-rooted perennial pastures in mixed farming systems in Western Australia has attracted interest as perennials can increase farm profit and diversity amongst farming enterprises, assist with controlling weeds and disease, provide summer feed for livestock and improve ecosystem sustainability (Millar and Badgery 2009; Moore et al. 2007, 2009). The environmental advantages of perennial pastures include reducing nitrate leaching and deep drainage below the root zone (Kemp and Dowling 2000) with attendant salinity and water logging benefits (Sandral et al. 2006), reduced soil erosion from improved soil structure and all year round ground cover (Seis 2007), and improved water infiltration (Wilson and Simpson 1994).

In spite of these advantages growing perennial pastures in phase rotations with annual grain crops and pastures can be problematic as the financial consequences of poor establishment tends to be greater for perennials than for annual pastures and it is sometimes difficult to remove perennials when moving back into cropping (Vere et al. 1997). In Western Australia pasture-cropping is a relatively new technology with the prospect of overcoming some of the difficulties of traditional phase rotational systems.

Pasture-cropping involves planting a winter cereal into a living summer active (C4) perennial pasture (Vandermeer 1989). The summer versus winter dominance of the pasture and cereal are complementary and this reduces the competition between crops planted in the same ground at the same time. Pastures are grazed up until sowing with herbicides applied to reduce competition from the host perennial and from competing annual species. The system can be focused either on grain or forage production (Badgery and Millar 2009)

Pasture-cropping avoids the need for summer fallows and allows summer rainfall to be utilised at the time it occurs rather than relying on storing water in soils for extended periods (Howden et al. 2005). Pasture-cropping was initially regarded as a means to better utilise poor soils (Hacker et al. 2009; Millar and Badgery 2009) but it is increasingly being evaluated for use on better soils and in different locations (Bruce et al. 2005; Harris et al. 2003, 2007). A variety of perennial species, such as lucerne, summer active (C4) native and subtropical grasses, serradellas, medics and a range of cereal and pulse crops including wheat, barley, oats, faba-beans, vetch, triticale and canola are candidates for pasture-cropping systems (Llewellyn pers comm).

Crop and pasture yields are likely to be affected by the resource requirements of the plants being grown together and the pattern of resource use by the plants can contribute to shortfalls in resources at critical times. The extent to which yield is affected will relate to factors such as soil fertility, water holding capacity and weather conditions as well as the characteristics of the plants and planting parameters such as row spacing, spatial arrangement and plant density. Competition for water, nutrients and light can reduce cereal yields and protein and contribute to increased grain contamination (Millar and Badgery 2009).

Examples of where pasture-cropping has been tried include the central west region of New South Wales where conventional phase rotations involving cereals and sown pasture have a relatively high chance of crop or pasture establishment failure on lighter soils. Typically these soils don't support long cropping phases due to low fertility and poor moisture holding capacity and introduced perennials rarely persist beyond a few years (Li et al. 2004; Mullen et al. 2006). In these circumstances pasture-cropping is thought to be a useful way to retain or rehabilitate perennial grasses and reduce the consequences of cereal establishment failure. Farmers in north central Victoria have sown cereals into lucerne stands as the economic returns from growing a cereal crop are perceived to be higher than grazing the lucerne itself and for environmental and sustainability benefits (Harris *et al*. 2003).

In Western Australia pasture-cropping is seen as a way to increase the perennial pasture component on farms while still producing a profitable cereal crop. In the northern agricultural region of Western Australia there is interest in subtropical grasses as pasture-cropping may provide opportunities to crop land that has not historically grown cereals.

Previous research on pasture-cropping in Western Australia has focused on lucerne based systems under favourable conditions of rainfall and soil types but until recently there has been little experimentation and economic analysis of pasture-cropped lucerne in lower rainfall areas, on marginal soils, and on pasture-cropping with subtropical grasses.

The evaluation of such systems via traditional field experimentation is difficult due to the presence of multiple interacting factors, high levels of seasonal variability, and differential performance of crops and pastures on different soil types (Pannell et al. 2006). In these circumstances bio-economic modelling provides a cost-effective alternative to identify research and development priorities for systems evaluation. This is particularly the case for novel systems such as pasture-cropping where there is a dearth of experimental information on the biological performance of the components or the value these might have in complex systems.

This study considers alternate ways to include pasture-cropping in mixed farming systems in Western Australia and identifies farm and agronomic factors that will contribute to or impede its uptake. The study forms part of the EverCrop research programme which is supported by the Future Farm Industries Cooperative Research Centre to develop new sustainable farming systems and technologies that will improve the resilience of Australian broadacre agriculture to climate change, climate variability and drought while improving productivity and sustainability.

The EverCrop programme considers the suitability of different perennials to mixed farming systems in various rainfall zones, their beneficial roles and how they can be adopted to make the greatest impact on farm at minimal cost. An important element of the programme is the adoption of adaptive research techniques: a cycle of identifying issues, opportunities and research needs; trialling and refining technologies on-farm; and sharing results and experiences with the wider farming community.

The potential for pasture-cropping to contribute to the improved utilisation of poor soils is of particular interest in this study. We are targeting poor soils in the central wheatbelt of Western Australia as continuous cropping is currently more profitable, albeit more risky (Hacker et al. 2009), on the better soils in this region and this is unlikely to be displaced by grazing systems unless there are large changes in current prices or productivities. For this reason it seems likely the soil make up of the farm and the enterprise choices (area cropped, livestock characteristics such as meat based versus wool based flock) will influence the area suitable for subtropical grasses.

Our aims are two-fold: (1) to assess the potential area of pasture-cropping on representative mixed crop-livestock farms and consider how this might be affected by the mix of soil types, the type of livestock production system, and the productivity of crops and pastures in the pasture-cropping system, and (2) to identify priorities for agronomic research into the pasture-cropping system through the analysis of factors that are influential in terms of the bio-economic performance of pasture-cropping.

Methods

MIDAS Model

The whole-farm economic model MIDAS (Model of Integrated Dryland Agricultural System) was used to address the study objectives for representative farm enterprises in the low to medium rainfall zone of the Western Australia cereal-livestock zone. MIDAS is a linear programming model that represents the biological, physical, technical and managerial relationships of a mixed farm in a specified region (Kingwell and Pannell 1987; Morrison et al. 1986). The objective function of the model is to maximise whole-farm profit and the model does this by allocating resources between enterprises subject to various resource, environmental and managerial constraints (Pannell 1996).

MIDAS uses a comparative static framework which implies the initial state of the modelled system is incompletely defined and consequently changes from an initial to a final state are not captured. Although MIDAS is a deterministic model and it does not explicitly consider variations in prices and productivities the model can be run with a range of price and production levels to assess their influence on the selected mix of enterprises and on the level of farm profit (Pannell 1997).

A number of studies (e.g. Pannell 1987) have demonstrated the importance of representing temporal interactions in farm models. One of the strengths of MIDAS is that a number of these types of interactions are represented. For example changes in cereal yields, that are due to growing pulse crops as a disease break crop, and the influence of crop sequences on herbicide and fertiliser requirements are represented in MIDAS. Another example is the selection of an optimal grazing strategy, as this depends on the availability and quality of pasture on different parts of the farm, and at different times of the year. The choice to graze one part of the farm affects pasture growth not just on the land that is grazed but it indirectly affects pasture growth on land that is not grazed and the MIDAS model simultaneously considers how this affects stocking rate, wool growth and quality and sheep live weight in assessing optimal grazing strategies.

MIDAS includes the livestock system as a categorical variable that can be varied between model runs. In any particular model run, the number of livestock on the farm is an endogenously modelled variable but the model structure requires the type of livestock system to be specified before the model is run.

The model accommodates eight land management units or soil types that are treated as homogeneous units in terms of crop yield and response to management inputs (see Table 1). Approximately 80 crop-pasture sequences are represented on each land management unit. The production parameters associated with each crop sequence include grain yield, grain quality, grain protein (wheat and barley), oil content (canola), and the quantity of crop residues and spilt grain and germination rates of pasture. The livestock parameters include wool cut, wool fibre diameter, hauteur and live weight. Input costs include fertiliser, chemicals for weed, pest and disease control, machinery costs, seasonal labour, crop insurance, seed costs, selling costs and transport, ownership costs of capital assets and sheep husbandry.

Table 1. Land management units (LMU) or soil types in the MIDAS model.

LMU	Name	Dominant soil type
1	Poor sands	Deep pale sand
2	Average sand-plain	Deep yellow sand
3	Good sand-plain	Yellow gradational loamy sand
4	Shallow duplex soil	Sandy loam over clay
5	Medium heavy soil	Rocky red/brown loamy sand/sandy loam; Brownish grey granitic loamy sand
6	Heavy valley floors	Red/brown sandy loam over clay; Red and grey clay valley floor
7	Sandy surfaced valley	Deep sandy surfaced valley; shallow sandy-surfaced valley floor
8	Deep duplex soils	Loamy sand over clay

Mixed farming system represented by MIDAS

The version of MIDAS used in this study is configured to represent a typical farm in the central wheatbelt, which is centred on the town Cunderdin (31°39'S 117°14'E) which is approximately 160 km east of Perth in Western Australia (see Figure 1). The central wheatbelt receives an average of 350 to 400 mm of rainfall per year with the majority falling between May and October (see Figure 2). The weather is characteristic of a Mediterranean climate with hot dry summers and cool wet winters. The crop and pasture sequences, livestock enterprises, stocking rates, soil types, labour and capital requirements that are represented in MIDAS are typical of the region.

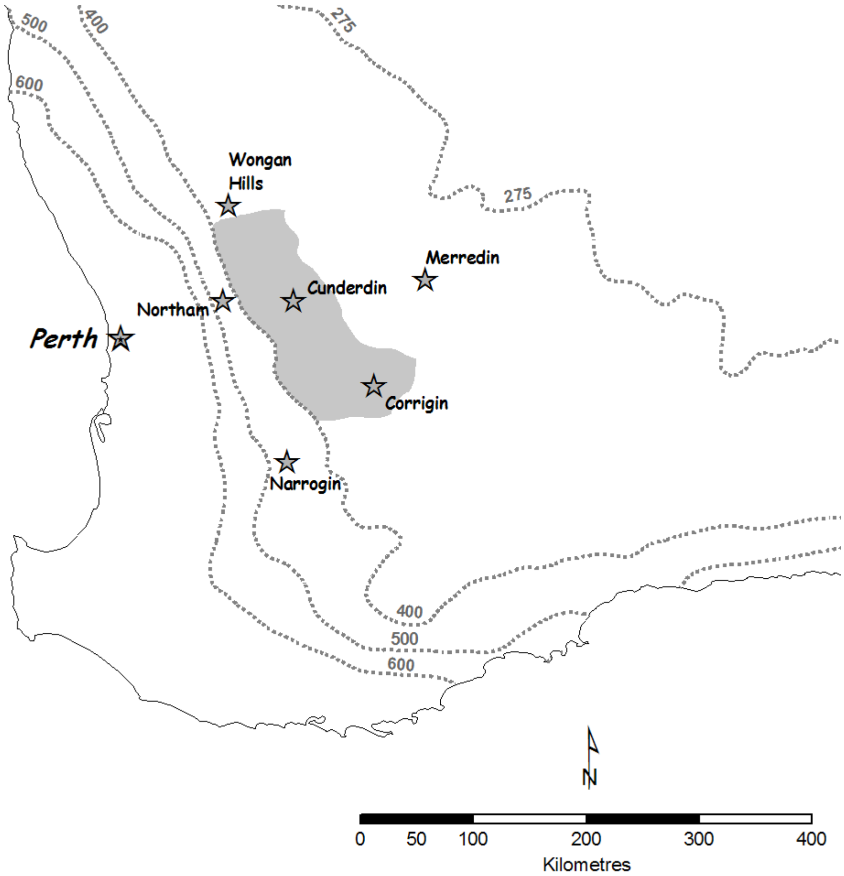

Figure 1. Central wheatbelt region in Western Australia.

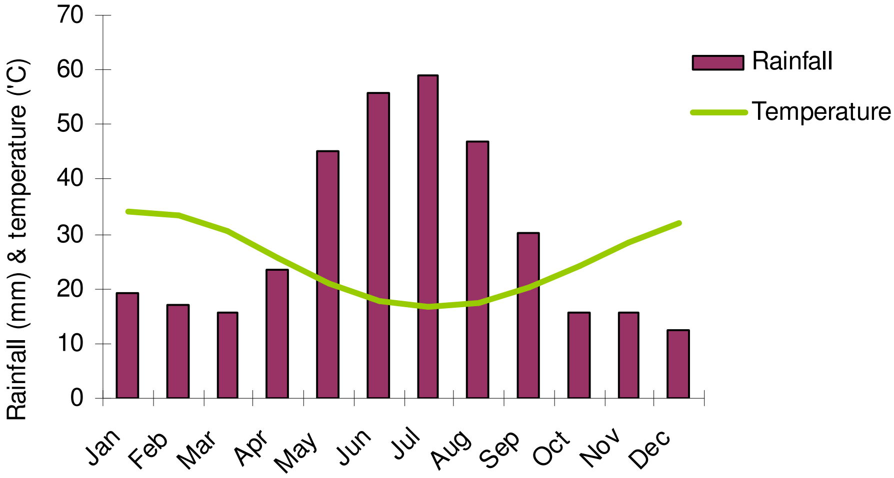

Figure 2. Average monthly rainfall (mm) and average maximum temperature (degrees Celsius) for the central wheatbelt town of Cunderdin (Bureau of Meteorology, 2009)

The growing season for crops and pasture is typically from April/May until October when about two-thirds of annual rainfall occurs. The remainder of the year is characterised by drought and an associated decline in the quality and quantity of feed available for livestock. This often culminates in an autumn feed-gap, with consequences for live weight gain, wool growth and quality, and reproductive performance (Rowe et al. 1989). During the autumn feed-gap sheep are often fed supplements such as grain and conserved fodder.

Perennial pastures are able to extract water from deeper in the soil profile than annual pastures and they normally produce more in summer than annual pastures. The ability of perennial pastures to produce summer feed reduces the autumn feed-gap but perennials can still be drought affected and their yield is variable (Moore et al. 2009). The autumn feed gap has important implications for the profitability of alternate feed sources and the timing of feed supply can be as important as the quantity and quality of the feed that is produced.

Typically farms in the central wheatbelt range from 900 to 2500 ha and they are run as family-owned enterprises with some external labour employed. Most farms produce a mix of grain, wool and meat. It is common for 50 to 70% of arable land to be sown to crop with the balance being in annual pasture. Pastures usually consist of subterranean clover with volunteer annual grasses and herbs. Sheep are the predominant livestock enterprise, although on some farms, cattle can be important (Morrison et al. 1986).

Sheep production systems are mainly based on the Merino breed and range from wool to meat dominant systems with meat production being more prevalent. In wool-dominant systems, ewes are replaced by lambs which are produced on farm and castrated male lambs (wethers) are sold as lambs to other graziers or as live sheep exports (18 months or older). Mixed wool-meat enterprises are self-replacing, and surplus ewes (cast for age and surplus ewe hoggets) are used for crossbred lamb production. Merino wether lambs are usually sold as prime lambs and wethers are sold as lambs to other graziers or for live export (18 months or older). In farm systems that are predominantly for meat production the emphasis is on merino ewes producing crossbred lambs for meat and replacement ewes are bought in.

Cropping systems are based around wheat, in rotation with canola (Brassica napus) and grain legumes including narrow-leafed lupin (Lupinus angustifolius), white lupin (Lupinus albus) and field pea (Pisum sativum). Perennial pastures in these systems are typically grown for 2-7 years as a monoculture in rotation with crops. On any given soil type the productivity of crops and pastures varies depending on their position in the rotation due to carryover effects such as soil fertility, weed burdens and plant diseases.

2.2 Including pasture-cropping in MIDAS

In this study consideration of pasture-cropping species is limited to subtropical grass and wheat. MIDAS was modified to include subtropical grass rotations on each of the 8 soil types or land management units. A 12 year phase of subtropical grass is included as a stand-alone crop and as a pasture-crop with wheat every 2nd, 3rd or 4th year (see Table 2). The main assumptions involving subtropical grass refer to its growth at different times of the year, on different soils, and in the presence of pasture-cropped wheat. Estimates of feed quality are from Moore et al. (2009) and forage production is estimated from a series of APSIM model runs generated by one of this paper's authors (see Figure 3). The subtropical grass sward is assumed to have a sub-clover content of 20%.

Table 2. Pasture-cropping rotations added to MIDAS

Rotation	Description
S6W	12 years continuous subtropical grass over cropped with wheat every second year
S4W	12 years continuous subtropical grass over cropped with wheat every third year
S3W	12 years continuous subtropical grass over cropped with wheat every fourth year
S	12 years continuous subtropical grass

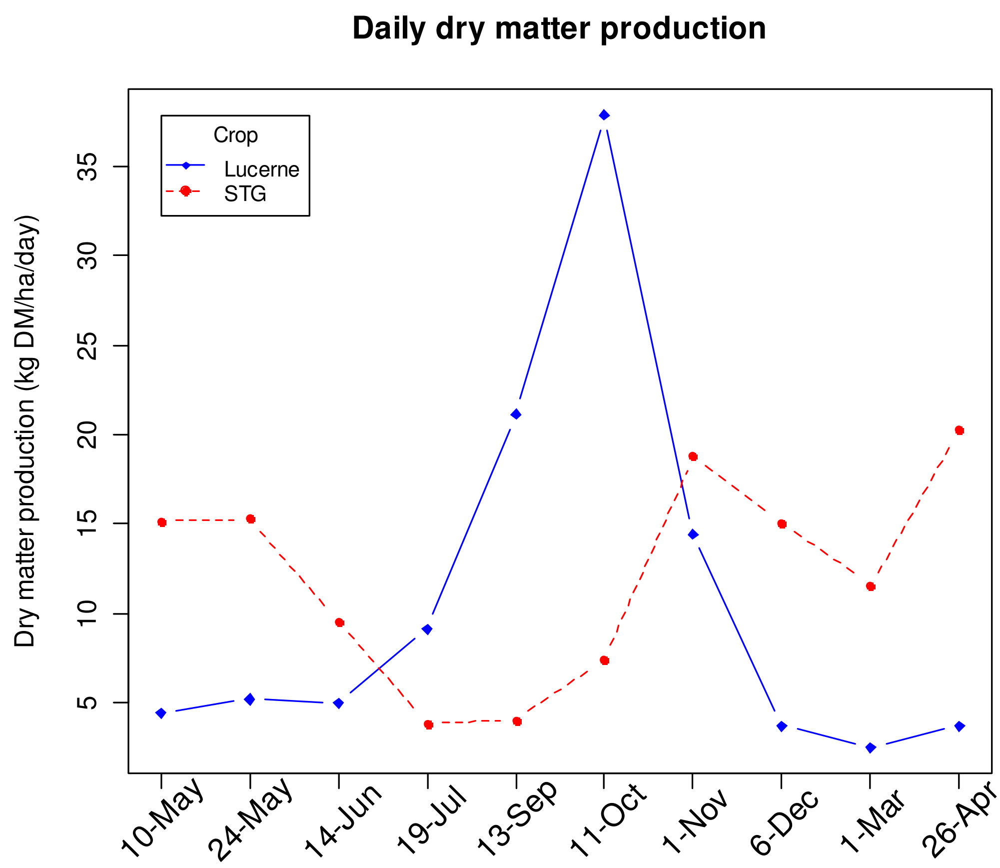

Figure 3. Dry matter production for lucerne and subtropical grass (STG).

In Figure 3 it can be seen that winter feed production from subtropical grass is relatively low (< 10 kg DM/ha/day), but in summer and autumn (December to May), subtropical grass produces a higher yield than lucerne. Depending on soil type, the annual yield of lucerne, subtropical grass, and annual pasture is 800-3600, 2800-4200 and 700-4800 kg DM/ha, respectively. An important assumption in this study is that subtropical grass yields are less affected by poor soils than lucerne (see Table 3). For example on poor sands the potential yield of lucerne is 50% of what is achieved on a more favourable soil but for subtropical grasses yields are 65% of those on an ideal soil.

Table 3. Relative yield of lucerne and subtropical grass on different land management units.

LMU	Relative Yield	
	Lucerne	Subtropical grass
1	0.50	0.65
2	0.65	0.75
3	0.90	0.90
4	0.75	0.75
5	1.00	1.00
6	0.75	0.80
7	0.75	0.80
8	1.00	1.00

Some other assumptions in the base runs with the model are (1) animals are excluded from grazing between planting and harvesting the pasture-cropped cereal; (2) there is no carry over of pasture after the pasture-cropped cereal is harvested; (3) there is a yield penalty of 15% for companion wheat crops relative to conventionally managed cereals and (4) there is no yield penalty or advantage to the subtropical grass outside the period the companion wheat crop is in the ground.

Crop husbandry involves: 2.0 l/ha of Sprayseed 250 applied prior to direct drilling wheat into subtropical grass; 0.5 l/ha Glyphosate CT and 0.8 l/ha Sprayseed 250 applied at the time wheat is sown; 20 kg N fertilizer/ha is applied annually to conventionally sown subtropical grass, 30 to 70 kg N fertilizer/ha is applied to companion wheat crops, and subtropical grass seed is sown at a rate of 4 kg/ha (Bagshaw et al. 2004). It is assumed the machinery requirements to establish and harvest a pasture-wheat crop are otherwise identical to conventionally sown wheat. The modelled farm is comprised of 2000 hectares.

Sensitivity analyses

There is uncertainty about the parameter values in any economic model. The modeller is unsure of the current values of parameters and even less sure about their future values (Pannell 1997). A sensitivity analysis provides a means of determining the influence of parameters on the conclusions that can be drawn and provides insight into the robustness of the solutions and the factors influencing them. The sensitivity analysis involved assessing the outputs of a variety of MIDAS runs in which the attributes of the farm, its management, and the agronomic characteristics of the pasture-cropping system are varied. Specifically, the model runs are grouped in terms of the types of factors that are altered (1) the enterprise mix or choice, (2) the soil type mix on the farm, and (3) the characteristics of the subtropical grass including how much it affects the yield of the companion cereal, and the importance of subtropical grasses feed quality and production at different times of the year.

With respect to enterprise choice: the area of land that is cropped (200, 400 … 1800 ha); and livestock system (wool or meat dominant system) were varied. As discussed above the relative yield of a crop varies between land management units or soil types. The mix of soil types on a particular farm is likely, therefore, to influence the suitability of the farm for different cropping and pasture systems. In this study ten different combinations of soil types were considered. These included a standard scenario that has been used in previous MIDAS studies of the central wheatbelt (Kingwell pers comm), and a uniform scenario where an equal area is allocated to each of the land management units.

The eight remaining soil type scenarios involved ranking the land management units in terms of the relative yield of subtropical grass, lucerne, annual pasture and wheat. These rankings were then used to apportion land which favoured versus disfavoured the respective crops. For example a soil type mix that favours subtropical grass is attributed a large area of a soil type (~ 25% of the farm) where the relative yield is higher for subtropical grass than other crops. Successively smaller areas of land are then attributed to soils where subtropical grass has a lesser advantage (see Table 4). The apportioning of land in this way is arbitrary but it allowed the sensitivity of the model to be assessed for a wide range of soil type mixes.

Table 4. Soil type scenarios: percentage of farm associated with each land management unit[5].

Scenario		LMU1	LMU2	LMU3	LMU4	LMU5	LMU6	LMU7	LMU8
1	Standard	7.0	10.5	17.5	10.5	10.0	10.0	15.0	19.5
2	Uniform	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5
3	STG Hi	25.0	21.5	3.6	0.0	14.3	10.7	7.2	17.9
4	STG Lo	0.0	3.6	21.5	25.0	10.7	14.3	17.9	7.2
5	Luc Hi	21.5	7.2	14.3	10.7	17.9	3.6	0.0	25.0
6	Luc Lo	3.6	17.9	10.7	14.3	7.2	21.5	25.0	0.0
7	Wht Hi	7.2	14.3	10.7	25.0	0.0	21.5	17.9	3.6
8	Wht Lo	17.9	10.7	14.3	0.0	25.0	3.6	7.2	21.5
9	Past Hi	3.6	7.2	25.0	21.5	17.9	14.3	10.7	0.0
10	Past Lo	21.5	17.9	0.0	3.6	7.2	10.7	14.3	25.0

The remaining runs with the MIDAS model assess the value of selected agronomic characteristics of pasture-cropping to farmers. In the base runs the companion wheat crop yields 15% less than a conventionally sown crop. However, there is uncertainty about the size of the yield penalty and its level is potentially important for the profitability of pasture-cropping. Similarly, it is useful to understand the yield or threshold below which it is unlikely that pasture-cropping will enter the farm solution. To assess the importance of forage quality for the farm system a range of subtropical grass digestibilities were evaluated.

An assumption of the study is that grazing animals are physically excluded from pasture-cropped paddocks when a cereal crop is present. This corresponds to periods 1 to 7 of 10 in MIDAS or from May until December (see Table 5 and Figure 3) in the years that a companion cereal is planted. However, as companion-wheat is sown to the same ground every 2 to 4 years and because crop rotations are assumed to be in a steady state, grazing animals are only excluded from a proportion of pasture-cropped land. The sensitivity analysis is used to assess the value of subtropical grass production in the early, middle and late parts of the year.

[5] STG refers to subtropical grass, Luc refers to lucerne, Wht refers to wheat, past refers to annual pasture, and Hi and Lo refer to a soil type mix that favours versus disfavours the respective crops.

Table 5. MIDAS time periods.

	From	To
1	10-May	23-May
2	24-May	13-Jun
3	14-Jun	18-Jul
4	19-Jul	12-Sep
5	13-Sep	10-Oct
6	11-Oct	31-Oct
7	1-Nov	5-Dec
8	6-Dec	28-Feb
9	1-Mar	25-Apr
10	26-Apr	9-May

In the current context the early part of the year corresponds to May 10th to July 18th or periods 1 to 3 in MIDAS. The sensitivity analysis involved multiplying the production of pasture-cropped subtropical grass by a scalar that was varied between 0 and 2. The default value of 1 implies subtropical grass is not grazed when it is accompanied by a cereal crop, but in the years when a companion crop is not present, the pasture can be grazed; a value of 0 means subtropical grass is not grazed in periods 1-3 regardless if it is accompanied by a cereal crop or not, and a value of 2 means the subtropical grass can be grazed in periods 1 to 3 whether or not it is accompanied by a cereal crop. In these runs the yield of the companion wheat crop is assumed to be unaffected by grazing.

The middle part of the year corresponds to periods 4 to 7 or when subtropical grass is dormant. As in the preceding experiment the yield of subtropical grass is scaled to produce a greater versus lesser amount of feed at a particular time of the year. In this experiment the scalar was varied between 0.5 and 1.5 with a default of 1.

There is uncertainty about the productivity of subtropical grass following the harvesting of a companion cereal crop (periods 8 to 10). This relates to the relatively poor understanding of the competition between subtropical grasses and companion cereals. Pasture and its companion wheat crop compete for resources but a companion cereal typically has relatively low water and nutrient demands following maturity and with the higher inputs it receives, coupled with the suppression of the underlying pasture, there is potentially more water and nutrients available to subtropical grass following cereal harvesting than if the subtropical grass was grown conventionally. As such it is unclear if subtropical grass yield in periods 8 to 10 will be lower, higher or unaffected by the companion wheat crop. To assess the uncertainty relating to the late part of the year the yield of subtropical grass is scaled by between 0.5 and 1.5, with 1 implying yield is unaffected by the companion wheat crop.

Results and Discussion.

Base runs

The base or preliminary runs involved modelling a meat dominant sheep and crop farming system on a standard mix of soil types (see Table 4). In these runs the area of cropping was varied both with and without pasture-cropping and the results are presented in Figure 4 and Table 6. It can be seen the inclusion of pasture-cropping has relatively little effect on the profitability ($85/ha versus $83/ha) of the farm system. In the base runs, the main effects of pasture-cropping involve small declines in arable cropping, annual pasture, and lucerne. Similarly, there are small declines in winter stocking rate and requirements for supplementary feeding.

In these runs subtropical grass only enters the farm plan on poor sands, and this partly explains why pasture-cropping had a small effect on the farming system. In MIDAS it is assumed that wheat yields on poor sands average only 42.5% those on higher quality soils. When this is accompanied by a yield penalty due to planting the cereal into pasture, the loss of winter grazing relative to a conventional subtropical grass stand, and there is only a small area of poor sand in this scenario, pasture-cropping only contributes to a small increase in farm performance. The results of the sensitivity analysis are considered in the next section.

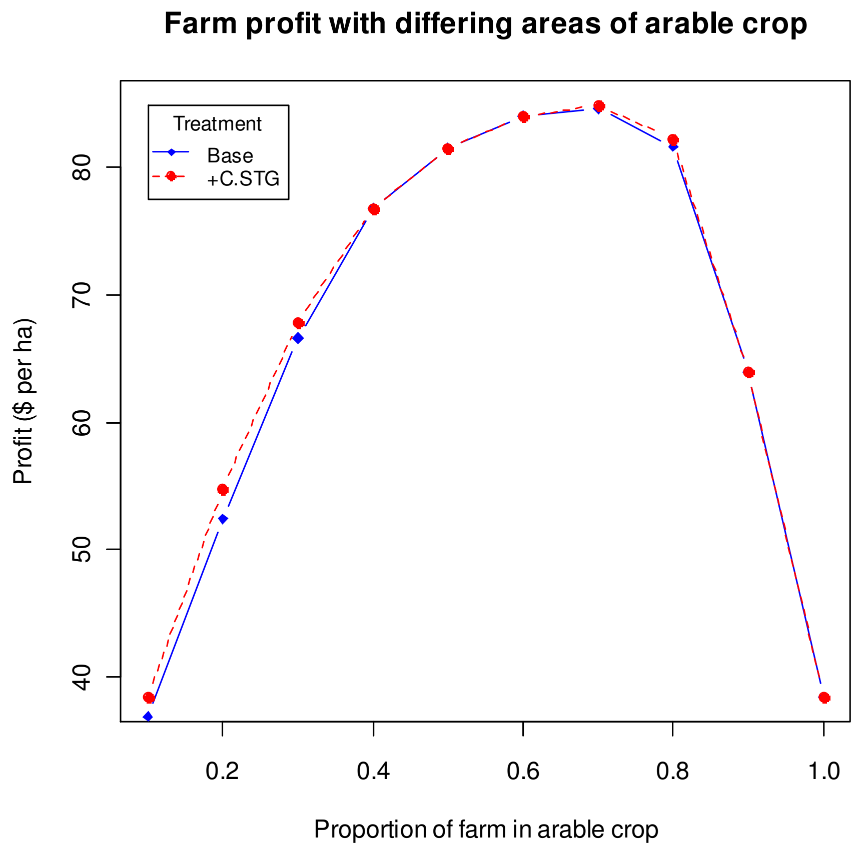

Figure 4. Farm profit with versus without pasture-cropping and differing areas of crop.

Table 6.

Treatment	Percentage of farm Arable Crop	Annual Pasture	Lucerne	C.STG	Supp. Feed (kg/DSE)	Stocking rate (DSE / WG ha[6])	Farm Profit ($/ha)
Base	70	15	15	-	4.3	6.9	83
+STG	67	13	13	7	3.9	6.5	85

[6] WG refers to winter grazed land.

Sensitivity analysis.

Altogether 284 model runs were performed and retained for analysis. A hierarchical cluster analysis was used to group the outputs from these runs. The MIDAS model outputs used in this analysis are similar to those in the base runs and include the areas of arable crops, annual pasture, lucerne, conventionally managed subtropical grass, and pasture-cropped subtropical grass. In addition stocking rate (dry stock equivalents/ha), supplementary feeding (kg/head) and profitability ($/ha) were recorded. An exploratory analysis was performed to determine if any separation existed between the types of farming systems that evolved from varying the parameters described above.

The major findings are: the enterprise choice (crop area and flock structure) influences the area of subtropical grasses selected in MIDAS. In line with expectations, increases in the area of arable crops are accompanied with decreases in the area of subtropical grasses, lucerne and pasture. In most of the model runs, subtropical grass, annual pasture and lucerne were all present but the area of subtropical grass tended to be less than the area of lucerne and in turn lucerne occupied less land than annual pasture.

This result reflects a combination of factors. Annual pasture, subtropical pasture, and lucerne produce forage at different times of the year, the relatively low feed value associated with subtropical grasses, and the correlation in the relative yield of subtropical grass, annual pasture and lucerne on different soils. That is subtropical grass has a relatively high yield on poor soils but on other soils its competitive advantage is less clear. In the following box plots – the plotted ranges refer to minimum, 1st quartile, median, 3rd quartile and maximum values respectively.

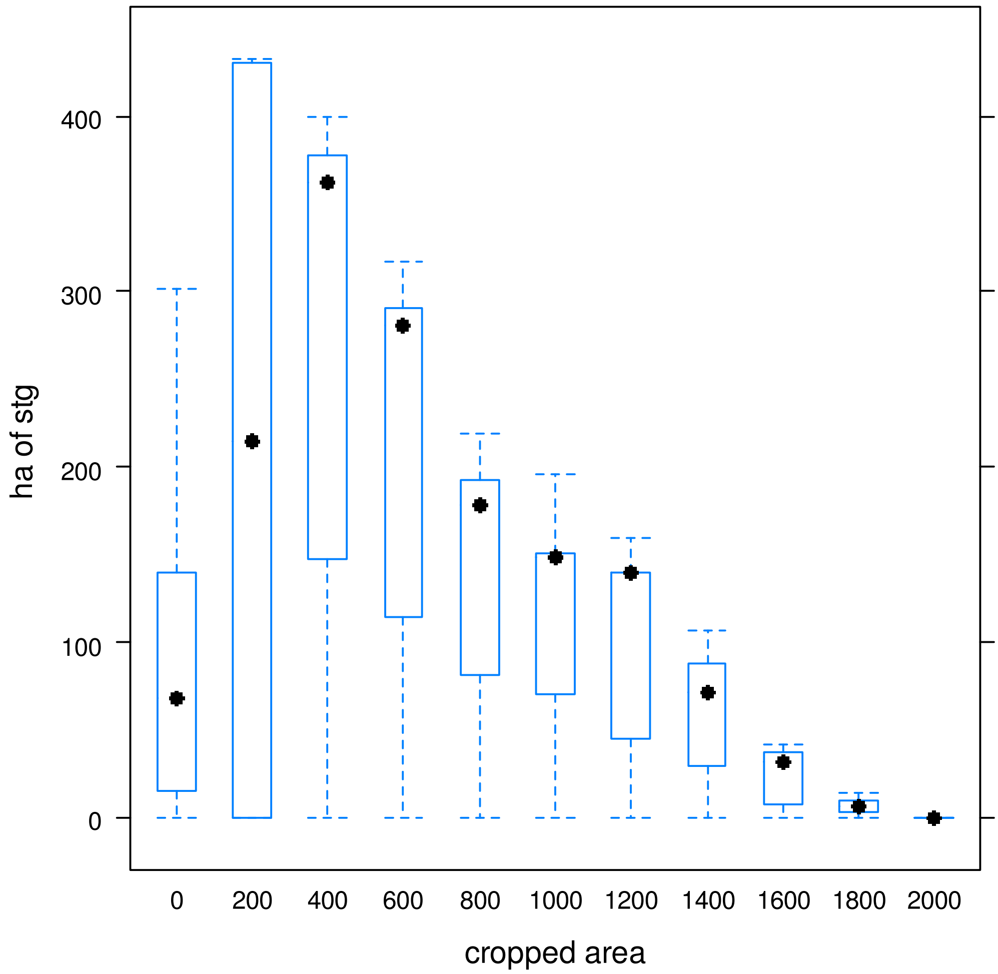

Figure 5. Area of arable crops versus area of subtropical grass.

Meat dominant sheep systems are associated with an increase (~ 40 ha) of subtropical grass compared to wool production systems. There is also a strong interaction between the area of subtropical grass, the choice of flock type and the soil type mix (see Figure 6). The area of subtropical grass in particular is strongly affected by the area of poor soils (LMU 1) providing meat sheep are present. In Figure 6 soil mixes 3, 5 and 8 have the largest areas of poor sand or 500, 429, and 357 ha, respectively, and they are associated with the largest areas of subtropical grass (>71 ha), providing meat sheep are present. In the case of wool dominant systems, subtropical grass is less of a feature of the farm system and the area of subtropical grass is less affected by the area of poor sand. It should also be noted that even when meat systems are present not all of the poor sands are devoted to subtropical grasses.

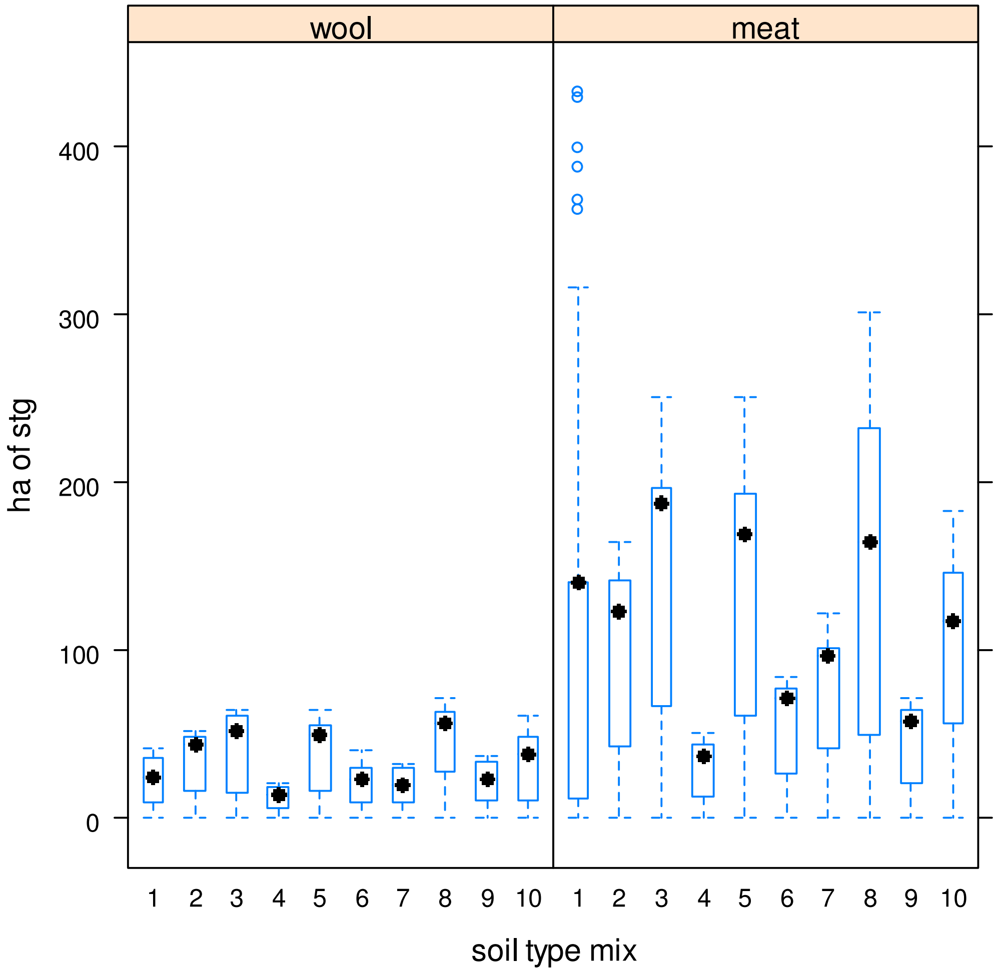

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Figure 6. Effect of soil type mix and flock structure on the area of subtropical grass.

The effect of subtropical grass feed quality was assessed by scaling the feed digestibility's of subtropical grass at different times of the year by a factor of between 0.5 and 1.5. The results suggest if the grazing quality of subtropical grasses is low (less than the default value) subtropical grass is not selected. In contrast the area of subtropical grass increases with increases in feed quality. This implies feed quality is an important determinant of the value of subtropical grass to the farming system. If the digestibility of subtropical grass can be increased by adopting alternate species or by breeding improved species this is likely to result in increased uptake of subtropical grasses by farmers.

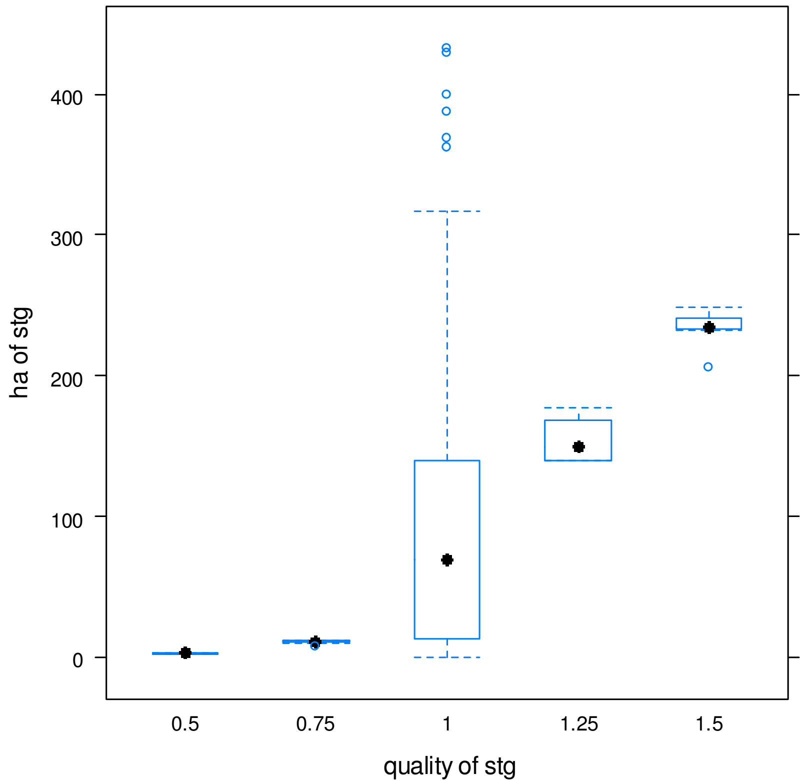

Figure 7. Effect of feed quality on the area of subtropical grass.

The yield penalty associated with pasture-cropped wheat is a significant determinant of the value of pasture-cropping when it declines below a critical limit. The results of the analysis suggest if the relative yield of a companion wheat crop declines below 0.6, or in other words the yield penalty is greater than 40%, pasture-cropping is no longer economic. However, when the relative yield of the companion wheat crop is above 0.6, the level of yield penalty does not have a large effect on the area of pasture-cropping (see Figure 8).

This result implies a companion wheat crop in a pasture-cropping rotation has value, and providing the returns from the companion wheat crop exceed its direct costs and any loss of grazing while the companion wheat crop is present, it will be selected, but it does not seem to be a major determinant of the area of pasture-cropping that is grown.

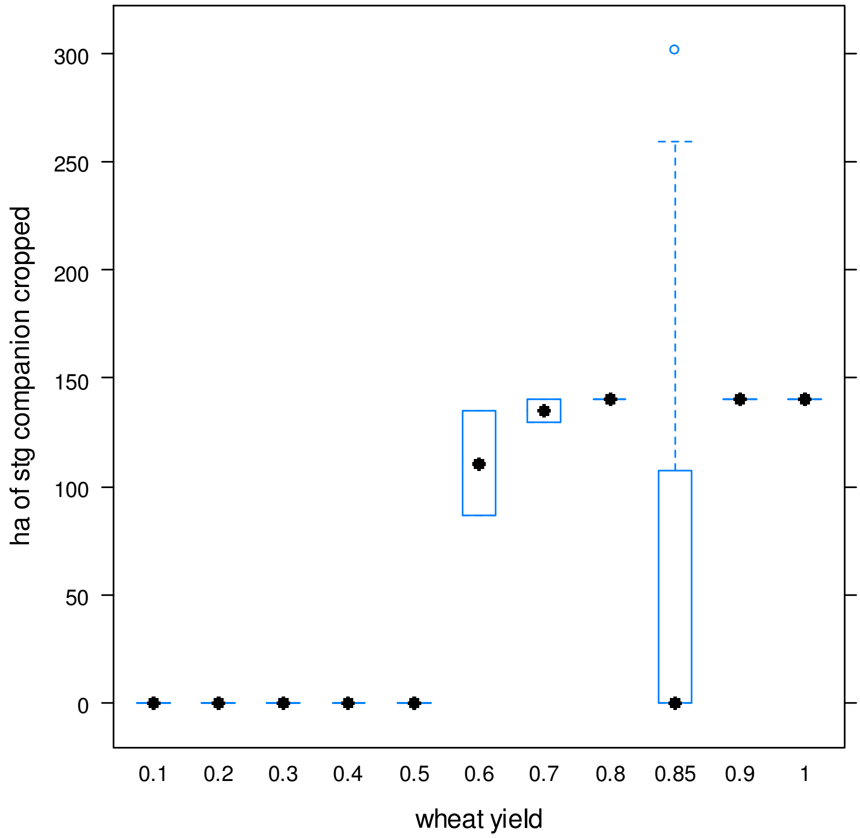

Figure 8. Effect of pasture-cropped wheat yield on the area of pasture-cropping.

The level of production by pasture-cropped subtropical grass in the early, middle and late parts of the year had little effect on the area of pasture-cropping. This result was unexpected as forage production should have a high marginal value in summer and early autumn when subtropical grass is active. In early summer there is normally sufficient forage from arable crop residues, annual pasture and lucerne, and consequently additional forage from subtropical grass has a relatively low value. But as summer progresses the availability and quality of other feed sources tends to decline and supplementary feeding becomes necessary. The most likely explanation for the low value placed on additional subtropical grass production relates to the relatively low digestibility of the forage during the periods when it is potentially most valuable. If the digestibility of the subtropical grass forage was higher it seems likely the value of additional production would also be higher.

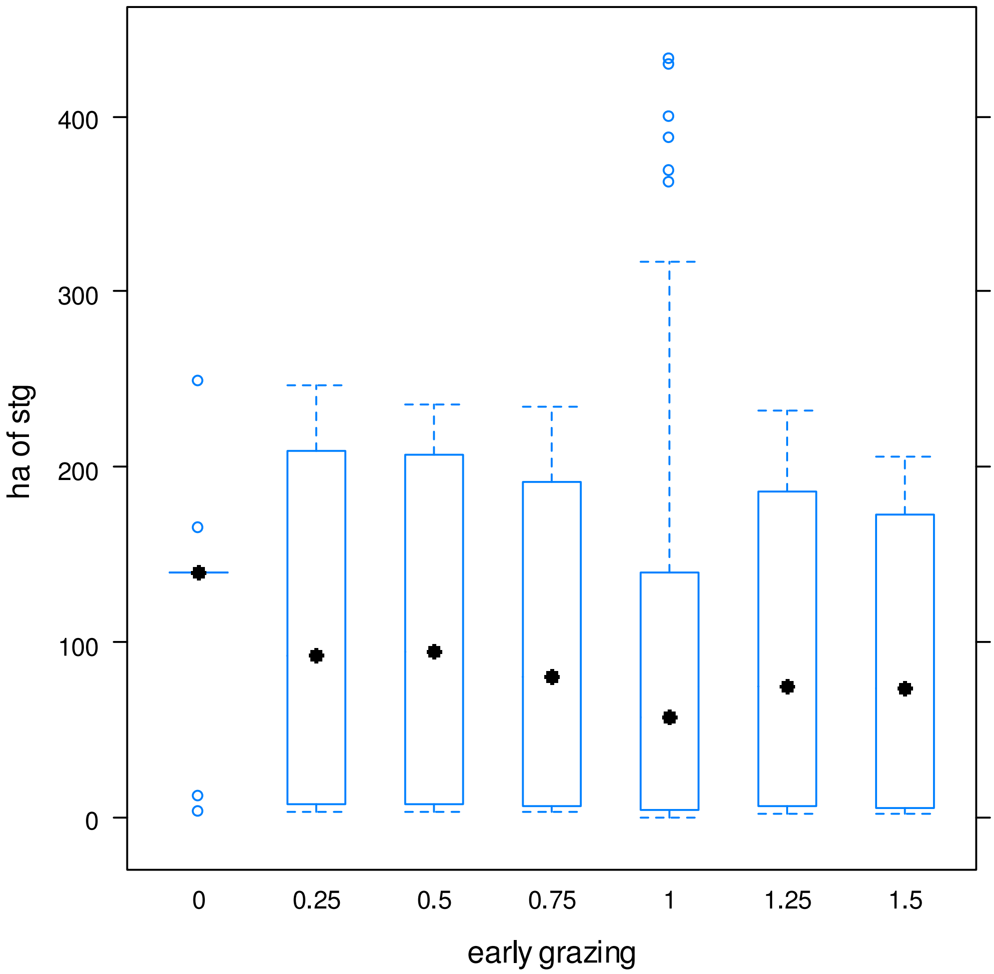

Figure 9. Level of subtropical grass production in the early part of the year (periods 1 to 3)

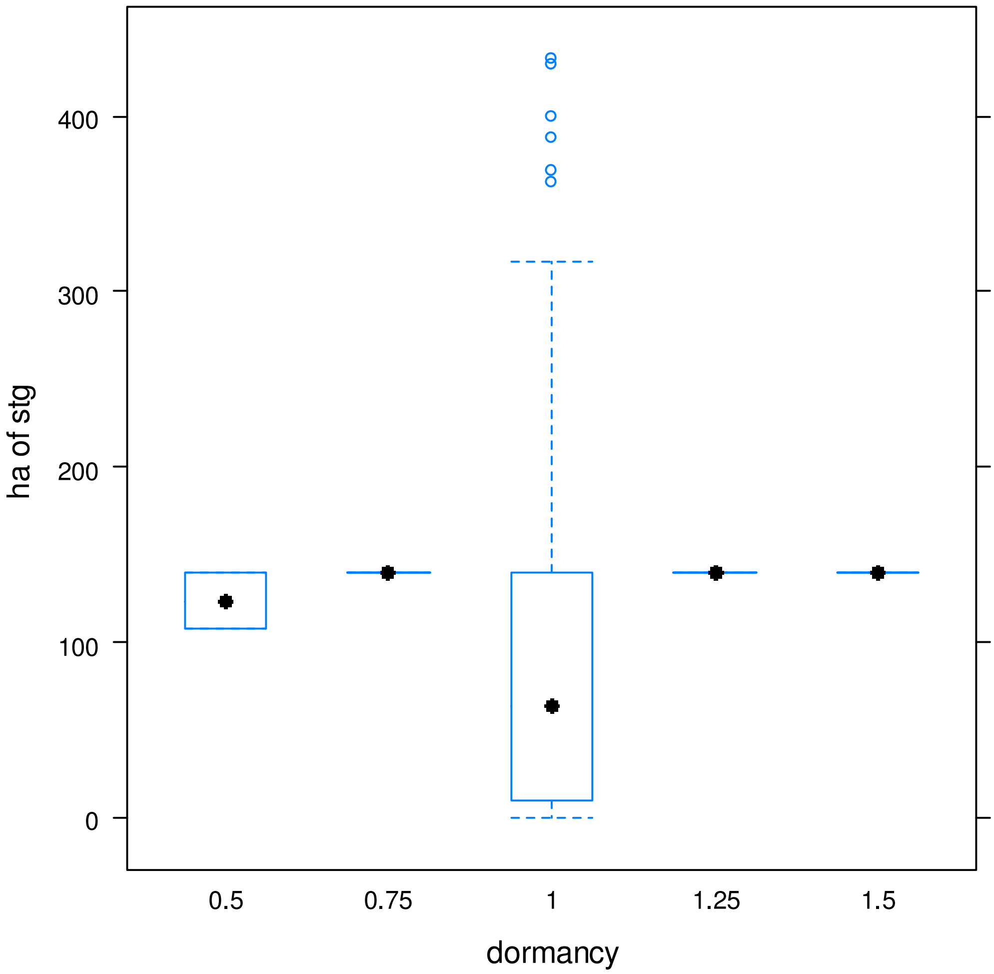

Figure 10. Level of subtropical grass production in the middle part of the year or dormancy (periods 4 to 7)

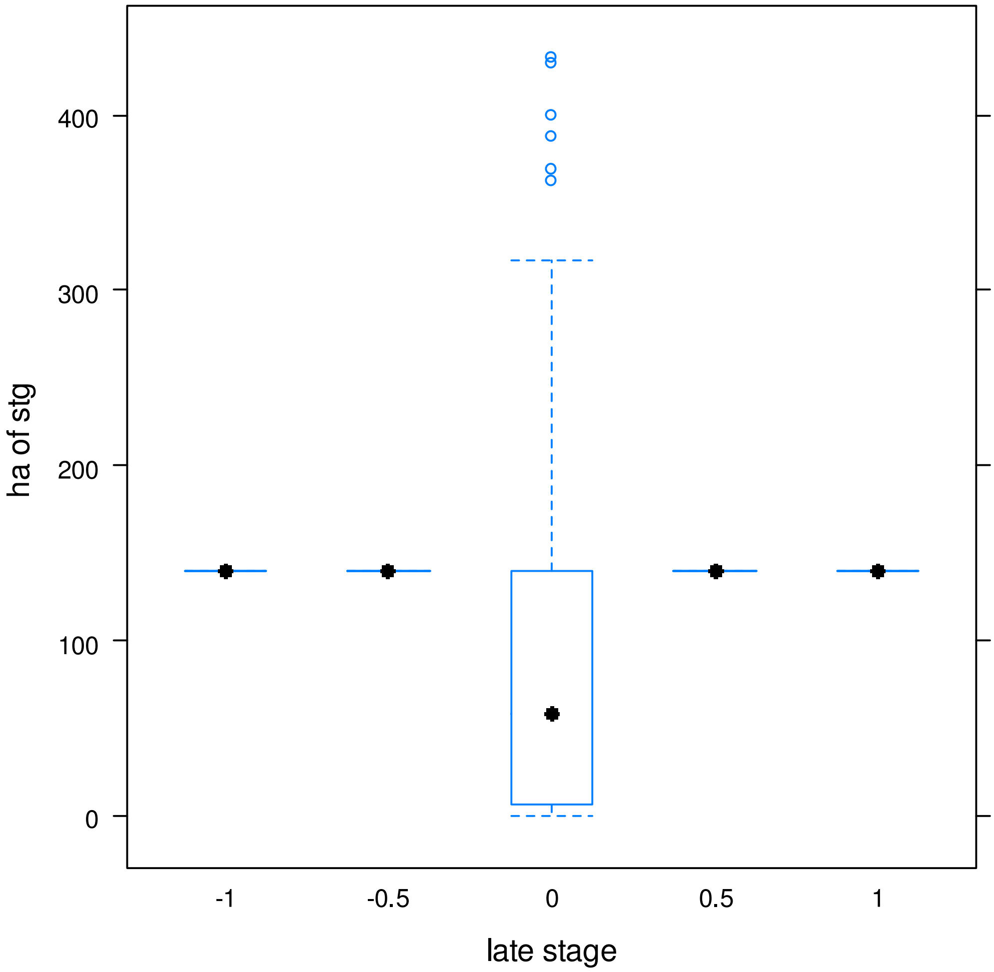

Figure 11. Level of subtropical grass production in the late part of the year (periods 8 to 10)

Conclusions

284 MIDAS simulations were conducted with varying soil type mix (10 combinations), enterprise mix (cropped area, wool sheep, meat sheep), subtropical grass quality, timing of subtropical grass growth and availability of feed, pasture dormancy and yield penalty to the companion crop. Subtropical grasses and companion cropping did not dominate the farming system and are primarily selected on LMU 1 or poor sand. The area of poor

sand is an important driver as is the enterprise choice (area of cropping and presence of meat sheet), the impact of the pasture on companion wheat yield and the feed quality of the subtropical pasture. The level of subtropical grass production at different times of the year was not an important determinant of the area of pasture-cropping – but there is likely to be a positive correlation between productivity, feed quality and the area of subtropical grass.

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