Land suitability for grain legume production in Western Australia

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Abstract

A land suitability model for grain legume production was developed using DAFWA's map unit database. Land capability was determined for narrow-leafed lupin, field pea, chickpea, faba bean, yellow lupin and lentil, based on the most limiting of 17 attributes assigned to each soil-landscape unit in the database. Bureau of Meteorology data was combined with the soil-landscape information to produce over 90,000 unique polygons making up the agricultural area of WA. Rules for growth and disease risk were assigned based on the climatic data. Finally, rules for profitability were developed using gross margins for each crop over two rainfall zones. Field pea, lupin, faba bean and lentil were the species predicted by the model to produce high gross margins over the widest area. Lupin was mapped mainly on the sandplain areas of the northern agricultural region which refelcts where most lupins are currently grown. The large area mapped as suitable for field pea helps explain the current rapid expansion of this industry in WA. There may be scope for a large expansion in faba bean production given the current area of production is much smaller than the area mapped as highly suited to its production. High gross margins for lentil occurred because high grain prices were attributed to this species. Risk from variability in lentil yield is likely to be high because only a small land area is mapped as highly suited to lentil production.

Introduction

The area sown to grain legumes in Western Australia has contracted by about 40% over the past 10 years. This has occurred at a time when the range of species and quality of varieties available to farmers has improved substantially. What, then, is the potential for these species in Western Australia and where should future research and development be directed?

Current assessments of the land suitability of grain legumes in Western Australia are largely based on soil pH, soil texture or rainfall (Siddique, 1999). Reasons for the recent decline in the area of production, however, are mainly a combination of seasonal (lower rainfall), economic (low prices) and biotic (diseases and weeds) factors. Assessments of grain legumes that also take these factors into consideration are needed to improved estimates of their potential in Western Australian agriculture.

Recent advances in our knowledge of grain legumes (Siddique *et al* 1999) and in our ability to model soils and landscapes for the south–west agricultural region of Western Australia (van Gool *et al* 2005) provide a mechanism to construct more comprehensive models of land suitability for crop production. This paper describes a simple rule-based model that estimates land suitability for grain legume production utilising soil, meteorological, economic, and disease data. The model can be used to estimate the impact of technological innovations on potential areas of these crops.

Methods

The model has three layers: 1) soil and landscape information, 2) temperature and rainfall data, 3) production rules. Gross margins are dependent of potential yield which in turn is modified by land capability and disease constants.

Soil and landscape information

Soil and landscape information is contained within the Map Unit Database developed by the Department of Agriculture and Food (Schoknecht, 2004). Information in the database varies in detail and scale depending on the constituent survey from which it was derived. Zone Land Units within the database were used as the basis for land capability ratings for grain legumes using the procedures describe by van Gool *et al* (2005). Zone Land Units are combinations of landform and soil type and are represented proportionally within Map Units.

Zone Land Units were divided into five capability classes for production of narrow leafed-lupin *(Lupinus. angustifolius* cv Mandelup or Tanjil), yellow lupin (*L. luteus* cv. Pootalong), field pea (*Pisum sativum*, cv Kaspa), faba bean (*Vicia faba*, cv. Fiesta), desi chickpea (*Cicer arietinum* cv Genesis 836) and lentil (*Lens culinaris*, cv Cassab). Land qualities rated were: flood hazard, soil permeability, pH at 0-10cm, pH at 50-80cm, surface salinity, surface condition, salt spray exposure, surface stones (>20mm), surface gravel (<20mm), soil trafficability, rooting depth, waterlogging risk, water repellence, wind erosion risk, soil workability and water storage. The land quality that was most limiting determined the capability class for each species on each Zone Land Unit.

Temperature and rainfall data

Climate surfaces for rainfall, maximum temperature and minimum temperature were obtained from the Bureau of Meteorology. These are mean daily values for each month for 1961 to 1990 shown on 2.5 km ? 2.5 km grid cells.

Table 1. Equations and coefficients use to estimate potential yield, land capability, disease risk and gross margin.

	Narrow-leafed lupin	Field pea	Chickpea	Lentil	Faba bean	Yellow lupin
<u>Yield Rule</u> *GR* = a ? (*wu* − b) for b ≤ *wu* ≤ c *GR* = d + (e ? (*wu* − c)) for *wu* > c *GR – rainfall driven grain yield* *wu - average rainfall 1st May to 31st October*	<u>North</u> a=14.4 b=134 c=297 d=2347 e=1.8 <u>South</u> a=18.3 b=159 c=298 d=2549 e=2.5	<u>North</u> a=14.4 b=111 c=246 d=1944 e=1.8 <u>South</u> a=18.3 b=132 c=247 d=2115 e=2.5	<u>North</u> a=13.2 b=134 c=297 d=2151 e=1.6 <u>South</u> a=16.8 b=159 c=298 d=2336 e=2.3	<u>North</u> a=14.4 b=111 c=246 d=2944 e=1.8 <u>South</u> a=18.3 b=132 c=247 d=2115 e=2.5	<u>North</u> a=14.4 b=134 c=297 d=2347 e=1.8 <u>South</u> a=18.3 b=159 c=298 d=2549 e=2.5	0.8 GR for narrow- leafed lupin
<u>Land Capability Yield Constant</u> *GRL* = *GR* ? f *GRL – land class driven grain yield.*	Values for “f” are constant for each species but vary with land class (LC). Very highly capable land: LC1 = 1.5 Highly capable land: LC2 = 1.0 Moderately capable land: LC3 = 0.67 Poorly capable land: LC4 = 0.33 Not capable land: LC5 = 0.10					
<u>Disease Rule</u> GRLD = GRL ? g *GRLD* –	Values for “g” are dependent on species and only apply to narrow-leafed lupin, yellow lupin, field pea and chickpea and dependent on whether a disease is triggered. Disease is triggered depending on rainfall and temperature and is not described here					

diseases driven grain yield (anthracnose, ascochyta or blackspot).	(Salam,*et al* 2002). Narrow-leafed lupin = 0.87 (all land classes); yellow lupin = 0.6 (all land classes); field pea = 0.9 (LC1, LC2) or 0.85 (LC3, LC4, LC5); chickpea = 0.75 (all land classes).					
<u>Gross Margin</u> GM = (GRLD ? gp) –vc *GM–gross margin* *gp–grain price* *vc–variable costs dependant on rainfall*	gp=$175/t vc >350mm $166 ≤350 $132	gp=$210/t vc >350mm $200 ≤350 $170	gp=$350/t vc >350mm $280 ≤350 $260	gp=$420/t vc >350mm $230 ≤350 $200	gp=$260/t vc >350mm $217 ≤350 $190	gp=$280/t vc >350mm $200 ≤350 $170

Production rules

Production rules are detailed in Table 1. The Land Capability Yield Constants were determined empirically by averaging yields over a range of soil types from DAFWA's species comparison trials. The APSIM lupin module (Farr?, 2004) was used to simulate lupin yields using historical weather data. A two-step linear regression was then fitted to the simulated data. These regressions were modified for the other species based on the published water use efficiency values because the APSIM modules for chickpea, field pea and faba bean simulated unrealistic yields for the Western Australian environment. The rule for yellow lupins was a constant 80% of the narrow leaf lupin yield based on the results from the crop variety testing trials conducted by DAFWA. There was more confidence in yield estimates for narrow-leafed lupin than for the other species because of the different procedures used for estimating yields.

Disease rules were derived from the ascochyta, anthracnose and blackspot models of Salam *et al* (2002). Disease rules were not developed for faba bean or lentil because new varieties and production techniques reduced the impact of disease in these species.

An additional rule to for disrupted reproductive development in chickpea at low temperature was applied based on monthly average temperature and rainfall during August to October. The rule is not described in Table 1 because of space limitations. Economic data were based on the Gross Margins Guide 2005, Western Australia.

Results

Predictions of land capability for each species showed that field pea were adapted to the largest area of land of all species (Table 2). Seventy percent of the land area was classed as moderately capable or better for field pea production. In contrast more than 60% of the land area was classed as poorly capable or not capable for production of all the other grain legume species. Field pea and lupin were the species with the largest area of land classed as highly capable for their production which was about 3 million ha each (15% of the area). Only 3% of the land area was classed as highly capable for chickpea and lentil. There is inadequate information about boron toxicity in the map unit database to adequately map boron toxicity as a possible limiting factor. If boron toxicity is included it is likely that the area of land classed as moderately capable for lentil would be substantially lower.

Field pea produced the highest yield of all species on 70% of the area (Figure 1). Lupins produced the highest yield on 18% of the land area and faba bean on 5%. High prices for grain of lentil and faba bean meant they highest gross margins on about 10% of the land despite producing the highest yield on a much smaller area. Narrow-leafed lupin and field pea produced the highest gross margin on 11% and 60% respectively of the area. There were relatively broad and contiguous areas where the different species produced the highest gross margins. Lupin dominated in the northern areas, faba bean in the south-west and field pea in the eastern wheatbelt.

Table 2. Area* ('000 ha) of land falling into each land capability class for grain legume species in the south west agricultural region of Western Australia (land used for dryland agriculture or plantation only).

Species		Very high (LC1)	High (LC2)	Fair (LC3)	Poor (LC4)	Not (LC5)
Narrow-leafed lupin	Area (ha)	0	2,659	4,188	3,828	8,122
	%	0.0%	14.1%	22.3%	20.4%	43.2%
Field pea	Area (ha)	60	3,034	9,940	3,368	2,395
	%	0.3%	16.1%	52.9%	17.9%	12.7%
Chickpea	Area (ha)	0	557	4,452	9,453	4,335
	%	0.0%	3.0%	23.7%	50.3%	23.1%
Faba bean	Area (ha)	50	1,719	3,699	8,981	4,348
	%	0.3%	9.1%	19.7%	47.8%	23.1%
Lentil	Area (ha)	62	466	4,425	7,898	5,945
	%	0.3%	2.5%	23.5%	42.0%	31.6%
Yellow lupin	Area (ha)	0	2,670	4,371	4,745	7,011
	%	0.0%	14.2%	23.2%	25.2%	37.3%

Discussion

Field pea, narrow-leafed lupin, faba bean and lentil are predicated by this model to be the grain legume species with widest potential in the agricultural areas of Western Australia. High gross margins for lentil and faba bean, however, are based mainly on land that was rated as only moderately capable for their production. The reliability of production is not estimated in the current model, but, is therefore likely to be lower for faba bean and lentil compared with field pea and narrow-leafed lupin. Chickpea did not feature as an important species, however, if the disease rules and gross margins were altered to reflect the release of a ascochyta resistant variety, then chickpea produced the highest gross margin on about 400,000 ha (data not shown).

We have demonstrated that spatial data on climate and soils can be integrated with models of plant growth and disease to develop a useful model of land suitability for grain legume production in Western Australia. The model we have developed, however, uses relatively coarse assumptions in defining its rules. There is scope to improve the accuracy and sophistication of these rules. For example, the field pea, chickpea and faba bean modules of APSIM can be used to generate yield rules for these species once they have been calibrated for Western Australia. Further improvements can be gained by estimating the effect of each soil property on the yield of plants, rather than grouping soils into one of five capability classes. The spatial capacity of the model can also be further utilized by incorporating the location of physical infrastructure (eg. receival bins) so costs and prices can be more accurately estimated based on distance. Other data layers (eg. frost) also need to be added.

The usefulness of this model is based on the structure of the Map Unit Database that allows detail soil information to be accessed and combined with other data as shown above. The scale and accuracy of the soil surveys that constitute the Map Unit Database imposes limitations to model but allows improvements as more data is added.

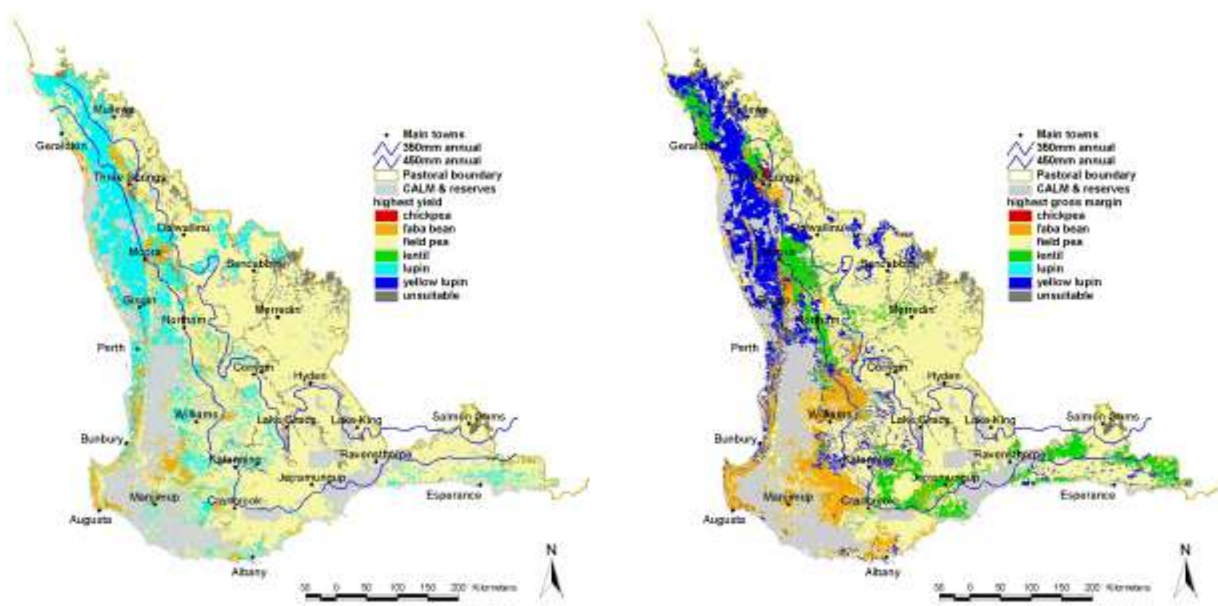

Figure 1. Maps showing species producing the highest yield (left) or highest gross margin (right).

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