Projected impacts of climate change on farm business risk in three regions of Western Australia

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Abstract

A farm simulation model known as STEP (Simulated Transitional Economic Planning) is used to examine the financial performance of a range of farms under current and projected climate in three regions of Western Australia. In two of the regions climate change is expected to cause more unfavourable production years, whilst in the other region more favourable production years are projected. Farms in regions where more adverse climate is projected are shown to experience increased business risk, in contrast to the findings for the other region. Characteristics of farms that increase their risk of business failure in the presence of projected climate change are small farm size, low initial equity and an enterprise mix that favours wool rather than crop production. For all types of farms, as would be expected, a favourable trend in the terms of trade increases farm business resilience. In the regions where adverse climate change is projected, crop dominant farms that currently have high equity appear capable of withstanding the projected adverse climate change whilst farms with similar characteristics in the other region are likely to prosper further, given their projected favourable change in climate.

Key words: climate change, business risk, farm viability, farm characteristics

Introduction

Projected climate change is a major challenge for farming regions of Australia (IPCC 2001; Pittock 2003; CSIRO 2007). For the agricultural region of Western Australia (WA), climate change is expected to cause a drying and warming of its climate (Pittock 2003). In recent decades this region has produced 40% of the nation's wheat but it is projected to be adversely affected by climate change (Howden *et al.* 1999; Reyenga *et al.* 2001; Howden *et al.* 2007).

Increased frequency of poor seasons (John *et al.* 2005; Thamo *et al*. 2015) in which low returns or losses occur is likely to cause farm businesses to incur large debts through seasonal expenditures and reduced revenues (Anderson 1979). Farm equity may fall, thereby impeding a farm's ability to obtain further credit for seasonal expenditures (Bierlen and Featherstone 1998) or the farm business may face higher risk premiums on their borrowings that lessen the farm's profit margin. If a farm cannot obtain further credit, or is unable to repay borrowed debt then the farm will become unviable (Peart 2005).

Farm survey data (e.g. Planfarm/BankWest 2014) reveals that under current climatic conditions there is a wide distribution in the profitability of farm businesses with profitability linked to the characteristics of each farm business. For example, larger farms rely on increased returns from economies of size (Helfand and Levine 2004; Latruffe *et al.* 2004) that lower average costs of production (Cattle and White 2007) and thereby support the farm's profitability. Western Australian farm sizes have been increasing and this trend is expected to continue (Kingwell and Pannell 2005).

One strategy adopted by many farm businesses, in response to climate and market risk, is to diversify their business assets and enterprises to reduce business risk. Farms often invest in off-farm assets to stabilise business equity levels and diversify their financial risk (Young and Barry 1987).

Another strategy is on-farm enterprise diversification. Research by John and Kingwell (2004) and John *et al.* (2005) highlights the economic importance of diversification into livestock. These studies suggest that climate change in the low rainfall eastern wheatbelt of Western Australia may cause the optimal farm plan to shift away from strategic cropping to a more extensive grazing system with opportunistic cropping. High input crop dominant businesses are known to face increased financial risk as farm input costs rise (Sadras *et al.* 2003; Plunkett 2015).

Economic conditions that are outside the farmer's control also impact upon a farm's financial performance. Australian farms have experienced a declining terms of trade for a number of decades (Chisholm 1992; Knopke *et al.* 2000; ABARE 2007), although recently from 1991 to 2006 the decline was only 0.9% per annum (Mullen 2007) and Tweeten and Thompson (2008) suggest the terms of trade decline may not be severe in coming decades.

Also outside the direct control of farmers are prevailing interest rates. Research by Barry *et al.* (1981) highlights the need for risk management strategies to reduce credit risk. Farms often depend on credit for seasonal expenditure and investment opportunities and are therefore exposed to interest rate risk. However, current economic conditions in Australia suggest that for the next several years a low interest rate regime is likely.

Farm businesses are not identical and so changes in their operating environments are likely to affect different farms differently. In the case of climate change the question arises as to how different farm businesses may fare under projected climate change. Will farm characteristics, such as large farm size and high equity positions, that have served the profitability of Australian farming so well over several decades, continue to be desirable business characteristics as projected climate change occurs? This paper examines this question by drawing on simulation studies of a number of typical grain and sheep farms located in different climate regions of the WA grainbelt. This study investigates what farm characteristics are likely to contribute to the resilience or vulnerability of farm businesses under region-specific current climates and projected climate changes.

This paper continues by describing the farm modelling approach. Results, discussion and a conclusion are then presented.

Methodology

Study regions

Representative farms are constructed to typify the farming systems observed in three farming regions of WA (see Figure 1). All the regions are characterised by a Mediterranean climate with cool wet winters and dry warm summers, with 80% of annual rainfall falling between April and October.

A farm located in the north-eastern low rainfall region receives an annual average rainfall of less than 325mm and a traditional farm in this region produces wheat (*Triticumaestivum*) and sheep, with a major focus on wheat production, complemented by growing lupins (*Lupinusangustifolius*) on favourable soils. These crops are grown in rotation with volunteer pastures, subterranean clover (*Trifoliumsubterraneum*) or chemical fallow.

By contrast, a farm located in the northern high rainfall region receives an average annual rainfall of around 550mm. The typical farming system comprises a mix of grain and livestock production. The crops produced are wheat, lupins, barley (*Hordeumvulgare*) and canola (*Brassica campestris*). These crops are grown in rotation with subterranean clover which accommodates merino sheep grown for wool, or merino ewes are mated to crossbred terminal sires for lamb production.

A traditional farm in the southern high rainfall region is livestock dominant with around 60% of land allocated to livestock enterprises (BankWest 2009). The region's annual rainfall is around 550mm. The sheep enterprise is run on legume dominant pastures. Crops grown in this region are wheat, barley, canola, oats and a small proportion of lupins.

STEP

STEP (Simulated Transitional Economic Planning) is an Excel®-based simulation model of a broadacre farm (Bennett *et al.* 2003; Abrahams *et al.* 2008). It is applied to describe a range of case study farm businesses in each of the three study regions (See Figure 1). STEP tracks a farm's physical and financial performance over a 20 year period. It integrates enterprise decisions into a whole-farm financial analysis. Information on enterprise gross margins, rotation options, fixed costs, interest rates, labour requirements, terms of trade and depreciation are incorporated in the model (Lien 2003).

STEP also considers changes in seasonal climatic conditions (Bennett *et al.* 2003). To simulate climatic variability, STEP uses random draws of crop and pasture yields from known historic and projected yield distributions. The same process applies to prices of commodities that are random draws from historical distributions, taking account of price correlations between commodities. Lambing percentages in each weather-year are also a random draw linked to crop and pasture conditions. These yields and prices are incorporated in enterprise annual gross margin calculations for all main enterprises.

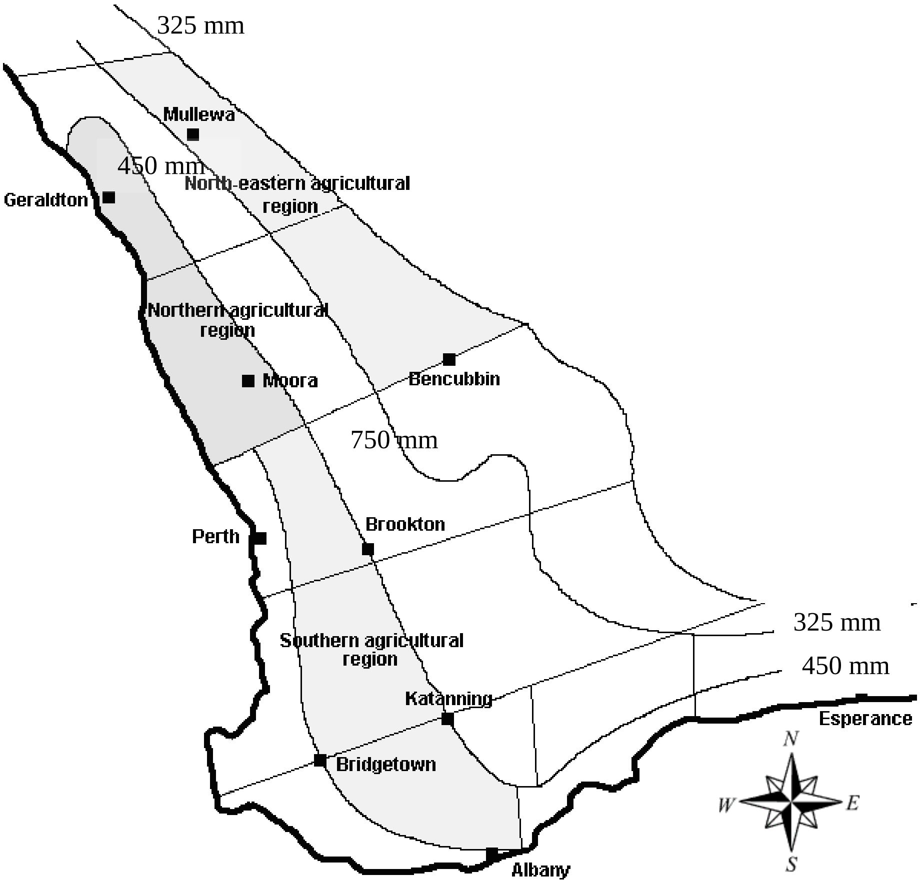

Figure 1. Map of the north-eastern, northern and southern WA study regions (shaded)

STEP allows for some adjustment of enterprise management and mixes on a farm. In the version of STEP used in this study, adjustments in enterprises are made in response to projected crop yield outcomes. For example, input costs are set at one of three levels (low, average or high) in response to prospective wheat yields; wheat production being the dominant enterprise on most farms in each region. The low input level is selected in weather-years when prospective wheat yields are in the lowest decile. These yields are below 1.85 t/ha in the northern high rainfall region, below 1.75 t/ha in the southern high rainfall region and below 0.5 t/ha in the north-eastern low rainfall region. In these poor years reductions in expenditure on fertilisers, chemicals, repairs, fuel and oil, contract costs, labour costs and personal drawings are assumed to occur. Also in the low rainfall north-eastern region in poor seasons, wheat is assumed to not be sown on clay soils, and would be replaced by volunteer pasture in these poor years. Also lupins would be dry sown and if a crop failure occurred then a broad-spectrum herbicide would be applied to the lupin crop early to boost the profitability of a wheat crop grown in the following year. In the northern high rainfall region in a prospective poor season, the wheat area is assumed to decrease by 8% and be substituted by pasture. These changes were based on farmer behaviour as recorded in farm surveys (e.g. BankWest 2007; BankWest 2009).

By contrast, in weather-years where prospective wheat yields are above 2.8 t/ha for the northern high rainfall region, above 2.75 t/ha for the southern high rainfall region and above 1.5t/ha for the north-eastern low rainfall region increases in nitrogen fertiliser (high inputs) applications occur. Hence, in 20% of years, these changes in farm management are assumed to occur. The changes in input and enterprise levels in response to prospective conditions reflect the state-contingent nature of farm management (Crean 2009), although in practice farmers are observed to often make few and small tactical changes to their farm plans (Kingwell 2006).

To initialise STEP to describe case study farms in each region, the percentage of land allocated to particular crop rotations was specified as shown in Table 1, with these percentages based on farm survey findings (BankWest 2009) and local farm management consultant opinion. In each region three main farm types were created to represent different degrees of crop dominance.

Table 1. The area of land allocated to pasture and crop enterprises in each study region

Percent of farm area devoted to this enterprise (%)	North-eastern low rainfall region			Northern high rainfall region			Southern high rainfall region		
	Area cropped (% of farm)			Area cropped (% of farm)			Area cropped (% of farm)		
	Low (52%)	Medium (72%)	High (84%)	Low (36%)	Medium (50%)	High (76%)	Low (36%)	Medium (42%)	High (64%)
Pasture	48	28	0	64	50	24	69	58	39
Wheat	52	72	72	28	28	35	8	11	18
Lupin	0	0	11	8	14	18	0	4	4
Barley	0	0	0	0	4	14	0	11	16
Canola	0	0	0	0	4	8	8	8	15
Oats	0	0	0	0	0	0	7	8	7
Fallow	0	0	16	0	0	0	0	0	0

In STEP a key output is the farm business's discounted cumulative financial position (Abrahams *et al.* 2008). In farm modelling discounted cash flow analysis often is used to determine the attractiveness of investments (Fazzari *et al.* 1988; Gilchrist and Himmelberg 1995), including their ease of debt-servicing. Each particular representative study farm was assumed to carry an initial level of debt that diminished or increased depending on the farm's debt-servicing ability over the 20 year period. Interest repayments on farm debt were calculated and included in the surplus/deficit calculation each year. The Net Present Value (NPV) of the annual farm profit stream was calculated to yield a cumulative NPV of farm profit.

The STEP model also reports the farm business equity position expressed as a percentage (farm equity x 100 divided by total assets). Farm equity is the sum of assets (land value, plant capital, livestock assets, off-farm assets and cash) minus liabilities (farm debt).

Off-farm asset values were based on farm survey data (BankWest 2009) at the commencement of the modelling period. Off-farm assets were assumed to be self-sustaining and injected a 3% return into the farm's cash flow budget.

Model assumptions

The wheat yield assumptions used by STEP are given in Table 2. These yields are based on modelling investigations and farm survey data.

The process for generating yield distributions firstly involved studying wheat yield data generated by the APSIM-Wheat model for each region (Keating *et al.* 2003; Kingwell and Farre 2009), under current climate and projected climate. APSIM-Wheat simulates wheat yield in response to water availability, nitrogen availability, temperature, CO_2 concentration, day length and radiation. The

APSIM-Wheat model calculates the yield limited by climate, but does not account for weed, pest, disease and trace element problems (Keating *et al.* 2003).

The climate data drawn upon by APSIM-Wheat came from a high resolution nested climate model of the CSIRO GCM MK3 that generated downscaled daily climatic data. The CSIRO GCM MK3 assumed CO_2 concentrations of 350 ppm for the period 1976 to 2005 (current climate) and concentrations of 440 ppm for the period 2035 to 2064 (projected climate).

Table 2. Wheat yield distributions used in the STEP model for each agricultural region

Case study farm	Wheat yield in current climate (1997/8- 2008/9) (t/ha)		Wheat yield in projected climate (2035 to 2064) (t/ha)	
	Mean	Yield distribution	Mean	Yield distribution
North-eastern low rainfall	1.30	normal	1.17	lognormal
Northern high rainfall	2.45	normal	2.39	normal
Southern high rainfall	2.35	lognormal	2.50	normal

The APSIM-Wheat model showed that under the projected climate, wheat yield was affected differently in the different regions (Kingwell and Farre 2009). To account for likely weed, pest, disease and trace element problems the wheat yields produced by Farre *et al.* (2007) were adjusted downwards to represent the wheat yields from 1997/98 to 2008/09 for each case study region in accordance with farm business records (e.g. BankWest 1998 to 2009). Then, using @Risk (Palisade Corporation 2009), best-fit distributions were fitted to the APSIM-adjusted wheat yield datasets for each region, under current and projected climate. The resulting average yields and distributional forms are specified in Table 2.

Drawing on farm business records (e.g. BankWest 1998 to 2009) for each study region, winter pasture growth, oat, barley, canola and lupin yields were correlated to wheat yields. Hence when random draws from wheat yield distributions were drawn to represent 20-year sequences of climate, these correlations were also used to determine the yields of the other crops and pastures. Stocking rates on each farm in each region were based on pasture production and stocking rates recorded in farm surveys (e.g. BankWest 1998 to 2009).

STEP accommodates variable prices by using random price draws. A lognormal distribution was fitted to a farm-gate wheat price series using @Risk (Palisade Corporation 2009). The farm-gate price of wheat for each region was based on Australian Premium White grade from 1995/6 to 2007/8. This price was obtained using pool prices less levies, freight from paddock to port, Australian Wheat Board finance costs and Cooperative Bulk Handling outturn costs. Similarly, a lognormal distribution was fitted to the prices of lupins, milling oats, feed oats, canola and barley; assuming 70% of the barley will be classed as manufacturing grade and the remainder as feed (DAFWA 2005). Price draws from these other crop price distributions accounted for the correlations among these prices, where the correlation coefficients were based on the prices from 1995/6 to 2007/8.

The best fit function for farm-gate wool prices and lamb and ewe prices over the period 1990/1 to 2008/9 was a normal distribution. These prices were also correlated using historical data, with the sheep prices being adjusted, where necessary, to account for the likely effect of weather-year conditions on the condition score, and therefore sale price, of the animals. The relationship between price and condition score was based on research of Kingwell (2001). In general, the higher the condition score the greater the price premium the animals received.

Aside from the yield and price data, other data for enterprise gross margins were obtained from a number of sources (e.g., Weeks 2008, DAFWA 2005, Ward 2009, ABARE 2009). To represent the advantages of break crops in the wheat dominant rotations in the north-eastern low rainfall regions, a 7% yield increase was applied to wheat following lupins, volunteer pasture or subterranean clover. A 7% yield decrease was applied to wheat crops following wheat (Ward 2009). A 300 kg/ha yield increase was applied to wheat crops after chemical fallow (Weeks 2008) and, based on farm survey data (e.g. BankWest 2007 & 2009), all wheat grown on farms in the northern high rainfall region was assumed to follow break crops. Barley was grown as a second cereal. All wheat and barley grown in the southern high rainfall region followed break crops and oats were grown as a second cereal (Hill *et al.* 2005).

Farm financial data mostly came from BankWest (2009). Information on farm characteristics such as farm debt, value of off-farm assets, farm sizes and value of plant capital were obtained from BankWest (1998 to 2008). Plant capital was determined by value per cropped hectare. Plant capital was $458 per cropped/ha for representative farms in the northern high rainfall region, $800 per cropped/ha in the southern high rainfall region and $269 per cropped/ha for the north-eastern low rainfall region. To replenish cropping machinery and other farm assets it was assumed that a cost of 20% and 25% of plant capital occurred every fourth and seventh year respectively. If the farm did not make an operating surplus in every fourth year when capital investment was required then the farm would delay the purchase for three years. However, the cost of the investment was higher to reflect a higher changeover price to upgrade machinery.

Due to the increased emphasis on livestock production in the high rainfall regions the STEP model of farms representative of those regions assumed a ewe dominant flock structure that focused on prime lamb production. The lamb production system assumed a self-replacing merino flock whereby surplus ewes were mated to crossbred terminal sires. Cross bred lambs were kept as carryover lambs and sold at 20.2kg carcass weight. Merino wether lambs were sold as store lambs.

By contrast, the sheep system in the low rainfall north-eastern region was assumed to be a flock structure that focused more on wool production. Surplus lambs from this flock were sold as store merino lambs. The wool production system assumed a self-replacing merino flock where wether lambs were kept for up to two years before being sold as shippers.

Experimental design

STEP was used in an experimental design outlined in Table 3. A combination of 2916 scenarios was examined for the northern and southern regions. Each combination was replicated a further 30 times through random draws from yield and price distributions. For the north-eastern region 1458 scenarios were examined. The farm and economic characteristics (e.g. interest rates, terms of trade) chosen were indicative of the current and historically observed ranges in values (BankWest 1998 to 2009).

The two main outputs from STEP reported in this paper were the NPV of farm profit over a 20 year period and the probability of farm equity (as a percentage) falling below 65% for one year in this period. This equity level was selected as an indicator of threatened farm business viability, as lending institutions become reluctant to lend further credit to farms with equity below this point (Peart 2005).

Farm business equity levels were partly based on land prices derived from farm survey data from Weeks (2008) and Landgate (2008). Farm land appreciation under current climate was determined by taking a sample of shires in each study region from 1994 to 2008 (Landgate 2008). Land appreciated in real terms by 2.3% per annum in the southern high rainfall region, 4.1% per annum in the northern high rainfall region and 3.5% in the north-eastern low rainfall region. As agriculture is almost the sole use of the land in these regions, the value of farmland is likely to reflect expected and actual flows of farm income (Herdt and Cochrane 1966; Shalit and Schmitz 1982).

If climate change and its associated variability lead to decreases in farm profit (Kingwell and Farre 2009), then land values can be expected to decline or stagnate (Kokic *et al.* 2005). Accordingly, in the STEP model based on climate change, in the northern and north-eastern low rainfall regions where adverse climate change is projected (see Table 2), land is assumed to appreciate at lesser rates of 3.1% and 2.5% per annum respectively. By contrast, farms in the southern high rainfall region that are exposed to more favourable growing conditions (see Table 2) are assumed to appreciate at a higher rate of 3.3% per annum.

The discount rate used in the NPV calculations was 7%, consistent with discount rates used in other recent research in the study region (Blake and Peek 2006; Grima 2008). A 2% increase in yield per annum was used to simulate technological advances over the study period that help offset the assumed declining terms of trade.

Table 3. The experimental design parameters used in STEP modelling

Item		North-eastern low rainfall region			Northern high rainfall region			Southern high rainfall region			Number of characteristics
Farm size (ha)		3,600	4,800	6,000	2,475	3,300	4,500	1,650	2,200	3,000	3
Off-farm asset ($'000)		160	1,000	2,000	355	710	1,420	375	750	1,500	3
Percentage of area cropped (%)		84	72	52	76	50	36	64	42	32	3
Starting debt ($'000)		0	500	1,000	0	1,250	2,500	0	1,000	2,000	3
Terms of trade	Percentage increase in returns	2			2			3			3
	Percentage increase in costs	4			3			2			
Interest rates	If in debit (%)	8.5			10.5			11.5			3
	If in surplus (%)	4.5			6.5			7.5			
Livestock system[1]		Merino wool production				Crossbred lamb production					2
Climate		Current climate				Climate change					2
Total number of treatments[2]											2916[3]

[1] North-eastern low rainfall region case study assumed a ewe dominant enterprise where all surplus lambs were sold

[2]1458 treatments were tested in the north-eastern low rainfall region as only one sheep enterprise is tested

[3] As 30 random draws occurred from the price and yield distributions; a complete set of simulations involved 2916 x 30 = 87480 observations.

Statistical analysis

Regression analysis was used to relate farm characteristics (farm size, percentage of land allocated to crop production, starting debt, off farm assets, terms of trade and interest rates) to measures of business performance (the NPV of farm profit and the probability of the farm's equity falling below 65%). Using STATA (v8) (StataCorp 2003) two different models were tested.

Firstly, the NPV of farm profit was regressed against a range of independent variables where for each region *i*:

$$Y_i = \beta_0 x_{0i} + \beta_1 x_{1i} + \beta_2 x_{2i} + \beta_3 x_{3i} + \beta_4 x_{4i} + \beta_5 x_{5i} + \beta_6 x_{6i} + \beta_7 x_{7i} + u_i$$

with x_0 indicating the climate scenario, x_1 is farm size, x_2 is off farm assets, x_3 is the percentage of land allocated to crop production, x_4 is the terms of trade, x_5 is the interest rate, x_6 is debt, x_7 is the sheep enterprise[1]and u_i is the regression error term. In analysing the results, each independent variable was a dummy variable, which enabled the analysis of the marginal effect from the base level for each simulation. The base level was small farm size, a high percentage of crop, a low level of off-farm assets, low debt, interest rates of 8.5% (when in debt), terms of trade decline of 2% per annum and the farm's sheep enterprise focusing on lamb production[1].

Secondly, a logit regression model was used to determine the probability of farm equity falling below 65%. Logit regression analysis allows the prediction of probability (0 to 1). Logit regression analysis assumes a cumulative logistic probability function and its structural equation is:

$$Y_i = \frac{1}{1 + e^{-(\beta_0 x_{0i} + \beta_1 x_{1i} + \beta_2 x_{2i} + \beta_3 x_{3i} + \beta_4 x_{4i} + \beta_5 x_{5i} + \beta_6 x_{6i} + \beta_7 x_{7i})}} + u_i$$

where the variables are as defined above.

Results and Discussion

The results of the regression analysis that related farm characteristics (farm size, percentage of land allocated to crop production, starting debt, off farm assets, terms of trade and interest rates) in each region, under current and projected climate, to farm business performance (the NPV of annual farm profit) are listed in Table 4.

A range of farm, economic and environmental characteristics explain a large proportion of the variation in the NPV of farm profit over a 20-year period (Table 4) with the estimated equation having an adjusted R^2value of 0.61 for the north-eastern low rainfall region simulations, 0.86 for the northern high rainfall region and 0.89 for the southern high rainfall region.

The most adversely affected region is projected to be the north-eastern low rainfall region, where climate change is expected to reduce the NPV of farm profit over a 20-year period by $1,323,125 ($P$ < 0.01). These results are consistent with findings of John *et al*. (2005) and Thamo *et al.* (2015) who found that projected climate change in the low rainfall region of the Western Australian wheatbelt will involve an increased number of adverse seasons, making farm businesses on average financially worse off. As a result of poor production years, farm businesses are forced to increase borrowings and reduce expenditure (Anderson 1979), thereby affecting their profits. Similarly, the northern high rainfall region is also adversely affected by climate change, but to a lesser degree. The NPV of the 20-year sequence of farm profit in this region is reduced by $437,780 ($P$< 0.01) under climate change. By contrast, the southern high rainfall region is expected to significantly benefit from climate change with its NPV of the 20-year sequence of farm profit projected to increase by $578,116 ($P$< 0.01).

Several significant interactions exist between climate change and other variables, such as farm size, interest rates, crop dominance and farm debt. These factors and interactions are separately discussed in sub-sections below.

The Logit regression results for the probability of farm equity falling below 65% during the 20-year period (Table 5) display a range of significant farm, economic and environmental characteristics.

[1] The sheep enterprise variable was only used in the high rainfall northern and southern agricultural regions where two different sheep systems are alternatives

Table 4. Regression results for farm business simulations, by region, where the dependent variable is the NPV of farm business profit. Estimated coefficients, t-stats and their associated probability values are listed. CC indicates the dummy variable of climate change. Figures in bold font are t-stat values significant at p<0.05

Variable	North-eastern low rainfall region			Northern high rainfall region			Southern high rainfall region		
	Coefficient	t-stat	*Prob*	Coefficient	t-stat	*Prob*	Coefficient	t-stat	*Prob*
Climate change	-1,323,125	**-16.63**	0.00	-437,780	**-10.10**	0.00	578,116	**19.48**	0.00
Farm size (medium)	2,193,178	**57.40**	0.00	2,274,123	**113.32**	0.00	1,418,554	**130.26**	0.00
Farm size (large)	4,295,346	**112.41**	0.00	5,338,482	**266.01**	0.00	3,384,245	**246.34**	0.00
CC farm size (medium)	-468,479	**-8.67**	0.00	-86,149	**-3.04**	0.00	234,919	**12.09**	0.00
CC farm size (large)	-767,636	**-14.76**	0.00	-169,723	**-5.98**	0.00	533,192	**27.44**	0.00
Off farm assets (medium)	516,591	**13.52**	0.00	224,271	**11.17**	0.00	273,280	**19.89**	0.00
Off farm assets (large)	1,120,159	**29.32**	0.00	645,004	**32.14**	0.00	787,744	**57.34**	0.00
CC off farm assets (medium)	61,343	1.14	0.26	24,881	0.88	0.38	-17,519	-0.90	0.367
CC off farm assets (large)	25,234	0.47	0.64	25,320	0.89	0.37	-28,864	-1.49	0.137
Area cropped (medium)	-1,095,647	**-28.67**	0.00	-2,858,807	**-142.45**	0.00	-1,282,485	**-93.35**	0.00
Area cropped (small)	-3,306,525	**-86.54**	0.00	-4,467,638	**-222.61**	0.00	-1,364,124	**-99.30**	0.00
CC Area cropped (medium)	5,915	0.11	0.91	149,062	**5.25**	0.00	-175,534	**-9.03**	0.00
CC Area cropped (small)	169,533	**3.14**	0.00	246,521	**8.69**	0.00	-174,990	**-9.01**	0.00
Terms of trade (-1%)	915,605	**23.96**	0.00	1,011,681	**50.41**	0.00	872,778	**63.53**	0.00
Terms or trade (1%)	3,153,592	**82.53**	0.00	3,460,900	**172.45**	0.00	2,738,441	**199.33**	0.00
CC Terms of trade (-1%)	35,944	0.67	0.51	-1,703	-0.06	0.95	12,957	0.67	0.505
CC Terms or trade (1%)	-153,992	**-2.85**	0.00	-59,595	**-2.10**	0.04	101,788	**5.24**	0.00
Interest rate (10.5%)	313,763	**8.21**	0.00	-313,613	**-15.63**	0.00	-638,555	**-46.48**	0.00
Interest rate (11.5%)	452,866	**11.85**	0.00	-570,317	**-28.42**	0.00	-1,075,639	**-78.30**	0.00
CC Interest rate (10.5%)	-344,394	**-6.37**	0.00	-67,583	**-2.38**	0.02	171,248	**8.81**	0.00
CC Interest rate (11.5%)	-469,209	**-8.68**	0.00	-98,395	**-3.47**	0.00	272,459	**14.02**	0.00
Debt (medium)	-1,128,813	**-29.54**	0.00	-3,004,378	**-149.70**	0.00	-2,922,710	**-212.75**	0.00
Debt (large)	-2,470,481	**-64.66**	0.00	-6,917,442	**-344.68**	0.00	-6,456,396	**-469.97**	0.00
CC Debt (medium)	-161,833	**-2.99**	0.00	-70,817	**-2.50**	0.01	247,829	**12.76**	0.00

CC Debt (large)	-189,004	**-3.50**	0.00	-147,971	**-5.21**	0.00	380,102	**19.56**	0.00
Sheep (wool)	N/A	N/A	N/A	-441,902	**-26.97**	0.00	-531,041	**-47.34**	0.00
CC Sheep (wool)	N/A	N/A	N/A	221,375	**9.55**	0.00	53,874	**3.40**	0.00
Constant	2,722,525	**48.41**	0.00	3,539,642	**115.46**	0.00	426,922	**20.34**	0.00

North-eastern low rainfall region: Adj. R-squared = 0.6129, root MSE = 2300000; *n* = 43740; Northern high rainfall region: Adj. R-squared = 0.8620, root MSE = 1700000; *n* = 87480; Southern high rainfall region: Adj. R-squared = 0.8911, root MSE = 1200000; *n* = 87480; significant at the 5% level

Table 5. Logit regression analyses for all scenarios where the probability of farm equity falling below 65% is at least 0.05. CC indicates the dummy variable for climate change. Significant t-stat values are in bold type

Variable	North-eastern low rainfall region			Northern High rainfall region			Southern High rainfall region		
	Coefficient	t-stat	*Prob*	Coefficient	*t*-stat	*Prob*	Coefficient	*t*-stat	*Prob*
Climate change	2.892	**9.64**	0.00	0.069	0.40	0.69	-0.259	-1.62	0.11
Farm size (medium)	-1.733	**-22.20**	0.00	-5.106	**-47.95**	0.00	-4.828	**-53.14**	0.00
Farm size (large)	-3.088	**-26.89**	0.00	-10.280	**-52.02**	0.00	-10.043	**-67.45**	0.00
CC farm size (medium)	0.3461	**3.70**	0.00	0.268	1.75	0.08	-1.717	**-7.90**	0.00
CC farm size (large)	0.733	**5.62**	0.00	0.584	**2.31**	0.02	-1.888	**-5.60**	0.00
Off farm assets (medium)	-1.202	**-16.19**	0.00	-0.630	**-9.20**	0.00	-0.779	**-12.90**	0.00
Off farm assets (large)	-2.834	**-25.39**	0.00	-2.147	**-26.79**	0.00	-2.410	**-34.51**	0.00
CC off farm assets medium	0.289	**3.23**	0.00	-0.022	-0.23	0.82	-0.0615	-0.64	0.52
CC off farm assets (large)	0.788	**6.20**	0.00	0.292	**2.74**	0.01	-0.383	**-3.32**	0.00
Area cropped (medium)	0.292	**3.30**	0.00	1.520	**19.10**	0.00	1.974	**29.15**	0.00
Area cropped (small)	1.152	**13.83**	0.00	2.570	**30.89**	0.00	2.189	**31.84**	0.00
CC Area cropped (medium)	0.001	0.01	0.99	-0.070	-0.65	0.51	0.013	0.12	0.90
CC Area cropped (small)	0.060	0.63	0.53	0.106	0.94	0.34	-0.052	-0.47	0.64
Terms of trade (-1%)	-0.267	**-3.44**	0.00	-0.609	**-8.74**	0.00	-1.517	**-24.41**	0.00
Terms or trade (1%)	-0.775	**-9.26**	0.00	-1.293	**-17.53**	0.00	-3.915	**-47.84**	0.00
CC Terms of trade (-1%)	-0.265	**-2.84**	0.00	-0.144	-1.54	0.12	0.211	**2.16**	0.03
CC Terms or trade (1%)	-0.332	**-3.31**	0.00	-0.481	**-4.75**	0.00	0.544	**4.26**	0.00

Interest rate (10.5%)	0.521	**6.15**	0.00	1.142	**15.05**	0.00	2.322	**32.83**	0.00
Interest rate (11.5%)	0.690	**8.25**	0.00	1.951	**25.02**	0.00	3.520	**44.82**	0.00
CC Interest rate (10.5%)	-0.169	-1.68	0.09	0.142	1.39	0.16	0.138	1.17	0.24
CC Interest rate (11.5%)	-0.172	-1.72	0.08	0.115	1.09	0.27	0.209	1.60	0.11
Debt (medium)	2.793	**10.01**	0.00	18.561	**	**	23.174	**212.21**	0.00
Debt (large)	5.284	**19.35**	0.00	26.779	**194.72**	0.00	30.208	**	**
CC Debt (medium)	-0.888	**-3.05**	0.00	1.219	**6.48**	0.00	-3.255	**-17.64**	0.00
CC Debt (large)	-1.658	**-5.82**	0.00	0.620	**	**	-2.056	**	**
Sheep (wool)	N/A	N/A	N/A	0.433	**7.46**	0.00	0.888	**17.33**	0.00
CC Sheep (wool)	N/A	N/A	N/A	-0.218	**-2.79**	0.00	0.020	0.25	0.81
Constant	-5.308	-18.63	0.00	-23.400	**-185.43**	0.00	-25.355	**-223.64**	0.00

North-eastern low rainfall region: Pseudo R-squared = 0.3958, LR Chi-square (25 df) 12860 ($P<0.00$); n = 43740. Northern high rainfall region: Pseudo R-squared = 0.7802, LR Chi-square (27 df) 62768 ($P<0.00$); n = 87480. Southern high rainfall region: Pseudo R-squared = 0.7889, LR Chi-square (27 df) 64937 ($P<0.00$); n = 87480. Figures in bold are significant at the 5% level

** No standard error values were generated due to the covariate pattern expressing only one outcome.

Many significant characteristics explain a large proportion of the variation associated with the risk of farm equity falling below the 65% threshold level. Coefficients in Table 5 are either positive (increases equity risk) or negative (reduces equity risk). Due to the non-linearity of the logit model the relative changes do not represent a marginal change.

Most scenarios for high rainfall farms reveal a very low risk of farm equity falling below 65%. By contrast, farms in the north-eastern low rainfall region, when facing the current climate and when all their characteristics are set at their base level, face a higher risk of business failure. The results in Table 5 illustrate that climate change does not significantly affect the risk of low equity to businesses with base level characteristics in the northern and southern high rainfall regions. However, climate change significantly increases the risk of farm equity being below 65% in the north-eastern low rainfall region. Climate change interacts with several variables (e.g. farm size, off-farm assets, farm debt) to increase the probability of exposure to low equity.

In the following sub-sections the role of key characteristics in influencing the NPV of farm profit and exposure to low equity are discussed.

Farm size

Farm size is a major determinant of profit and risk in all regions. Farms located in all regions significantly decrease the risk of farm equity falling towards unviability when farm size becomes larger (*P*<0.01). Farms in the high rainfall southern region show more negative coefficient values for farm sizes than those located in the northern region. This suggests larger farms in the high rainfall southern region have less equity risk than those in the low or high rainfall northern region. Further, climate change increases this risk for large farms in the northern high rainfall region and for all farms in the north-eastern low rainfall region.

Farm size is found to be a significant determinant of the NPV of farm profit over the 20-year period. Farm profits are significantly higher in all regions as farm size increases in the current climate (*P*<0.01). Climate change reduces farm profits in the north-eastern low rainfall region and northern high rainfall region (*P*<0.01). However, climate change causes farm profit in the southern high rainfall region to increase.

These results are consistent with the findings of Hooper *et al.* (2002) that large farms have superior profits to those generated by smaller farms. Also, research by Shepard and Collins (1982) indicated the rate of bankruptcy was lower when farm size was larger. Farms that benefit from increasing farm size use economies of scale to lower their average cost of production (Hooper *et al.* 2002; Cattle and White 2007).

As a result of projected climate change, farms operating in the northern high rainfall and north-eastern low rainfall regions are liable to experience lower farm profit and greater financial risk. The reduced farm profit is due to lower production caused by climate change. These farms also face an increased exposure to the risk of low equity. However, higher farm profits in the southern high rainfall region that are projected to accompany climate change in that region help lessen their risk of insolvency. Overall, these results suggest farms generating higher profits (often larger farms) are able to maintain cash reserves which buffer the farm against unfavourable seasons and help achieve higher equity. These are important findings as they suggest a possible adaptation to the changing climate. Increasing farm size is an important characteristic as it mollifies adverse effects or in the case of southern high rainfall farms, enhances the financial benefits of climate change. However, the converse observation is that smaller farms may face a far more serious financial challenge in a worsening climate.

Farm debt

Higher farm debt significantly increases the risk of insolvency and reduces farm profit in all regions (*P*>0.01). All study regions display large positive coefficients (P<0.01) for debt variables. The interaction of climate change with farm debt in the southern high rainfall region is to lessen the risk of farm failure.

Climate change further increases the probability of farm equity falling below 65% at some stage during the 20-year study period. For example a north-eastern low rainfall farm with medium debt and operating in a future climate scenario displays a probability of 0.77 of farm equity falling below 65% at some stage during the 20-year study period. The same farm operating in the current climate displays a lesser probability of 0.49 of farm equity falling below 65% at some stage during the 20-year period. Similarly, in the northern high rainfall region climate change further increases the risk of farm insolvency.

The NPV of the stream of farm profit is also significantly reduced in all regions when farms are exposed to lower equity positions. For example, a northern high rainfall region representative farm experiences a reduction in farm profit by $3,004,378 when farm debt was increased to $1,250,000. Under climate change the same farm's financial position worsens by the NPV of farm profit declining a further $70,817 (*P*> 0.01). By contrast, climate change in the southern high rainfall region enables a farm with moderate debt to improve the NPV of its profit stream by $247,829.

Farms with high debt are required to make large interest repayments (Peterson *et al*. 1991). If those farms produce poor profits they may then be unable to meet those interest repayments, therefore eroding farm equity and increasing farm business risk. Compounding this problem, farms typically use debt-financing rather than equity finance or leasing. As a result, farms that generate low profits can be at high risk of not being able to repay debt and therefore are at increased risk of failure. Shepard and Collins (1982) found that the rate of farm failure increased through high use of debt finance, especially where land values failed to rise. Accordingly, farms that maintain high equity and thereby avoid the need to make large interest payments are more resilient in the face of climate change than farms with low equity.

Off-farm assets

Farms with access to off-farm assets reduce the farm's financial risk by providing additional equity and an opportunity to increase farm profit. Access to revenue generated by off-farm assets can support on-farm investments and farm profit-making activity. There are no significant risk interactions between climates and farms with medium amounts of off-farm assets in the high rainfall regions. However, in the north-eastern low rainfall region, climate change reduces the effectiveness of off-farm assets in reducing business risk.

Farms with access to large amounts of off-farm assets and the income they generate also create higher farm profits. A farm in the north-eastern low rainfall region with $2,000,000 in off-farm assets increased the NPV of their stream of farm profits by $1,120,159. The base case north-eastern low rainfall region representative farm displayed the highest NPV of farm profit due to farms in that region typically containing higher levels of off-farm assets (BankWest 2009). Climate change did not significantly alter the NPV of farm profit associated with different levels of off-farm assets.

High amounts of off-farm assets provide a complementary income stream that is especially valuable in poor seasons. However, the results show that off-farm assets, although important, are not as significant a determinant of farm business profitability and risk of business failure as farm size or amount of debt.

Area cropped

An interesting finding of the regression analyses is that farms with a higher percentage of land allocated to crop production in fact lessen their risk of business failure. This was a common theme in all regions (Table 5). Farms in the current climate with the highest probability of equity falling below 65% at some stage in the 20-year period were farms with low amounts of land allocated to crop production ($P< 0.01$). Moreover, in all study regions, climate change does not interact with the crop dominance of farming systems to significantly affect the probability of farm business failure.

The NPV of the stream of farm profits is higher for farms that allocate more land to crop enterprises. Results in Table 4 show that traditional livestock dominant farming systems, such as those located in the southern and northern high rainfall regions, display lower NPVs of farm profits than farms of equivalent size that run crop dominant systems. The northern high rainfall region farms showed the greatest decline in profit when crop area was decreased. For example, the NPV of the stream of farm profit was reduced by $4,467,638 when the area of crop was reduced from 76% to 36% of the farm area in that region.

Crop dominant farms display a higher NPV of the profit stream and have a lesser risk of low equity compared to pasture dominant farms. These results contradict the findings of John and Kingwell (2004) and John *et al.* (2005) for low rainfall farms in the eastern wheatbelt of Western Australia. These researchers found that a strategic shift away from crop dominance was a more profitable strategy in responding to adverse climate change. Yet, the simulation results in the current study are consistent with farm survey data (Martin *et al.*2007) that showed cropping enterprises had higher average business profit than livestock or mixed enterprises from 2004-05 to 2006-07, even though there was widespread crop failure in 2006-07 due to a severe drought. Crop dominant farms produce higher farm profit in favourable seasons yet also suffer larger losses in poor seasons. However, the profit retained from the favourable years can create a buffer for the farm to withstand poor seasons and cropping losses in some poor years can be reduced through reduced expenditure on inputs.

In the north-eastern low rainfall region the results highlight the profitability of including a fallow phase in the cropping rotation on the farm. This rotation combined with lupin production on sandplain soils is shown to be a more profitable land use than using sheep grazing on volunteer pasture. Chemical fallow techniques have been shown to decrease the probability of crop failure in the study area (Laing *et al.* 2009) and some new crop technologies (controlled traffic farming and variable rate technology) have further boosted profits from cropping (Kingwell and Fuchsbichler, 2011). Many of these practices and technologies were not available for consideration by John and Kingwell (2004) and John *et al.* (2005) in their studies that indicated a reduction in cropping intensity due to climate change. Also since the 1990s higher returns from cropping enterprises have contributed to the reduction of sheep numbers in many parts of Australia (Martin *et al.*2007), including the regions considered in this study. Further, higher long term productivity gain in cropping enterprises has encouraged a swing out of wool production (Nossal *et al.* 2009).

Terms of trade

Favourable terms of trade lessen farm financial risk and increase farm profit. The results in Table 5 show a favourable terms of trade in all regions significantly decreases the risk of farm failure (P< 0.01). The interaction between different rates of change in the terms of trade and climate change is significant in the north-eastern low rainfall and southern high rainfall, yet only for favourable terms of trade in the northern high rainfall region.

The greatest increase in farm profit due to terms of trade occurs on farms in the northern high rainfall region. The NPV of farm profit was increased by $1,011,681 when the terms of trade changed from an annual rate of -2% to -1% and farm profit increased by $3,460,900 when terms of trade became favourable (P<0.01). The interaction between climate change and terms of trade was only significant when terms of trade was at 1%. Climate change reduces the favourable impacts of any increased terms of trade on farm profits in the north-eastern low rainfall and northern high rainfall regions (Table 4) where climate change reduces crop yields. By contrast, in the southern region where crop yields are increased by projected climate change, farm profit is further increased when favourable terms of trade apply (P<0.01).

Favourable terms of trade increase farm profit and decrease the risk of farm failure. Australian farms' terms of trade, the ratio of the prices farmers receive to the prices paid for inputs, has declined at an average annual rate of 1.6% a year over the period 1977-78 to 2007-08 (Nossal and Sheng 2010). The importance of declining terms of trade to farm businesses is highlighted by Islam (2004) and Connell *et al.* (1996) who discuss the need for farms to maintain productivity growth to remain competitive in international markets. However, recently from 1991 to 2006 the decline was only 0.9% per annum (Mullen 2007). The results in Tables 4 and 5 show farms operating with a -2% terms of trade significantly display a higher risk of farm failure and have a lower NPV of their stream of farm profit.

Interest rates

In all regions the risk of low equity increases significantly with higher interest rates (Table 5). Higher interest rates cause more farm revenues to be devoted to repaying debt, both short-term and long-term, and so profits are reduced, thereby exposing a debt-laden farm business to more downside risk. High interest rates reduce farm profit by $-1,075,639 in the southern region and by $-570,317in the northern high rainfall region. The southern region is more exposed to the impacts of high interest rates on debt as farms in that region are less crop dominant and therefore they have a reduced capacity to quickly pay off debt. In addition, farm size is much smaller in the southern region so overhead costs per hectare are higher and impact on the farm's ability to service debt.

The interaction between interest rates and climate change for farms located in the northern high rainfall and north-eastern low rainfall regions results in further erosion of farm profit. By contrast, climate change reduces the adverse effect of high interest rates in the southern high rainfall region. All climate change and interest rate interactions are significant (P <0.05).

These results are supported by Patrick and Ludwig (1968) who indicated the main effect of interest rates was to reduce funds available for personal expenditure and savings, which leads to lower accumulative net profit. Results indicate that farms in marginal financial situations fail earlier under higher interest rates. Farms can implement risk management strategies against interest rates rising over the short term and medium, such as using fixed interest rates on a proportion of debt (Peart 2005). However, debt-laden farms are inevitably exposed to changes in interest rates.

Sheep in high rainfall region

Both high rainfall regions showed the lowest risk of farm business failure and the more profitable sheep enterprise in these regions was a flock structure centred on prime lamb production rather than wool production. Joining surplus merino ewes to terminal meat sires to produce crossbred prime lambs was the more profitable sheep flock structure. The regression results show that farms based on wool production lessened the NPV of their stream of farm profit by $441,902 and $531,041 in the northern and southern high rainfall regions (*P*<0.01) respectively. The probability of farm equity falling below 65% at some stage over the 20-year period is also significantly decreased when crossbred prime lamb production is substituted for a wool production (*P*<0.01) (Table 5). Farms operating wool enterprises are found to be at high risk of insolvency.

General Issues

The simulation results presented above indicate that projected climate change is likely to affect farm businesses differently, depending on the region in which the farm is located and depending on the unique characteristics of the farm business. However, not only will farm businesses be separately affected by projected climate change at their location but they will also be affected by the aggregate regional impacts (favourable or unfavourable) of projected climate change. In short, a region's rural economy will be altered. By illustration, if adverse seasons become more frequent then this will have a flow on effect to local communities and small businesses and affect the viability of regional communities (Heathcote 1988). If farm incomes decrease, farms will be more reluctant to offer employment within the local communities, therefore contributing further to the demise of rural communities (Alston and Kent 2004). Furthermore, some businesses may switch further into cropping and thereby require less sheep labour thus further reducing employment options for some workers.

The results in this study have implications for government policy. If drought becomes more frequent in the northern and north-eastern regions then the nature and role of government policy regarding drought will become particularly important. Historically drought policy has provided financial assistance to farms declared to be in exceptional circumstances (Botterill 2003). However, in recent years this policy has shifted more towards promoting greater self-reliance and risk management in farming systems. By identifying the characteristics of farms that are likely to be more resilient (or vulnerable) to climate change, the findings of this study may help farms and the application of drought policy to ensure more farm businesses remain viable and that rural communities are less impaired by climate change, where that change is adverse.

Conclusion

Climate change projections indicate that not all regions in the Western Australian wheatbelt will be adversely affected. The southern high rainfall region in this study, for example, is projected to benefit through more favourable growing conditions. However, the north-eastern low rainfall and northern high rainfall regions are projected to face a deterioration in their growing conditions.

This research investigates how farm business performance is affected by the characteristics of farms and their operating environment, including climate change. A key measure of farm performance as reported is the likelihood that farm equity will slip to a threshold level at which point banks become reticent to provide carry-on finance. The significant characteristics that lessen this risk of low farm equity are large farm size, low initial indebtedness, having access to valuable off-farm assets, having a high proportion of farm area allocated to crop production, having prime lamb rather than solely wool production as the focus of sheep enterprises, experiencing favourable terms of trade and enjoying low interest rates. To some degree, a farm may have control over the first five characteristics. This suggests that under climate change, large farms, crop dominant farms and those maintaining high levels of equity have a more robust business structure to cope with or exploit projected climate change.

This study's results provide insights into the adaptations farmers can undertake in response to, or in preparation for, climate change. For example a north-eastern low rainfall farm may include fallow phases in the cropping rotations or include lupin production on sandplain soils, as these land uses under climate change are more profitable than sheep grazing volunteer pasture on these soils. Also, for farms located in the north-eastern low rainfall region it may be feasible to consider purchasing land in the adjacent northern high rainfall regions to offset the effect of climate change, or alternatively purchasing land in the southern region. However this spatial diversification may not be practical due to logistic issues such as movement of livestock and machinery or the greater costs of coordination and control that accompany such purchases. A profitable strategy for farms in the high rainfall regions could be to increase the area of land allocated to crop production and to focus livestock production on lamb production rather than wool production.

The study's results, however, need careful consideration for farm planning decisions. Although certain farm characteristics are shown to provide resilience, this does not mean that investments in these characteristics always are necessarily economically justified. For example, although large farms are shown to be better able to accommodate the impacts of projected climate change, this does not necessarily mean it is wise for all small farms to purchase additional farmland. The desirable timing and amount of land purchases requires individualized analysis.

By identifying the characteristics of farms that are likely to be more resilient (or vulnerable) to climate change, the findings of this study may help farmers and government to undertake actions that ensure more farm businesses remain viable and that rural communities are less impaired by climate change.

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