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Linking ecology and economics for woody weed management in Queensland's rangelands

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Abstract

Some of the economic research being undertaken in woody weed management in Queensland's rangelands is presented. The focus of the research is to link economic and ecological models of grazed lands which contain exotic woody weeds in order to assess their impacts. The constraints imposed by economic considerations on control options for woody weeds are assessed by considering two examples. The first involves linking a benefit cost analysis of control to a model of spread of prickly acacia. The second is an assessment of rubber vine containment using fire management. Preliminary results of both examples are presented and economic implications discussed.

1. Modelling the spread and control of prickly acacia

Introduction

Prickly acacia (*Acacia nilotica*) is a major woody weed of the Mitchell grass downs of western Queensland and also grows in coastal areas. It was first introduced into Queensland in the 1890's. In 1926 it was recommended by the Department of Agriculture and Stock as a suitable shade tree for sheep in western Queensland and was extensively planted around homesteads, bore drains and dams during the second quarter of this century, not only for shade but also for fodder, because of the protein rich pods. Prickly acacia was declared noxious in 1957.

The wool crash of the 1970's saw a swing from predominantly stocking sheep to cattle. This, and the series of wet years in the 1950's and again in the 1970's promoted massive spread of prickly acacia throughout the northern downs and the establishment of dense impenetrable thickets. The slump in cattle prices during the 1970's led to high stocking rates which may also have been significant in providing large numbers of cattle as dispersal agents (Mackey *et al.* 1996a).

Prickly acacia is currently estimated to infest 6-7 million hectares in Queensland and is conservatively estimated to be costing producers at least $4.3 million per year in reduced beef and wool production, increased management costs and direct control costs (Miller, unpublished data). Other costs such as reduced property values and environmental costs could not be valued.

Many landholders are controlling prickly acacia at low densities even though there are some animal production benefits to be gained such as its use as a supplementary feed and increased lambing percentages. Some landholders have also chained paddocks of prickly acacia in recent years to provide drought feed for their livestock. However, many landholders are not controlling paddocks of high density prickly acacia because it is prohibitively expensive to do so compared to the benefits to be obtained from control.

The spread of prickly acacia was modelled to show how its distribution and density may change over time given different climatic conditions. The biological model was then linked to an economic spreadsheet of control to show the costs and benefits of control at various stages of spread and density of prickly acacia. The results show the opportunity cost of not controlling prickly acacia now and how that could impact on profitability into the future.

Methodology

The change in prickly acacia density over time was simulated using a transition matrix model. The model is similar to others used for the study of change in woody plant cover (for example, Scanlan and Archer 1991). In general, these models are based on the probabilities of change from one category of cover to another. In this model, an enhancement takes into account the neighbourhood density. In general, an area that is surrounded by other areas of woody cover will have a greater probability of changing to a higher level of woody cover than areas surrounded by grassy areas.

The transition probabilities for the model were developed from a set of aerial photographs of Mitchell grasslands with prickly acacia (Brown and Carter, in press). The aerial photographs were taken in an area between Julia Creek and Richmond. The first interval (1960 to 1974) was a period of below average rainfall, whereas 1974 to 1994 was a period of average to above average rainfall with several years known to be suitable for recruitment of prickly acacia. For the purposes of this paper, the interval 1960 to 1974 will be defined as a DRY period and the interval 1974 to 1994 will be defined as a WET period. Between 1960 and 1994 there had only been minimal control work undertaken in the study area.

Over 5,000 cells (each 20m X 20m) were assessed for the level of cover at each time, and the transition probabilities to and from each of 6 categories of cover were calculated. The six categories ranged from zero trees per hectare to greater than 100 trees per hectare.

The model has a 20-year time step and has only two sets of transitions - one for above-average rainfall periods (WET) and one for below-average rainfall (DRY). It would be vastly improved if annual transitions were available for a wide range of climatic conditions. Such detailed data sets are uncommon for woody plant dynamics. Specific scenarios were chosen to represent the extremes that could be expected in coming decades. Alternatively, it can be used to hypothetically evaluate management decisions that could have been made in the past.

The model was used to simulate several climate scenarios - for example, what is the time trend of prickly acacia cover if the probability of above-average rainfall periods is changed? It is also possible to specify different initial conditions. This influences the time trend of cover because of the density-dependent probability of change. The model can also be used to simulate management interventions by altering the transition probabilities between classes, for example, a basal bark treatment could be simulated by having all transitions from high levels of woody cover to the lowest level of cover during the time step during which the treatment was applied.

Assumptions used in the analysis

There are many assumptions associated with this model which make it difficult to link into an economic analysis. For example, the 20 year time steps are very long in terms of economic planning. However, it was possible to undertake some basic economic analyses that showed the relative costs of undertaking control at the beginning of each time step. It was also possible to make some generalised projections of the potential forgone income and increased costs from increasing prickly acacia densities based on the survey undertaken by Miller (1996).

Certain simplifying assumptions were made. It was assumed that the optimal control technique for prickly acacia in an uplands environment was basal bark spraying with Starane® and diesel at a cost of about $0.15 per tree. Control costs comprised the costs of chemical, diesel, labour and application costs. Average control costs were determined based on six density classes. It was also assumed that follow up would cost as much as initial control but be spread over 3 years subsequent.

Densities of prickly acacia were assumed to be twice that seen from the air photos (in that only prickly acacia with canopy diameter greater than 3 metres could be detected from the air). Other control options could be substituted for basal bark spraying and these are outlined in March (1995). Grubbing, stickraking, ground application with Velpar®, overall spraying and chaining are all options in certain situations.

A major assumption is that the real cost of prickly acacia control and technology remains constant over time. Similarly, it is assumed that biocontrol is not an option in the foreseeable future. While the former assumption is somewhat unrealistic, it allows the direct comparison of the nominal trade offs which would be made at different time periods given current technology.

Results

An analysis of the air photos revealed that prickly acacia would increase in density and area after a run of good wet seasons and would tend to change little in density and area in a run of dry seasons. As the probability of changing to increased cover actually increased with higher cover levels, the WET periods provided positive feedback into the model of prickly acacia spread.

Many scenarios were run using the model and spreadsheet. Two of the more interesting simulations are presented in Table 1. The first scenario assumes a very light initial infestation; 9 percent of the paddock has 1-25 trees/ha and only 1 percent has greater than 100 trees/ha. This is typical of many paddocks in the Julia Creek/Richmond area where there is a dense population of trees along a bore drain or around a watering point and there is a light infestation across part of the rest of the paddock.

Table 1. Analysis of controlling prickly acacia under two starting conditions over two 20 year periods climatically similar to 1974-1994.

Starting conditions and scenario	IRR	Discount rate	NPV	BCR
90% Open, 9% light (1-25/ha), 1% heavy (>100/ha) followed by two WET time steps.	9.6%	8%	$703	1.5
		6%	$2,431	2.7
		4%	$6,276	5.2
1994 densities, 25% Open, 23% light, 39% moderate, 13% heavy followed by two WET time steps.	3.5%	8%	-$13,164	0.4
		6%	-$9,800	0.6
		4%	-$2,818	0.9

It was estimated that it would cost about $1,600 ($16.28/ha) to control the initial infestation. The model was run for 2 WET sequences (with and without control) and the impacts of the increased prickly acacia were estimated on production and mustering costs. These costs were then discounted to determine if the benefits of controlling prickly acacia outweighed the costs of initial control. The results show a net present value (NPV) of $703 at an 8 percent discount rate, a benefit cost ratio (BCR) of 1.5 and an internal rate of return (IRR) of 9.6 percent (Table 1).

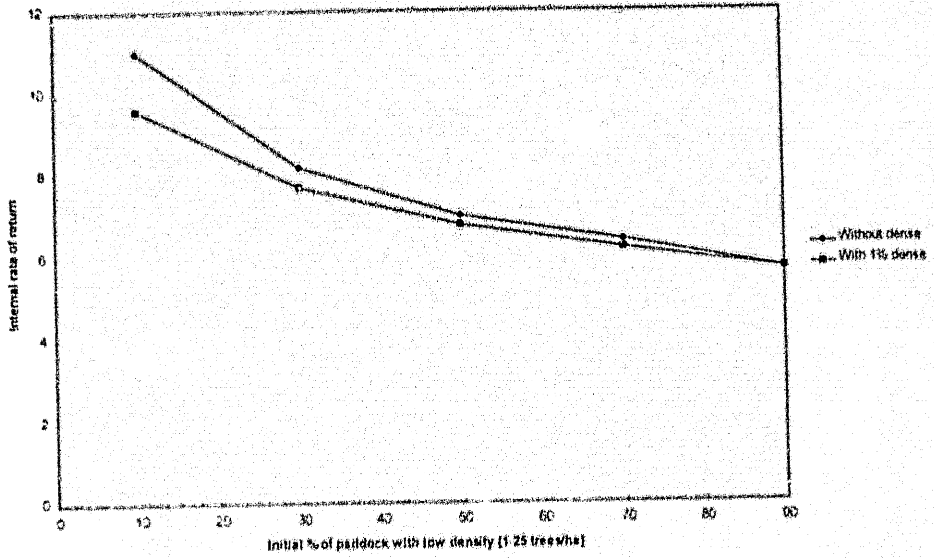
The starting scenario for the second example in Table 1 is for the actual densities estimated from the 1994 aerial photograph. Control and follow up costs for the 1994 example would be almost $27,000 ($26.73/ha). While the benefits of control would be more substantial than the previous example, they were not sufficient to outweigh the costs of control as evidenced in the NPV (-$13,164 at 8 percent), BCR (0.4) and IRR (3.5 percent). Loans are available for woody weed control through the Queensland Industry Development Corporation at 6 percent (March 1995).

The impact of increasing woody cover on the economics of controlling prickly acacia was examined by modelling the increase in prickly acacia given different starting conditions. Initial cover of low density prickly acacia (1-25/ha) ranged from 10 to 90 percent, and one set of simulations had 1 percent dense prickly acacia while the other had no dense patches. The IRR for the control operation declined as the degree of cover of low density patches increased (Figure 1).

Also, the inclusion of a small proportion of dense patches had a considerable impact at lower cover levels. It creates a difference of more than 1 percent in the IRR when there is only 10 percent cover of the lighter infestation and shows how even a small increase in the amount of prickly acacia can adversely affect the economics of control.

During periods where DRY conditions prevail, the above analysis does not hold as the density of prickly acacia changes little during these periods. Dense patches of prickly acacia tended to thin out somewhat after a run of dry seasons.

Figure 1. Comparison of returns from control given different prickly acacia density starting scenarios.



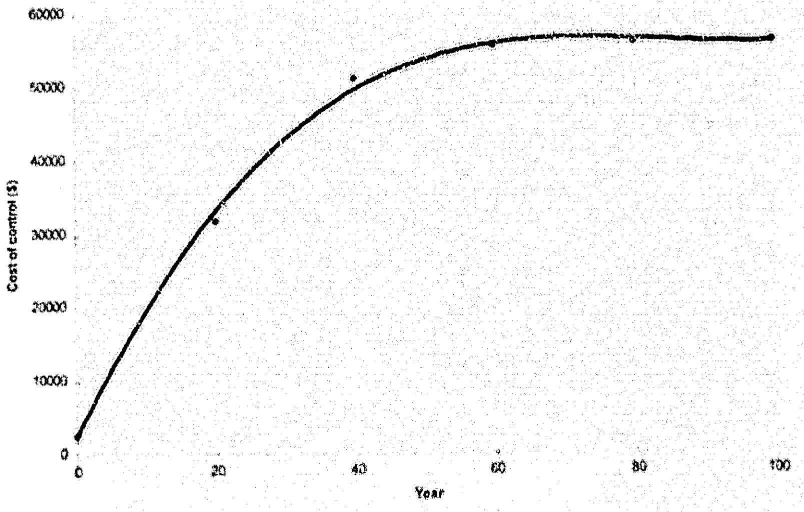
The spread of prickly acacia is highly dependent on the probability of it being a WET sequence or a DRY sequence of years. This has implications for the economics of control. The highest return on investment were for the scenarios which had a light infestation followed by a WET sequences of years. This was due to a relatively low cost of initial control and follow up and relatively large savings in forgone production and increased mustering costs.

The model also shows that once prickly acacia has reached a relatively high density the costs of control are prohibitive compared to the potential gains to be made given the factors which could be valued. The model showed that the cost of controlling prickly acacia increased rapidly if it was allowed to spread and thicken from a relatively small base. This is shown in Figure 2.

The scenario presented in Figure 2 is for a paddock that has a small amount of prickly acacia in year zero. It was assumed that 33 percent of the paddock had a low density of prickly acacia (1-25 trees per hectare). This initial infestation would only cost less than $3,000 to control ($2.76/ha), including follow up work. However, if it was not controlled and the subsequent time steps had above average rainfall (WET scenarios), then the cost of control would reach about $55,000 by year 60 ($55.49/ha).

The model was not designed to provide specific management recommendations. Insufficient data were available to allow this. However, it was possible to test some general hypotheses about the control and impact of prickly acacia. The results were found to be particularly sensitive to the seasonal/climatic conditions experienced during each time step. Results were also sensitive to discount rate, value and amount of production forgone, number of musters and costs of control. Accurate data on many of these variables are not available.

Figure 2. Control costs in relation to the timing of control for a 1,000 ha paddock



Payback periods were found to be very long for investment in control of prickly acacia. Incorporating additional costs into the model would shorten the pay back period while including the benefits of prickly acacia would lengthen the pay back period. It may be possible to incorporate more of the costs and benefits into the economic component to provide a more complete assessment. These include costs such as reduced property values, capital expenditure and management impacts, and benefits such as increased lambing and drought feed (Miller 1996).

Conclusion

The analysis reinforces some commonly held beliefs about prickly acacia and its management. These include recommending its control when it is present at relatively low densities. The models' results show that the Department of Natural Resources management recommendations and the actions of landholders who are controlling prickly acacia at low densities are soundly based. While the return on investment for controlling prickly acacia may be low, allowing the weed to increase in area and density will eventually reduce property viability.

The analysis found that the payback period for prickly acacia control is very long term in nature. Often it can exceed 60 years and intergenerational issues become important. Therefore, it can be understood why it can be difficult to encourage control of prickly acacia, especially when there may also be net benefits from it at relatively low densities.

This model is not to be used to make specific management recommendations as to the control of prickly acacia. Rather, it should be seen as an indicative approach to what could happen to prickly acacia over coming decades and what could be done about it at different times given different starting scenarios. This is because the model is relatively simplistic in its handling of the actual dynamics of prickly acacia and the economics and control options are not complete.

There is potential for both the biological and economic components of the model to be further developed to provide better estimates of the true impact of prickly acacia and repercussions of management decisions that are made. Work on both components of the model is continuing.

2. Modelling the use of fire for rubber vine containment

Introduction

Rubber vine (*Cryptostegia grandiflora*) is a major woody weed of tropical and subtropical Queensland. It is estimated that rubber vine now covers more than 700,000 hectares with an estimated agricultural production impact of $18 million per year in lost production and control costs (Mackey *et al.* 1996b). There are also significant environmental impacts associated with rubber vine.

An economic assessment was undertaken to determine if the benefits of burning for rubber vine containment (in the form of maintaining pasture production over time) would outweigh the actual costs of burning and forgone production from spelling a paddock to build up fuel loads. Pasture production using burning and no burning scenarios was modelled using GRASP (McKeon *et al.* 1990) and animal production was simulated using equations contained in GRASSMAN (Scanlan and McKeon, 1990).

Methodology

GRASP is a daily time step simulation model developed over a period of 20 years. Basic inputs into the model are soil water holding capacity; soil fertility; pasture basal area; tree cover; daily temperature, humidity and rainfall. Outputs include soil water balance (runoff, drainage, evaporation, transpiration); pasture biomass (green, dead, detachment) and condition; and animal production.

GRASP has not been parameterised for simulating growth in areas with rubber vine. However, equations relating rubber vine cover and pasture growth were available from field data collected at Charters Towers (J.S. Vitelli and J.C. Scanlan, unpublished data). This enabled the predicted growth in grassy areas to be reduced depending on the degree of rubber vine cover to provide an estimate of pasture growth in rubber vine areas. The change in rubber vine cover was based on field data collected at Charters Towers (M.P. Bolton and J.C. Scanlan, unpublished data).

GRASSMAN is a decision support software package for use in grazed woodlands. This 6 month time step model contains equations that allow the estimation of cattle liveweight gain from stocking rate and pasture biomass, provided the maximum per head production at very low stocking rates is known (McKeon *et al.* 1990). These equations are based on grazing trials of both native and improved pastures in northern Australia.

This analysis used historical climatic data for the Charters Towers region, to model the spread of rubber vine and the possibilities of using fire to contain it. This approach is more useful than an "average" year approach where the inherent variability in climatic conditions over time cannot properly be taken into account.

Assumptions underlying the analysis

The analysis used historic climatic data from 1955 to 1995 but it was assumed the climatic conditions from 1955 commenced in 1997. A hypothetical, fertile paddock completely infested with a low density of rubber vine near Charters Towers was chosen. It was assumed to be about 15 percent of the area of the property (that is, about 3,000 hectares). Two possible stocking regimes were used (representing the extremes of what stocking management is actually used). The first was a variable stocking rate utilising 40 percent of annual growth. The second was a set stocking at 3.6 ha /Adult Equivalent (with stock redistributed over the rest of the property while the paddock to be burned was spelled).

A burn was simulated every 8 years or the first appropriate year thereafter based on the simulated pasture growth data. Pasture growth of at least 2,500kg/ha in the rest year was required for a burn to be effective. Burning every 8 years was assumed to be sufficient to contain rubber vine. The timing between burns and the amount of fuel available are both important in determining the effectiveness of fire to contain rubber vine. Variable costs of burning were assumed to be $0.60/ha including fire break maintenance, labour and vehicle variable costs (updated from Hodgkinson *et al.* 1984). The paddock was rested 12 months (November to October) before burning in the following November and a further 2 months after burning to allow pasture regeneration as the wet season commenced.

The hypothetical rubber vine density at the beginning of the analysis was assumed to be just starting to impact on production with density and canopy cover doubling in the first 10 years. The analysis commenced with 6 percent canopy cover of rubber vine in the first year (1955) and finished with 72 percent in year 40 (1995). This situation represented the no burn scenario (without other control options either).

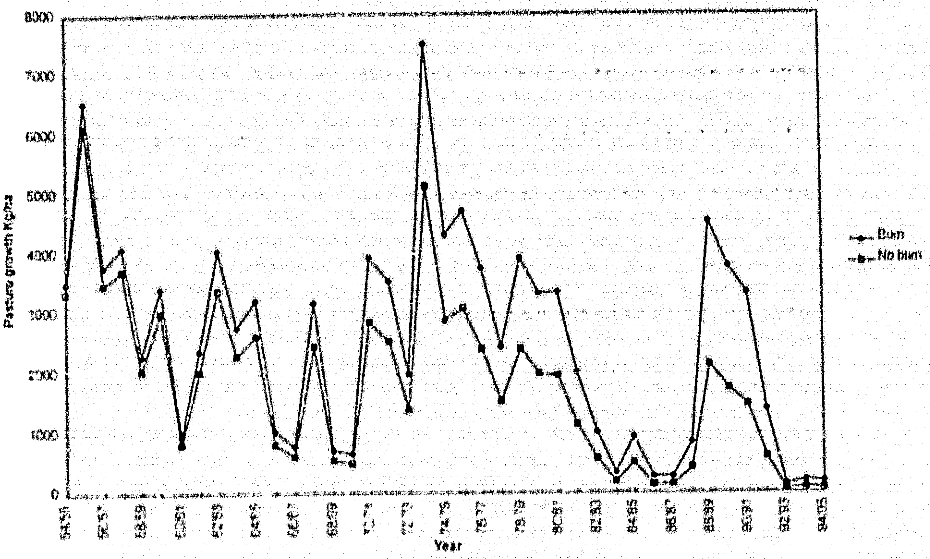
Live Weight Gain calculations were based on GRASSMAN equations. Comparisons were made of gross beef production (priced at $ .70, $1.00 and $1.30/kg liveweight). A real discount rate of 8 percent was used.

Results

Based on the above assumptions, burns were simulated in 1957, 1965, 1973, 1981 and 1991. A comparison of modelled pasture growth between the 'burn' and 'no burn' scenarios is presented in Figure 3. The benefit of burning is represented by the gap between the two lines in Figure 3.

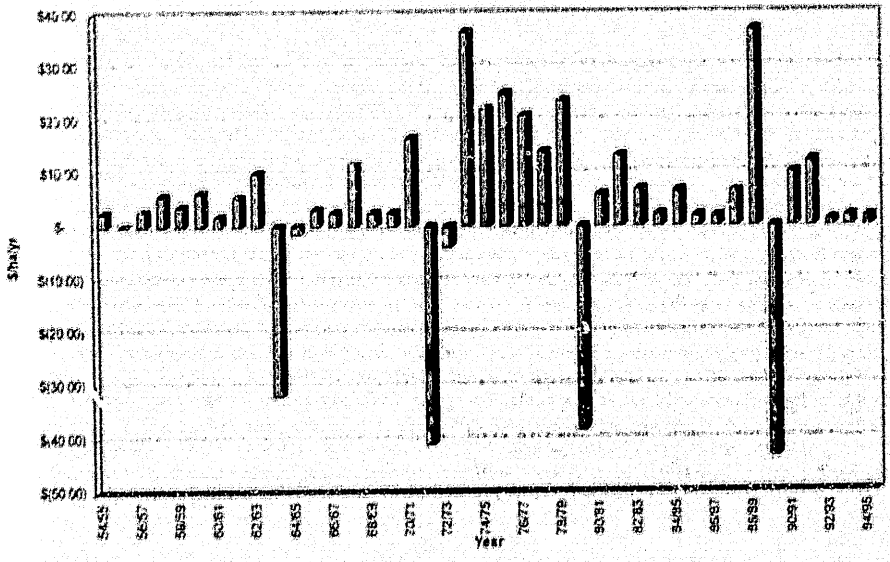
From Figure 3, it can be seen that the largest differences occur in the latter stages of the time horizon as rubber vine is shown to have its greatest impact. However, this is also when discounting has its greatest impact and the effect on the analysis is minimal. It can also be seen that the largest absolute differences occur in the 'big years'. This means that years in wh[illegible] the paddock is rested prior to burning are actually among the best years of [illegible] response. The 'poor' years such as those of the middle 1980's show that the [illegible] much pasture response difference between 'burn' and 'no burn' scenarios bu[illegible] also the years when the pasture that is there is most important.

Figure 3. Comparison of pasture growth between 'burn' and 'no burn' scenarios for a paddock of low density rubber vine in 1955



This difference in pasture production (Figure 3) can be converted into cash flows per year per hectare as shown in Figure 4.

Figure 4. Annual net cash flow of difference per hectare between 'burn' and 'no burn' scenarios for variable stocking rate (in real non discounted dollars).



Note: it has been assumed there is no production trade off in the big pasture production year of 1956 which coincided with a rest year.

The results of the benefit cost analysis are shown in Table 2.

Table 2. NPV's and BCR's for fire management of rubber vine (with liveweight beef valued at $1.00/kg)

Discount rate	Stocking regime	PV(benefits)	PV(costs)	NPV ($/ha)	BCR
8%	Variable	$94.80	-$130.85	-$36.05	0.7
	Set	$37.98	-$65.65	-$27.67	0.6
6%	Variable	$126.91	-$143.83	-$16.92	0.9
	Set	$50.80	-$71.81	-$20.01	0.7
4%	Variable	$175.21	-$158.67	$16.54	1.1
	Set	$73.01	-$78.88	-$5.87	0.9

The results of this partial analysis (Table 2) show that pasture production benefits and resultant beef production responses were not sufficient to justify burning to contain rubber vine, given the climatic conditions between 1955 and 1995 (but commencing in 1997) and a discount rate of 8 percent rate. The costs of forgone production from spelling more than outweighed the benefit of maintained pasture production in non-burn years.

Sensitivity analyses on the base results reveal that the results are sensitive to the assumptions concerning destocking. Using a discount rate of 4 percent in the variable stocking rate scenario would result in a positive NPV. However, such a low discount rate would need to be justified.

Further, a landholder's ability to redistribute stock across the rest of the property in 'big' years without a production loss had a significant effect on the results. The amount of time the paddock was rested after a burn also affected the results. A shorter rest than 2 months would improve the viability of burning while a longer rest would decrease viability. Similarly, maximising the time period between burns while still achieving rubber vine containment will help optimise the economic return from burning.

Agisting, rather than redistributing stock across the rest of the property, may be a viable option in some circumstances. This would be contingent on agistment being available and at a reasonable cost. Finally, it was found that the extended run of below average seasons from the 1980's and the 1990's adversely affected results.

Conclusion

The grass production benefits and resultant beef production responses from use of fire were not sufficient to justify burning to contain rubber vine, given the climatic conditions between 1955 and 1995, and the assumptions in the model. The climatic conditions which actually eventuate in coming decades will help determine if burning to contain rubbervine is economically viable or not.

Other benefits of rubber vine containment such as maintaining property values, preventing increased mustering costs, potential pasture quality benefits and environmental benefits were not incorporated into this assessment. If these could be valued and incorporated into the model, it may show that fire is an economically viable management option. Further research and a whole property assessment is required to determine this. No account was taken of taxation considerations or the inherent risks involved in burning.

Acknowledgments

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