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EUCALYPT DIEBACK AND STOCKING RATES IN SOUTHERN NEW ENGLAND, NEW SOUTH WALES

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The decline and death of eucalypt woodland is common in many parts of Australia. Although this dieback may benefit graziers, because higher stocking rates may follow depletion of woodland, the loss of native vegetation has become an issue for local and national debate. The basis for public concern rests on perceived external costs from the loss of woodland. It is sometimes asserted that there are aesthetic costs because vegetation has changed, a loss of heritage because native woodland is disappearing, and ecological damage due to soil erosion and changes to water quality. Rarely are these externalities substantiated or valued, although all may exist or arise in the future (but see Greig and Devonshire 1981, for one effective valuation).

The dieback of woodland raises some serious economic issues which of course embrace these externality arguments. The issues may be posed as a series of questions. Are there, in fact, benefits to graziers from dieback? Are the benefits substantial and in what circumstances do they occur? Have the social costs from dieback exceeded the social benefits? Will the social costs from further increments in dieback exceed the social benefits? And what is the most efficient way to achieve a goal of woodland preservation, if such is desirable? The objective here is to attempt to answer these questions for a particularly important case, namely eucalypt dieback in the New England region of New South Wales.

The case study involves paddock data for a representative sample of grazing properties in southern New England. The immediate effect of any decline in woodland area or condition will be on the potential carrying capacity for livestock. Many of the biological aspects of the causes and control of eucalypt dieback remain uncertain. These aspects are not addressed here.

An Analytical Model

Variations in stocking rate depend on variations in the inputs of labour, management, capital and land. To concentrate on the influences

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of management and the characteristics of land, the following simple model was estimated:

(1) Stocking rate = *f* (management variables, site variables and woodland condition)

Stocking rate (*DSE*) was defined as the total number of dry sheep equivalents carried per hectare, over the whole year. Following O'Sullivan and Buffier (1983), the different kinds of livestock were converted to dry sheep equivalents according to their energy requirements.

The application of superphosphate is a common way to increase stocking rate. This variable was defined as the total quantity (kg) applied per hectare over the last 10 years. The fertiliser variable (*SUPER*) was expressed in natural logarithms and a positive sign was expected.

Farm managers can clear their woodland. To allow for this possibility, a dummy variable (*CLEAR*) was included. This variable took a value of zero if no clearing had occurred since 1970 and unity otherwise. Increases in the amount of clearing should lead to increases in stocking rate so a positive sign was expected.

Pasture production normally depends on a complex set of land characteristics including soils, topography and potential for cultivation. A proxy was used to represent these land characteristics. Land becomes more undulating and harder to cultivate and the soil tends to become less fertile with moves eastward in the study area. Thus, a variable called *EAST* was included and measured as kilometres from a westerly point in the study area. A negative sign was expected.

The altitude of the study paddocks varied from 427 to 1527 metres. This very wide variation should lead to wide variations in microclimate which in turn, should affect pasture production. An altitude variable was defined as the minimum altitude (*MINALT*) of the paddock and measured in metres.

Dieback kills eucalypt trees and so reduces the quantity of live tree cover per paddock. Efforts to preserve live woodland would concentrate primarily on this same quantity as, of course, would any efforts to clear trees. Woodland condition was therefore specified as the quantity of live tree cover, measured as square metres of tree bole area per hectare.

There has been no measurable regeneration in the sample paddocks in the last decade. The existing trees show little or no growth and there has been no clearing in 164 of the 192 paddocks since 1970. The variable, live tree cover, should therefore measure the direct effects of dieback. The relationship between this variable and stocking rate should be competitive throughout, showing decreasing returns. Therefore the variable was squared, called *LIVCOVSQ*, and a negative sign was expected.

Increases in diversity of plant species may improve the habitats of predators which eat the eucalypt leaves. In discussing tree decline in New England, Davidson (1981) noted that woodland with a wide variety of tree species and tree sizes is least affected by dieback. He suggested that graziers should maintain a whole ecosystem of trees, shrubs, herbs and animals with perhaps a thousand species in all. A variable for species diversity (*SPDIV*) was therefore included. It was recorded as the number of species present along transects of 10 trees and a negative sign was expected.

Application

Data collection

The study area was located south of Armidale and north and west of the tableland escarpment. The sampling frame was based on the Australian Map Grid. A grid interval of 10 km was chosen and properties on the intersection of this grid were selected to give a total sample of 19 properties which together had 192 paddocks. Data were collected for each of these paddocks as well as for each property as a whole.

Interviews with the property owners and managers provided information on stocking rates, fertiliser applications and woodland clearance. Altitudes were obtained from maps and aerial photographs for 1973 provided data on previous woodland condition. Field surveys in 1980 yielded information on the quantity of dying or dead woodland, species diversity and the quantity of live tree cover.

The mean property size was 663 hectares, with a minimum of 85 and maximum of 2164 hectares. The stocking rate per paddock varied from 2.4 to 16.6 dry sheep equivalents per hectare, with a mean of 9.4. In 1980, 29 per cent of the average property was covered by woodland at an average density of 0.9 m^2 of tree bole area per hectare, but 52 per cent of this tree cover was dead or dying.

Causality and correlation

As specified, stocking rate depends on the quantity of tree cover and not *vice versa*. Several arguments support this specification. First, stocking rates should be higher on cleared land than on equivalent land with more tree cover, *ceteris paribus*.

Second, there are two distinct phases of the woodland/stocking relationship. In young stands of woodland, grazing will destroy natural regeneration and the relationship will be the opposite to that specified. In mature woodland, there remains little regeneration, and the trees are large enough not to be trampled, or browsed to death. At this later stage, woodland has a major effect on stocking but livestock themselves have little or no effect on tree growth.

There was no shrub regeneration in 144 of the 192 paddocks and no sapling regeneration in 125 of them, probably due to grazing over the previous decades. These, and most paddocks in New England, are clearly in the mature phase where there is very little regeneration left to destroy. Thus, the quantity of tree cover is no longer influenced by grazing, but the quantity of grazing per hectare does depend on the tree cover.

The highest correlation between any pair of independent variables was 0.30 (LIVCOVSQ and MINALT). There were another five correlations over 0.20 in the total of 21 possible.

A disaggregated model

An aggregate model may mask important sub-relationships—particularly when the range of values for a key, independent variable is wide. In this case, the mean quantity of live tree cover is 0.201 m^2 per hectare with a standard deviation of 0.384. This relatively large deviation suggests a wide, well-spread distribution of values.

As defined above, the live tree cover variable is to be squared to capture the competitive relationship between stocking and the quantity of woodland. As such, a given decrease in cover would lead to a greater increase in stocking for densely-wooded paddocks than for sparsely-wooded paddocks. The aggregate model has been defined to capture this relationship for all 192 paddocks.

A priori, the sub-relationships between live tree cover and stocking rate are worth examining to investigate whether the effects of the independent variables differ in densely-wooded and sparsely-wooded paddocks. To explore these relationships, the 192 paddocks were disaggregated into six groups, depending on their amount of live tree cover. The 46 with no tree cover were designated as group zero. The 146 with woodland were divided into five, nearly equal groups. Group 1 contained the 30 paddocks with least dense woodland while group 5 contained the 29 with the most dense woodland. The model was estimated for each of the groups of paddocks. While the relationship between stocking and live tree cover should still be negative within groups, it should now be linear. Thus the live tree cover variable was left in linear form for the disaggreated analysis, and labelled *LIVCOVLIN.*

Results

The estimated model for all paddocks together was as follows:

$$(2)\quad DSE = -0.653 + \underset{(9.1)^{***}}{3.093\,SUPER} - \underset{(11.7)^{***}}{0.012\,EAST} + \underset{(1.3)^{*}}{0.002\,MINALT}$$

$$+ \underset{(5.6)^{***}}{2.253\,CLEAR} - \underset{(3.4)^{***}}{0.524\,SPDIV} - \underset{(4.7)^{***}}{0.388\,LIVCOVSQ}$$

$$\bar{R}^2 = 0.701$$

The t-statistics in parentheses indicate significance at the 1 per cent level (***), 5 per cent level (**), and 10 per cent (*).

The controllable woodland variables are *CLEAR* and *LIVCOVSQ*. The coefficients on both are statistically significant. The responsiveness of stocking rate was measured through the elasticities which were: *SUPER* +0.33; *EAST* −1.00; *MINALT* +0.22; *SPDIV* −0.10; *CLEAR* +0.04; and *LIVCOVSQ* −0.02.

The disaggregated models for the separate groups of paddocks are shown in Table 1. Live tree cover (LIVCOVLIN) and species diversity (SPDIV) were significant in only the two most densely-wooded groups (4 and 5). Apparently changes in live tree cover are not associated with changes in stocking rate in the sparsely-wooded paddocks of the sample (groups 1 to 3).

Consider now the financial magnitudes of the effects of dieback. The annual decrease in the percentage of live tree cover between 1973 and 1980 was approximately 2.5 per cent. This percentage is equivalent to an absolute decrease in LIVCOVSQ of 0.11 m^2 per hectare. When inserted into equation (2), this decrease leads to an increase of 0.043 dry sheep

TABLE 1

Models to Explain Variations in Stocking Rate for Each of Five Paddock Groups (following equation (2))[a]

Independent variables	Paddock group[b]				
	1	2	3	4	5
SUPER	1.853 (2.4)**	−0.170 (0.2)	4.264 (6.0)***	3.737 (4.1)***	4.295 (4.7)***
EAST	−0.012 (4.3)***	−0.012 (4.7)***	−0.010 (3.7)***	−0.011 (4.2)***	−0.007 (1.7)*
MINALT	0.004 (0.4)	−0.003 (0.3)	0.006 (1.3)*	0.002 (1.1)	0.003 (1.1)
CLEAR	2.639 (1.8)*	1.621 (1.2)	2.995 (2.7)**	0.553 (0.5)	0.786 (0.5)
SPDIV	−0.067 (0.1)	−0.096 (0.2)	−14.708 (0.3)	−0.840 (1.8)*	−0.731 (1.3)*
LIVCOVLIN	8.424 (0.2)	−6.74 (0.3)	−1.960 (0.4)	−2.801 (1.4)*	−1.529 (2.7)**
Intercept	4.129	24.093	−14.708	−4.045	−11.480
$\bar{R}^2$	0.570	0.499	0.750	0.561	0.669

[a] The numbers in parentheses are *t*-values.
*** significant at the 1 per cent level.
** significant at the 5 per cent level.
* significant at the 10 per cent level.

[b] All groups have some woodland. Paddocks in group 1 contain the least woodland while paddocks in group 5 are the most densely wooded.

equivalents (0.11×-0.388) per hectare. There are 663 hectares on the average property so the property-wide increase in stocking is 28.5 dry sheep equivalents per year. O'Sullivan and Buffier (1983) list a gross margin of $10 per dry sheep for a wether enterprise on the New England Tablelands. At $10 per dry sheep equivalent, the annual increase is $285. This annual change has been continuing over the last seven years, at least. At this rate, the general decline in woodland now contributes almost $2000 per year to average property income.

Group 5 is the most densely-wooded class of paddocks. The coefficient on the live cover variable in Table 1 is -1.529, so a unit decrease in live tree cover increases the stocking rate by about 1.5 dry sheep equivalents (or about 14 per cent). A one-unit decrease removes nearly 60 per cent of all the live woodland. Proportionally then, a grazier who chooses to clear 30 per cent of the woodland would obtain a 7 per cent increase in stocking rate. Such an increase would raise the stocking rate on these densely-wooded paddocks from 6.6 to 7.1 dry sheep equivalents. This is an increase of 33 equivalents per 66 hectare paddock. At $10 per unit this is worth $330 per paddock per year to the farmer.

Discussion

Although there has been some debate on the social costs of eucalypt dieback, to date there have been no estimates available of the benefits from the increased stocking that follows dieback. The present results have indicated that the accumulated effects of recent dieback now add on average some $2000 per year to the gross margin of each sample property. If this sample is representative of southern New England (Dumaresq, Uralla and Walcha shires), the increase in property gross margins is in the order of $1.7m per year for the region as a whole. Overall, it appears that eucalypt dieback has benefitted these graziers.

The importance of this level of benefit can be assessed in terms of the relative increase in income, and the size and role of the remaining woodland resource. An extra $2000 added between 5 per cent and 12 per cent to the gross margins of the survey properties in 1980, a year of drought in the region.

The elasticities from equation (2) indicate that changes in stocking rate are more responsive to the application of fertiliser than to changes in live tree cover. But on average, some 15 per cent of each paddock is still covered by live woodland. This large area of live tree cover means that woodland management is still important and there is a large remaining area in which dieback can occur and offer further monetary benefit.

The benefits are not distributed evenly between paddocks, as the results of Table 1 indicate. Increases in live tree cover are significant determinants of increases in stocking in densely-wooded paddocks but no significant relationship could be established in sparsely-wooded paddocks. Benefits will therefore accrue in densely-wooded, rather than sparsely-wooded, paddocks. Environmentalists have argued that increases in tree cover are always essential for livestock management in New England. In contrast, these results indicate that decreases in tree cover increase revenue in densely-wooded paddocks and changes in tree cover in sparsely-wooded paddocks seem to have no generally-demonstrable effect on stocking.

The interesting economic issue now becomes, do the social benefits of a further increase in dieback exceed the social costs? These social costs include possible higher production costs to future farmers and any increased aesthetic and heritage costs. They include possibly unfavourable ecological effects and so higher production costs to downstream farmers. The region under study includes headwaters of the Macleay, Namoi and Gwydir Rivers. Although none of these costs were estimated in the study some implications can be derived. With about 15 per cent of each paddock still under live tree cover, non-marginal reductions in woodland should be sustainable without noticeable loss of stock shelter or soil erosion. Also, any aesthetic and heritage costs may be borne by high-income, well-educated persons. These arguments imply that some social costs could be small and some may be borne by those in society best able to carry them. The results allow the argument to proceed beyond these qualitative arguments on social costs. Only in densely-wooded paddocks does a decrease in live tree cover clearly lead to the benefits of increased stocking. Thus, there may be some threshold quantity of live woodland below which there are no stocking benefits. Presumably any external and other social costs still exist, so social costs of further dieback may well exceed social benefits below this threshold. The 58 paddocks of groups 4 and 5 in Table 1 appear to be above this threshold. The remaining 134 (or 70 per cent) lie below it.

The opportunity costs of achieving a predetermined social goal can often be estimated, and such data are useful for decisions when the full set of benefits and costs cannot be estimated. Consider a goal to preserve native woodland and the specific but modest program of preserving one-tenth of the existing dense woodland in southern New England. This would be achieved by fencing out stock, and encouraging regeneration. The gains from further dieback in this kind of woodland were estimated to be \$330 gross margin per year per survey paddock. If such gains are representative of this kind of woodland in all three shires of the region, this program would deny further gains of \$460 000 per year to the landholders. This is the annual opportunity cost of such a program. The attendant issues of who should bear these costs, in what proportions and in what ways, can be addressed more effectively with this estimate of the magnitude of the costs.

A program to preserve dense woodland, rather than sparse woodland, would be one way to achieve a social goal of preserving native woodland. But the results indicate a potentially more efficient way to achieve this. No relationship could be established between changes in live tree cover and changes in stocking in sparsely-wooded paddocks. Preservation of woodland in these paddocks may be associated with no loss in stocking. *Ceteris paribus*, the most efficient way to preserve a given quantity of live tree cover is to do so in sparsely-wooded paddocks.

The analysis of economic issues can now be extended from comparisons of benefits and costs to a review of actual and potential public policies. Few graziers in the sample are presently clearing woodland, even though some 15 per cent of the area of each property is still under live tree cover. Indeed there has been no clearing at all, over the past ten years, in 164 of the 192 paddocks. But while the graziers are in this sense conserving their woodland, dieback is continuing.

The New South Wales Department of Agriculture, the Forestry Commission of New South Wales, and environmental groups are urging graziers to conserve even more woodland, to take measures to combat dieback and to establish plantations. The response to this substantial extension effort has certainly been a greatly-increased awareness of the problem. But the intense, continued effort suggests that many feel the response to have been insufficient. Increases in stocking have long been observed to follow increases in dieback and clearing. Less well-known is the specific result of this study that the increases in stocking may not apply in sparsely-wooded paddocks. More widespread dissemination of this information may assist the extension work.

The intense, continuing, awareness program is accompanied by arguments that more effective kinds of policies are necessary (see Mosley 1981). Many environmentalists argue that any policies which promote retention of woodland must now involve strong financial incentives and/or regulations to control the use of this freehold land.

If landholders are to be as well off after a policy as before, they should be compensated for the specific opportunity costs that a policy imposes on them. The cost for the modest program to preserve one-tenth of dense woodland in three shires was estimated to be of the order of $460 000 per year. Compensation of this magnitude seems too high to receive general community or Treasury support.

Changes to property rights could, no doubt, be devised to promote the retention of native vegetation and to combat some of the causes of the decline of eucalypt woodland. Such regulations could help to internalise and to reduce external costs. But the real issue is whether such regulations and institutional changes should be devised at all. The results of this study, with the conservative estimates of magnitudes involved, indicate that past dieback has increased property gross margins in the three shires of southern New England by around $1.7m per year and a modest program to preserve native woodland would impose an opportunity cost on these properties of $460 000 per year. New or restrictive policies to influence the management of woodland on these grazing properties may therefore be premature.

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