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PRIVATE PROFITABILITY OF RANGELAND REHABILITATION AND THE CASE FOR PUBLIC FUNDING

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ABSTRACT

The issue addressed in this paper is the appropriate source of funding for rangeland rehabilitation. From an economic rationalist point of view, two questions are pertinent to this policy issue. Is it profitable for private managers of pastoral properties to rehabilitate rangeland? If not, then on what grounds might it be in the public interest to do so?

Evidence is presented that it is profitable to rehabilitate slight to moderately degraded range, but unprofitable to rehabilitate severely degraded range. The relevance of various market failure arguments to the case for public funding of rangeland rehabilitation is then discussed.

INTRODUCTION

The issue which I have been asked to address in this paper, namely the appropriate source of funding for rangeland rehabilitation, rather begs the answers to a prior pair of questions. Specifically, should degraded rangeland be rehabilitated, and if so can it be safely left to the self-interest of managers of pastoral properties to do so?

I intend to spend much of this paper addressing these two primary issues before turning to the issue of funding *per se*. At the outset though, let me make it clear that there is little which is original in the ideas which I am going to discuss below. Most of the arguments and counter-arguments have been made before by, *inter alia*, Chisholm (1), and MacLeod and Johnston (2).

In preparing this paper, I have started from the untested assumption that the majority of the audience believes that all degraded rangelands should be rehabilitated, and furthermore that if the only way to bring about this desired outcome is to fund it publicly, then a *prima facie* case exists for public funding.

Many of the hard-nosed economic mandarins in Canberra who ultimately control the purse strings, and so determine whether or not there will be any contribution for rangeland regeneration from the public purse, start from a different premise. While they are familiar with the conservation arguments, many are so-called economic rationalists who need a different set of arguments to be convinced that they should recommend to their political masters that public funds be used for this purpose. As someone who is versed in the logic of the economic rationalists, but who also recognises that environmental amenities make a key contribution to human welfare, I have decided that the most useful contribution I can make is to structure this paper to highlight the types of questions which need to be answered if more public funding is to be made available for rangeland rehabilitation.

A CONCEPTUAL FRAMEWORK

In order to address the question of whether degraded rangeland should, or should not be rehabilitated, I first want to refer to some results from the literature on fisheries economics. It might seem more than a little bizarre to compare the watery environment of the fishery with arid rangeland, but from an analytical point of view they are equivalent in at least one sense. Specifically, both are renewable resources. Moreover, at an analytical level, there is a formal equivalence between the size of the fish stock on the one hand and range condition on the other, and between the level of harvest from a fishery and the level of production from grazing animals on rangeland. In both cases, multiple levels of sustainable production are conceptually possible.

First note that the net reproductive capacity of a biological population will be a function of stock size because the intrinsic growth rate of the population is increasingly offset by "natural" mortality due to limited environmental carrying capacity. Moreover, since a condition for sustainability is equality between the amount of the stock harvested by man, and net reproductive capacity, this relationship can be treated as equivalent to the relationship between sustainable production and size of the resource stock.

In general terms, this relationship will take the form depicted in Figure 1. This extremely simple conceptual model of the stock dynamics of a renewable resource can be used to discuss the basic issues involved in rehabilitation of degraded rangeland.

Note in particular that the climax level of the resource stock, X_m, is associated with zero sustainable yield. Consequently any exploitation of the resource stock for human betterment involves some diminution of this climax stock level. In a sense then, any exploitation by man could be regarded as causing degradation insofar as stock size is reduced below its upper bound level. However, defining degradation as a reduction in level below the socially optimal level of exploitation is more consistent with the perspective of an economic rationalist, and so will be used in this paper.

Also note that sustainable yield reaches a maximum at some lower level of the resource stock, X_b, and that attempts to further exploit the resource beyond this point of maximum sustainable yield will degrade the resource stock to the point, X_c, below which total depletion of the resource stock becomes inevitable.

In order to talk about rangeland degradation within this framework, we first need to identify the optimal level of utilisation of the range, which also will be defined in terms of the size of the resource stock, X. Note that this optimal stock size, X^*, can lie anywhere within the range from X_m to X_c.

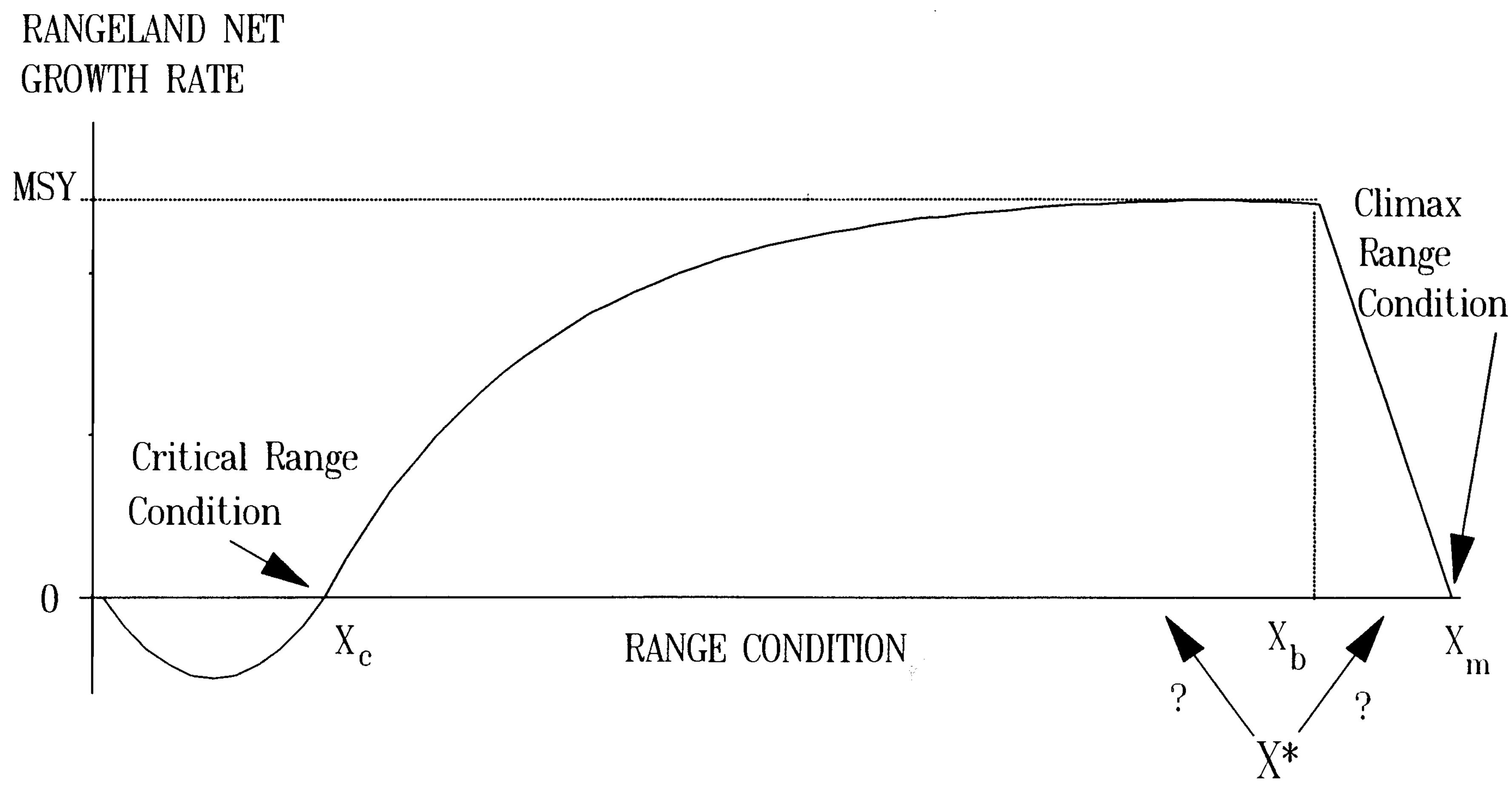
In fact, if harvesting costs are zero, it is conceivable that the optimal size of a renewable resource stock is zero. In other words, the optimal strategy is to totally deplete the resource stock. As an example, results from bio-economic analysis of fisheries have demonstrated that total stock depletion is optimal when the discount rate is sufficiently high and/or when the intrinsic growth rate of the renewable resource is sufficiently low.

An extreme case in point is a mineral ore body, which could be treated as a renewable resource that just happens to have an intrinsic growth rate equal to zero. Clearly, if the mineral resource is worth exploiting at all, then it is worth exploiting it to the point of exhaustion as long as it is costless to dig it up. For a renewable resource with a positive intrinsic growth rate, the analytics are more complicated, but the end result is essentially the same.

For grazed rangelands, X^* probably is fairly close to X_b, but it might lie either to the left or to the right of X_b. Once X^* has been identified, rangeland degradation can be defined as a reduction in the level of the stock of range condition below this optimal level. Furthermore, it will be convenient to classify degraded range as being either moderately degraded (i.e. $X_c < X < X^*$), or severely degraded (i.e. $X < X_c < X^*$).

An interesting issue is whether the critical stock level, X_c, is greater than zero or not. If it is greater than zero, and if the rangeland is degraded to the point where range condition is less than X_c, then zero grazing pressure

FIGURE 1: RELATIONSHIP BETWEEN SUSTAINABLE RANGE PRODUCTION AND RANGE CONDITION.



will be necessary but not sufficient for rehabilitation of the degraded range. In addition, some form of restorative process, such as water-ponding, re-seeding, or similar techniques will be necessary if rehabilitation is to be successful.

If the range is only moderately degraded, in the sense that range condition, or resource stock level, X, is greater than X_c, then it will be feasible to rehabilitate the range simply by reducing grazing pressure such that realised yield is less than sustainable level of yield at that particular stock level.

Clearly then, in order to delineate the extent of rangeland degradation, it is first necessary to identify the level of optimal range condition. For reasons to be discussed below, the optimal degree of exploitation of rangeland from the private prospective of a pastoral property manager concerned solely with maximising profits may well differ from that derived from a broader social perspective involving optimal utilisation of the range in the public interest. However, the mere fact that rangeland is degraded does not necessarily mean that it will be either profitable or socially desirable to rehabilitate it. Indeed, the fact that the need for public funding is such a topical issue suggests that many managers find it unprofitable to attempt to rehabilitate degraded range.

DEGRADATION VERSUS REHABILITATION

In many respects, the costs and benefits of rehabilitating degraded rangeland are the mirror image of the benefits and costs of conservative rangeland management to avoid degradation in the first place. However, there are some obvious differences. Consequently, proof that degradation is unprofitable and/or contrary to the public interest is necessary, but not sufficient to establish that degraded rangeland should be rehabilitated.

The most obvious difference is that some forms of degradation are to greater or lesser degree, "irreversible". For instance, if the seed bank for desirable rangeland plants is exhausted, then the range will not naturally regenerate even if it is totally destocked unless additional re-seeding costs are incurred. Other forms of degradation, such as severe soil erosion, are even more "irreversible", as the costs of rehabilitation are in almost all cases prohibitive.

More striking still as an issue is the oft claimed conservation benefit of genetic diversity. Degradation which diminishes diversity is one of the most clear-cut examples of an "irreversible" change, as there is no good reason to suppose that any feasible form of rehabilitation short of radiation treatment will somehow restore genetic diversity in any meaningful way.

A related distinction is between the time profile of the degradation process and that of the rehabilitation process. Both are subject to extreme stochastic influences, which makes it very difficult to be precise about the degree of such differences. As Chisholm (3) notes "All human land usage affects the state of the land and its impact is critically influenced by nature's wheel of fortune which brings great variations in rainfall, wind, and temperature patterns. Much land degradation takes place during periods of extreme climate conditions such as prolonged droughts, severe flooding and so forth."

If regeneration is profitable, a subsidiary issue is the optimal time path to restoration of range condition. Subject to certain simplifying assumptions, results from the literature on fishery economics suggest that total de-stocking until range condition is fully restored to the long-term optimal level should be implemented. However, in a non-linear world where it is not costless to adjust stocking rates and other management instruments, a more complex strategy which is conditional on both range condition and recent climatic events is much more likely to be optimal. Results from a study described below support this proposition.

PRIVATE PROFITABILITY OF RANGELAND REHABILITATION

There seems little doubt that much of the existing degradation of rangeland was due to ignorance of the managers about the long-term consequences of over-stocking. Most managers now take care to avoid over-stocking range that is still in good condition, so casual empiricism suggests that range which is in poorer condition is degraded in the sense defined above. This conclusion is supported by the findings of a limited number of empirical studies which have attempted to estimate the economic returns from rehabilitation. These studies range from fairly straight forward budgeting exercises such as those by Penman (4) through to more advanced analyses employing sophisticated techniques such as dynamic programming (Kennedy (5)) or optimal control theory (Karp and Pope (6); Williams (7)).

More recently, the University of Western Australia and the Western Australian Department of Agriculture have jointly conducted an in-depth study of the economics of rangeland rehabilitation in the arid winter rainfall pastoral zone of Western Australia. A brief outline of the approach we employed, and one or two of the key findings obtained from this study, follows. Because of the ecological diversity of this very large region, the results obtained should not be regarded as quantitatively accurate for all parts of the region, but I believe that they are indicative of the qualitative importance of the various determinants of profitability of rangeland rehabilitation.

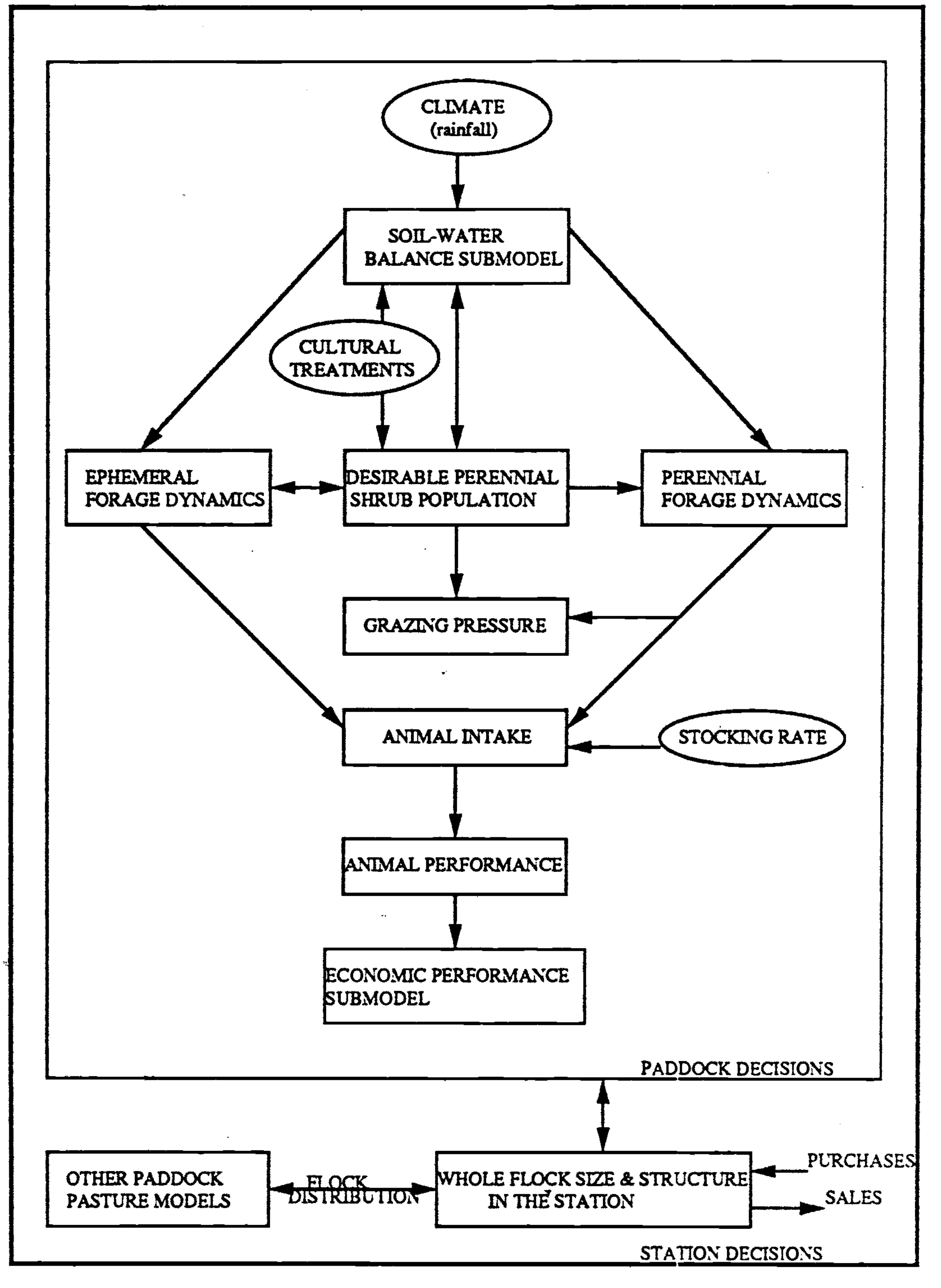
Collectively, a number of features of this study set it apart from previous attempts to analyse the economics of rangeland rehabilitation in Australia. The first and most important is the integration of detailed modelling of the biology of the rangeland ecosystem with sophisticated quantitative economic analysis. Next, and almost as important, the design of the study was driven by the perception that the two key features pivotal to the economics of rangeland rehabilitation are, on the one hand the extremely stochastic or variable nature of the climate which determines the success or otherwise of rehabilitation strategies, and on the other the very long time lags involved in the relationship between range condition (stock level) and sustainable production.

While there are relatively few viable techniques available to rehabilitate degraded rangeland, the fact that they can be employed in various permutations and combinations over time and space means that there are an almost limitless number of alternative possible rehabilitation strategies. In principle, all should be evaluated simultaneously. Unfortunately, to evaluate all, or even most of these strategies in a comprehensive and systematic manner, it is necessary to resort to sophisticated and complicated mathematical procedures if results are to be obtained significantly sooner than would be possible by conducting field trials.

However, no amount of sophisticated analytical methodology can compensate for factual information. Consequently, a detailed simulation model of the rangeland ecosystem based on the best available scientific information was used to generate transition probabilities characterising the likelihood, *ex ante*, that any defined rehabilitation strategy would bring about a change in range condition from one period to the next. These probabilities were then used as input to an optimal control algorithm to identify optimal strategies for rangeland rehabilitation.

The simulation model of the rangeland ecosystem, termed IMAGES, which was developed as part of the study, is documented in a paper by Hacker *et. al.* (8). Some appreciation of its overall characteristics can be gained from Figure 2. As this simulation model specified the characteristics of the rangeland ecosystem in much more detail than could be incorporated into the optimal control framework, considerable simplification along the lines described by Hacker *et. al.* (9) was necessary to obtain empirical results.

Figure 2: Conceptual Model of a RangelandGrazing System at the Whole-property Level



Selected results from the economic analysis of rangeland rehabilitation using stochastic optimal control theory are reported in Wang and Lindner (10). The key feature of these results is the finding that while it is profitable, at a real discount rate of six per cent, to rehabilitate lightly to moderately degraded range as defined above, it is generally unprofitable to resort to re-seeding in an attempt to rehabilitate severely degraded rangeland which will not, or is most unlikely to regenerate solely in response to total or partial de-stocking.

In other words, if the range is already severely degraded, then the most profitable course of action is to opportunistically graze the land whenever it manages to produce any forage. The model predicts that the inevitable outcome of pursuing such a strategy will be to totally degrade the range.

At the other extreme, range which is either in good condition, or only lightly degraded, can be exploited on a sustainable basis by matching the stocking rate to the feed availability. This grazing management strategy will preserve the range in good condition in perpetuity.

Finally, for range which is moderately to heavily degraded, the model suggests that there might be some value in de-stocking during seasons when there are good prospects for seedlings to become established, but that otherwise the range should be exploited in a similar manner to that for severely degraded range. The most likely outcome of pursuing such a strategy will be to maintain the range in severely degraded condition, but with some remnant perennial vegetation.

Like all analyses of this type, the results depend critically on the assumptions made. The findings outlined above were derived on the assumption that de-stocking and re-seeding were the only rehabilitation methods available, and ignored the possibility of some form of land reclamation. Under these conditions, re-seeding is a very risky procedure as the prospect of seedlings germinating and surviving to become established perennials depends critically on seasonal conditions **and** on grazing pressure in the following two years. Even so, the result that a strategy of re-seeding severely degraded rangeland only when the outlook was favourable would still not be profitable is surprising. The sensitivity of this result to the two key assumptions of a real discount rate of six per cent, and an annual cost of $16 per hectare for re-seeding if and when it is profitable to do so, is discussed below.

A related assumption was that any benefits from re-seeding, as measured by increased potential for rangeland regeneration, were restricted to the year in which the cost of re-seeding was incurred. This was assumed on the ground that any seed which did not germinate would be eaten or lost before the subsequent period. By contrast, other rehabilitation techniques involving land reclamation such as water-ponding, the object of which is to increase retention of both seeds and soil moisture, are much more long-lived. The analysis was re-run for the case where water-ponding was possible and assumed to persist indefinitely.

The results are substantially the same as those described above except that water-ponding in association with de-stocking was found to be profitable for most classes of severely degraded range. The model predicted that in these cases, there was a high likelihood of range condition eventually being restored to moderate to good condition so long as optimal grazing management strategies are followed. However, water-ponding was not profitable for very severely degraded range, and even where it was profitable, there was a small probability that the range would continue to regress to a totally degraded state, and a quite high probability that final range condition would still involve a moderate degree of degradation.

To sum up, these results suggest that no public funding is necessary to ensure rehabilitation of lightly to moderately degraded rangeland, but that the converse may be the case for moderately to severely degraded rangeland. Whether public funding for these cases can be economically justified or not, and if so on what grounds, is discussed in the following and final section of this paper.

MARKET FAILURE

Economic rationalists accept that decision-making based on the aim of maximising private profits need not lead to outcomes which are in the public interest. The accepted reasons for a possible divergence between privately optimal and socially (publicly) optimal choices in the case of land degradation and range rehabilitation have been discussed at some length by, *inter alia*, Quiggin (11), Kirby and Blyth (12), Chisholm (13), and MacLeod and Johnston (14).

As Kirby and Blyth (15) point out, to provide an economic justification for government intervention, it is necessary to first demonstrate market failure (i.e. where private decisions result in an inefficient allocation of community resources), and the second requirement is that the benefits of any proposed government intervention can be shown to exceed the costs. In other words, demonstration of the existence of market failure is a necessary condition for government intervention, but the sufficient condition is that the benefits of intervention exceed the costs of doing so. It is outside the scope of this paper to discuss the various possible forms of government intervention, so I will restrict my remaining remarks to the possibility of market failure in the context of rangeland rehabilitation.

To convince a body such as the Industries Commission that the potential exists for market failure in the funding of rangeland rehabilitation, one or more of the following arguments needs to be sustained:

(i) private decision-makers have imperfect knowledge.

(ii) managers of pastoral properties have incomplete property rights in the rangeland.

(iii) the social discount rate is less than the private cost of funds.

(iv) there are off-site benefits arising from rangeland rehabilitation.

There seems to be little doubt that a lack of understanding of the long-term consequences or over-stocking was one of the main causes of rangeland degradation in the past. However, modern managers have had the benefit of a substantial body of publicly funded research, and should not be unaware of the potential benefits of rangeland rehabilitation. Moreover, even if it could be plausibly argued that imperfect knowledge was still a problem, the first best remedial action would be to make more information available rather than to publicly fund rangeland rehabilitation, *per se*.

Market failure also can arise if the private manager is fully aware that the benefits of rangeland rehabilitation exceed the costs, but cannot capture all of the benefits because of inappropriate land-tenure arrangements. This problem of incomplete property rights is likely to lead to market failure wherever managers of severely degraded rangelands only hold finite term leases.

In the study described above of rangeland rehabilitation in the arid winter rainfall pastoral zone of Western Australia, it was assumed that pastoral property managers had freehold title to the rangeland, so that the benefits of rehabilitation would be realised in perpetuity. When rangeland is leased for a finite term, aggregate benefits are diminished even when discounted, so there is even less likelihood that rehabilitation will be profitable.

The importance of long-term security of land tenure is highlighted by the finding in our study that expected or average time required to restore severely degraded range to good condition using optimal grazing management strategies was of the order of 25 to 30 years. Clearly benefits would need to be realised for many more years for it to be profitable to undertake an investment that takes such a long time to reach full productivity. Again though, the fact that much of Australia's rangeland is leased rather than owned does not constitute sufficient justification for public funding of rangeland rehabilitation, as an alternative would be to convert existing leases to freehold or perpetual leasehold.

Another possible source of market failure arises because the discount rate relevant to society's choices about investment decisions arguably should be less than the opportunity cost of funds for private investments.

In brief, the main bases for these arguments are that individual time horizons are finite, while an infinite outlook is appropriate for social decision-making; and/or that society at large is better able to bear the risk associated with individual investment decisions because they can be spread over a larger number of people as well as being diversified across a range of different investments; and/or because private investment decisions have to based on the post-tax rate of return, while the pre-tax rate of return is appropriate to social investment decisions. This is a contentious issue, and it is beyond the scope of the paper to go into the pertinent arguments in more detail. All that I propose to do here is to indicate the quantitative significance of some of these arguments, and then to illustrate the sensitivity of the rangeland rehabilitation decision to the choice of the discount rate.

The top marginal tax rate in Australia is just under 50 per cent at the present time, so it is conceivable that the required pre-tax rate of return could be as much as twice that of the post-tax rate of return. In practice, there are substantial opportunities for tax minimisation, including some special provisions for tax write-offs relating to soil conservation measures. Consequently the discrepancy between the pre-tax and post-tax required rates of return are likely to be considerably less than a factor of 100 per cent; and for many cases may well be negligible.

Quantifying the importance of the risk spreading and risk diversification argument is not so straight forward. Many economists now argue that corporations can raise finance through the share market, and also can take advantage of other risk reducing opportunities such as insurance. If all risk could be eliminated by such devices, then the discount rate appropriate for private investment decisions should be the risk-free interest rate. Empirical evidence from studies of the share market does not support this point of view, as it suggests that risk premiums are not negligible, and could be equivalent to an increase in the discount rate of seven to ten per cent.

However, by far the most contentious issue is the argument that individual decision-making is myopic, and that a lower social discount rate is appropriate to allow for inter-generational considerations.

In a recent review of this issue, several authors have concluded that the social discount rate should be about two per cent. This compares with current levels of real interest rates which are in the range of five to ten per cent, and with common practice in many government departments of using a social discount rate of similar magnitude.

In the optimal control analysis of rangeland rehabilitation described above, a real discount rate of six per cent was used to derive the result that moderately degraded range could be profitably rehabilitated by grazing management strategies alone, but that re-seeding of severely degraded range was not profitable so that such land would eventually be totally worthless. To test the sensitivity of these results to the discount rate, the rangeland rehabilitation decision was also analysed with an alternative objective function involving maximisation of average annual expected return. This is equivalent to assuming a zero discount rate, which provides an indication of the upper bound to the social net return to rangeland rehabilitation.

Given this assumption we found that it was always profitable to rehabilitate degraded rangeland irrespective of the state of degradation. Specifically, it was found that the optimal strategy for moderately degraded range was still to rely solely on grazing management, but that re-seeding together with de-stocking were more profitable than only de-stocking severely degraded range. In all cases, pursuing profitable strategies was likely to eventually restore range to good condition. It is worth noting though that even with re-seeding, the mean or expected time required to totally restore range condition from a severely or even moderately degraded state was of the order of 20 to 30 years.

The final possible cause of market failure is the existence of so-called off-site benefits from rangeland rehabilitation which are ignored by property managers when they decide whether or not to undertake this risky investment. Direct off-site effects of rangeland degradation could include silting of waterways, etc. arising from water run-off and soil erosion. Chisholm (21) concludes that "in the pastoral zone, particularly the semi-arid areas, land degradation appears to be primarily an on-site problem".

Many conservationists would contest this conclusion on the ground that there are significant indirect off-site effects. For instance, rehabilitating severely degraded rangeland close to roadways and/or waterways is likely to provide aesthetic and/or recreational benefits to tourists and other travellers in arid pastoral areas. Pastoral property managers are unlikely to take these benefits into account when deciding whether to rehabilitate this rangeland because they cannot capture any of these returns. In addition, it has been suggested that there may be non-user off-site benefits referred to by economists as option values and/or existence values. Option value is the amount current non-users of rangelands are willing to pay to avoid irreversible changes, such as the extinction of a species or an ecosystem. By definition, rangeland rehabilitation reverses previous degradation, so it is difficult to imagine justifying public funding on the basis of option values.

A stronger case can be made on the ground of existence value, which in some sense equates with the more generally used conservation value.

In economic theory, existence value is the amount non-users are willing to pay simply to preserve some aspect of the environment without any expectation of ever being able to directly experience it. The strength of the conservation movement clearly demonstrates that such indirect off-site benefits of rangeland rehabilitation need to be taken into account. However, whether the level of existence value is sufficient to justify public funding when rangeland rehabilitation is not privately profitable is ultimately an empirical issue requiring further study. To illustrate, let me conclude with a few simple sums.

Woods (22) estimated that about 107,000 km^2 of pastoral country in Western Australia was substantially degraded in the sense of being affected by vegetation degradation plus moderate to severe soil erosion. On the basis of some limited sensitivity analysis carried out on the cost of re-seeding in the optimal control study described above, it would seem necessary to subsidise re-seeding to the tune of at least $5/ha in order for it to be privately profitable to attempt to rehabilitate this type of degraded rangeland. For the sake of the argument, it can be assumed that the aggregate subsidy required would be of the order of $100 million, or about $100 per head for every employed person in Western Australia.

I leave it to the reader to complete the calculation by estimating the following:

•the percentage of the work force with a conservation ethic;

•for this group, the average willingness (and ability) to pay for **all** forms of conservation;

•the proportion of this total willingness to pay for conservation that conservatively-minded workers would allocate to rangeland rehabilitation.

If the aggregate willingness to pay derived from answering these questions exceeded $100 million, then it might be possible to persuade the government to introduce a range rehabilitation tax to be used to subsidise re-seeding or otherwise treating severely degraded rangeland.

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