7

Submission to the Natural Resource Management (Climate Change) Inquiry Addressing Terms of Reference (b) and (c)

Introduction

The processes involved in managing natural resources for sustainable outcomes are no different for the global warming/climate change scenario than any other set of conditions. Natural resources must be managed to achieve the following three objectives:

- Maximum profit for the land manager.
- Long term ecological integrity.
- Maintaining landscape resilience.

These will be discussed in some detail to demonstrate their inter-connectedness.

Production Functions, Profitability and Natural Resource Management

There is something intrinsically appealing about the concept of good natural resource management improving farm profitability. The following is presented as proof that farmers cannot maximise their profit if they are not optimising farm NRM. A number of natural resource indicators are presented as measures of potential farm profitability. If these outcomes are achieved, farm sustainability would also be enhanced.

The Economics of Production and Natural Resource Use

The microeconomic theory of the firm with regard to production is based on three important concepts:

- The producer wishes to maximise profits.
- To maximise profit, each input (e.g. a) should be used to the point where the value of its marginal product (MP_a*P_o or MVP_a) equals its marginal cost (P_a) or $MVP_a/P_a = MVP_b/P_b = \ldots\ldots\ldots\ldots = MVP_n/P_n = 1$ for all n inputs. This determines optimal output volume.
- Input mix should be varied until the ratios of their marginal products equal their price ratios, i.e. $MP_a/MP_b = P_a/P_b$ or $MP_a/P_a = MP_b/P_b = \ldots\ldots\ldots = MP_n/P_n$ for all n inputs into a production process. MP_a/MP_b is also known as the rate of technical substitution (RTS) and measures the amount of one input (a) that can be substituted for another input (b) to leave total quantity of production unchanged. This measures relative input intensity.

For the purposes of this analysis, we will consider the two input case. The two inputs are defined as either purchased or free. The only input that is free to farmers is the weather. Weather is defined as rainfall, solar energy and wind run and its net effect can be measured as rainfall use efficiency (RUE) or the amount of rainfall that is utilised, in situ, for production of plant material. The components of RUE are crop production, livestock production, litter and positive or negative change in plant mass.

Because the weather is effectively free, it should be utilised up to the point where its marginal product is zero or production from the available weather is maximised (condition three above. If $Pi = 0$ then MP must also equal zero. $MP = 0$ when production is maximised.). For any level of production, the weather should be substituted for purchased inputs to the point where the rate of technical substitution between the weather and purchased inputs is zero, i.e. where purchased inputs for that level of production are minimised and utilisation of the weather is maximised. By definition, $P_{weather} = 0$. Therefore, $MP_{weather}/MP_{other\ inputs}$ must also equal zero which can only happen if $MP_{weather}$ equals zero.

From the above theory, it becomes immediately obvious that, if other elements of the natural system are deemed to be free, e.g. inherent soil fertility, then the optimal management strategy is to maximise the utilisation of those elements to the ultimate detriment of the natural resource base. Many of the broad scale, degrading, agricultural practices, e.g. over-clearing woody vegetation or overgrazing leading to low ground cover, can be explained by the theory of costless inputs. Failure to fully value the natural resource base makes non-sustainable resource use an optimal management decision. Organic carbon falls into this category. In the past, there has been no cost attached to carbon additions and no price for its sequestration.

It can also be readily seen that the combination of inputs that maximises RUE is also the lowest cost, sustainable way to achieve any given level of production. If existing RUE is less than the maximum possible, it takes more purchased inputs to achieve the same volume of production. By implication, combining inputs in a way that maximises RUE produces the most labour efficient method of achieving a given volume of production.

These theoretical relationships are shown diagrammatically in Figure 1. The production function shows all the different input-output combinations that are possible with existing farm management. For the purposes of this exercise, we shall consider two points on that production function, A and B which give outputs of Q_a and Q_b, respectively. These two outcomes can be plotted onto an isoquant map. Isoquants represent all the possible combinations of inputs that could achieve a given amount of output. From this map in Figure 1, it can be seen that it is possible to utilise different combinations of weather and purchased inputs to achieve the same amount of output.

At one end of the spectrum, a given amount of production could be achieved by utilising most of the available weather and few purchased inputs or by using more purchased inputs (e.g. feed supplements) and less efficient use of the weather. The most appropriate mix of inputs is determined by tangency between an isoquant (RTS) and the price ratio of the inputs. This price ratio is described by an isocost line, or budget constraint. It measures all possible combinations of inputs that could be purchased with a given budget. In this case, where inputs are defined as either free or purchased, the budget constraint is parallel to the RUE axis.

Profit is always maximised when the utilisation of the free input is maximised, i.e. when RTS between the weather and other inputs is zero. The most appropriate level of purchased inputs is that which allows maximum rainfall use efficiency (RUE) to be achieved for any level of production (RUE has been postulated as an appropriate surrogate for weather. This will be expanded later.)The expansion path for the farm business is defined by these tangency points and identifies the most efficient way to combine resources to achieve higher levels of production.

Bear in mind that there are two different processes at work here. Profit is maximised **under existing management** when $MP = P_i/P_o$ from an individual's production function. This does not imply that existing management - the combination of the various inputs to achieve this level of output - is optimal. It is simply the best possible under the circumstances. If $MP = P_i/P_o$ and RUE is high (>50% for example), then farm management may be approaching optimal. Management is optimised when inputs are utilised in the most profitable way and is determined by the marginal products and prices of the various inputs. We shall now discuss the factors that influence RUE to prove the connection between sustainability and profit maximisation.

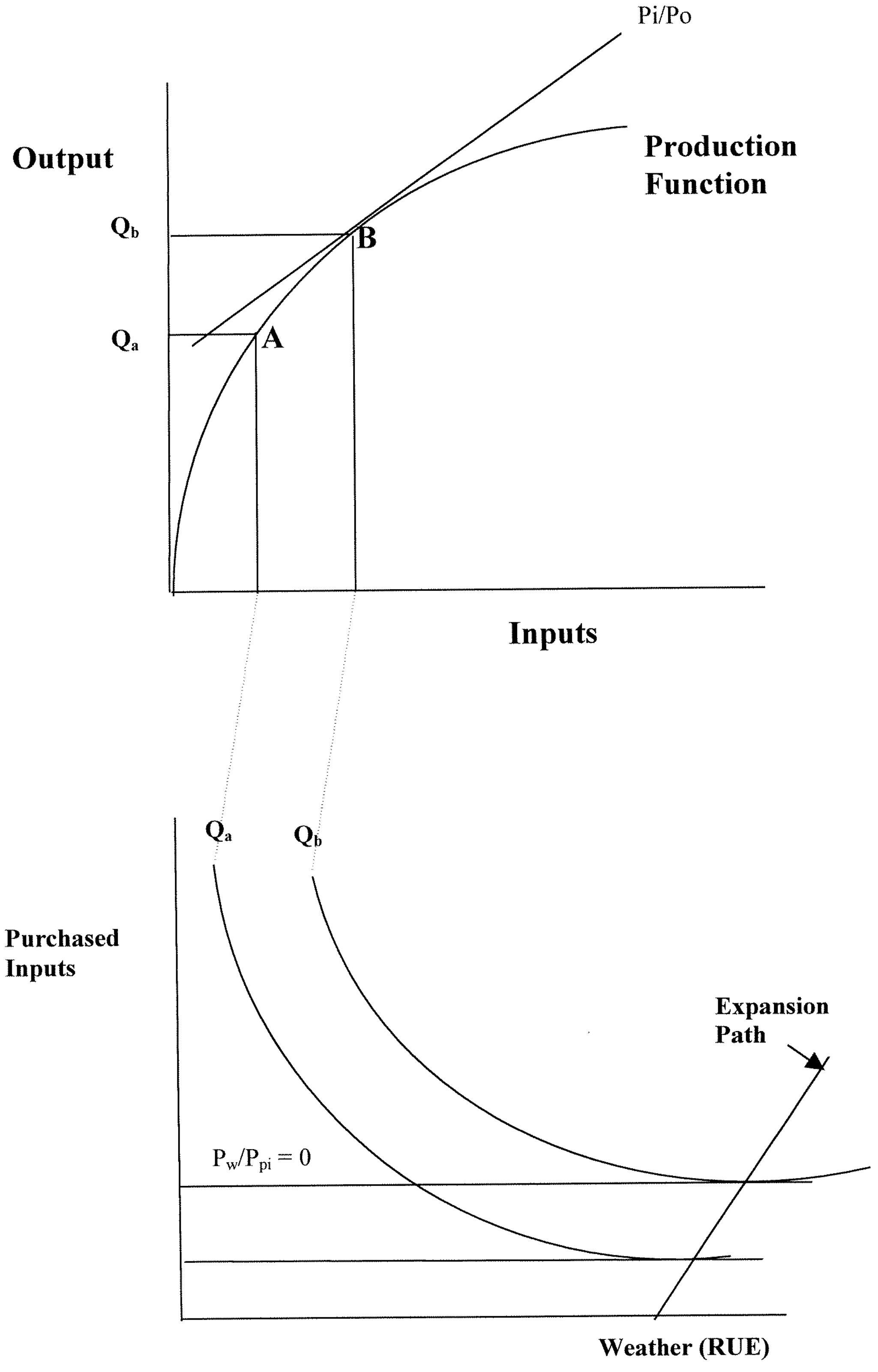

Figure 1: The Relationships Between a Production Function and Associated Isoquant and Isocost Map.

The level of production where Pi/Po is just tangent to the production function (Qb), although optimal in terms of the existing input mix, can be achieved by any number of input combinations on the isoquant Qb. Not all of these combinations can be optimal. Thus, the existing input mix may be optimal, but there may be an alternative input mix that gives a better result for the farm business.

Rainfall Use Efficiency

Much of the seminal work on RUE in Australia was conducted by French and Schultz. They determined how much production could be expected from 1mm of rain/ha for different crops and pastures under non-limiting conditions. Field results can be tested against these benchmarks as an indicator of the RUE of different farming systems, the higher the RUE the more efficient the system.

This concept has been somewhat corrupted into water use efficiency (WUE) which allows fallow rainfall (available rain that produces little plant growth) to be discounted by fallow efficiency (the amount of rain that falls on a fallow that is still available for crops, estimated by Freebairn to be 20-25% in northern farming systems). Stored fallow water may also be less productive because it takes more energy to extract it as its availability falls. Productive potential falls before there are any visible signs of water stress. WUE has also tended to apply to productive outputs (cropping, grazing and litter) rather than all plant growth including woody vegetation. It is perfectly acceptable to have surpluses of vegetative growth if they are dictated by economics and efficient natural resource use. In fact, it will be demonstrated that large surpluses are essential for profit maximisation.

Work undertaken by Gardiner and Browne (unpublished), as part of the Property Management Planning courses delivered by Farming for the Future, found that RUE on 1700 farms across northern NSW varied from 6% to 70%. Similar research undertaken south of Tamworth showed that RUE for different paddocks on the same farms varied from 9% to 74%. Average RUE across all farms was about 21%. Because we know that it is possible to achieve RUE of >60%, it is highly unlikely that RUE of 21% reflects an optimal use of available weather. We also know that the paddocks and farms with the highest RUE are the most profitable. The following tables give an indication of the amount of rainfall that is converted to production by different commodity groups in NSW and Australia.

Data comes from ABARE Farm Surveys, Selected Physical Estimates by major farm enterprise. By comparison, all broad acre farmers in Victoria utilise an average 200mm of rainfall while Western Australians use just 30mm.

Table 1 Rainfall Use Efficiency of NSW Farms

Farm Type	Rainfall Used (2002-03)	RUE (2002-03)	Rainfall Used (2003-04)	RUE (2003-04)
All Broad acre	68mm	19%	73mm	18%
Specialist Cropping	57mm	14%	94mm	19%
Mixed Livestock and Cropping	83mm	21%	81mm	16%
Specialist Sheep	28mm	11%	45mm	15%
Specialist Beef	185mm	21%	138mm	16%

Table 2 Rainfall Used on Australian Farms

Farm Type	Rainfall Used 2002-03	Rainfall Used 2003-04
All Broad acre	37mm	41mm
Crop Specialists	63mm	104mm
Mixed Crop and Livestock	98mm	102mm
Sheep Specialists	34mm	29mm
Beef Specialists	27mm	28mm

The above figures clearly show that, on average across both NSW and Australia, rainfall used in the production of agricultural products is certainly less than 20% of what is available and probably closer to 10%.

If less than 20% of the available rainfall is being converted to production, where does the rest go? There are four causes of rainfall loss:

- **Run-off.** The five main factors that influence run-off are rainfall intensity, soil structure, slope, ground cover and depth to an impermeable soil layer. It is generally recognised that a minimum of 70% ground cover is required to slow run-off and the rate of soil loss. The above mentioned Tamworth trials showed that run-off ranged from 4% to 19% between the best and worst paddocks. If maximising RUE is necessary for profit maximisation, ground cover cannot be allowed to fall below 70% because of water loss to run-off. Low ground cover and poor soil structure often work in tandem for the obvious reason that soils with low infiltration rates harvest less available rain for plant growth. Incorporation of large volumes of organic material is the long term answer to soil structural decline. This is only possible if there are large surpluses of organic matter regularly available at a whole farm level. Large surpluses are necessary to maximise profit. High levels of ground cover also modify rainfall intensity by slowing the flow of water across the landscape and allowing more time for infiltration.

- **Deep drainage.** The two main factors effecting deep drainage are soil texture and agronomy. Water is held in the soil by surface tension, capillary pressure and electro-magnetic attraction. Coarser soils with lower clay content drain more freely than fine soils with high clay content. Organic matter performs a crucial role in replacing the shrink-swell clays in old, highly weathered Australian soils, again reinforcing the need for continuous, large surpluses of organic material. Agronomic practices that store rainfall in the soil for later crop use can also increase deep drainage. Freebairn (op. sit.) estimates that as much as 10% of fallow rainfall is lost to deep drainage. Conversely, under natural vegetation, water loss to deep drainage is about 0.5%. Permanent perennials (trees and shrubs) and a mix of perennial and annual grasses that produce whenever rain falls would serve to minimise deep drainage. Prolonged bare fallows, especially in higher rainfall areas, would aggravate this problem.

- **Evaporation.** This is a function of temperature gradient, ground cover and wind run. Large temperature gradients on bare soil with high wind speeds have the capacity to shift large volumes of water from the soil. At some of the Tamworth trial sites, evaporation accounted for 51% of total rainfall. Evaporation loss can be controlled, to a large extent by high ground cover (>70%), large volumes of crop and pasture residues (litter) and slowing wind speed by incorporating windbreaks into the landscape. Wind run data would suggest that, in northern NSW, wind speeds are sufficient to have a major impact on crop and pasture production on about 30% of days. This is supported by research undertaken by Bird (3) in the western districts of Victoria, which showed that 30% of the land area could be planted to shelter without affecting overall production. Again, profit cannot be maximised if most of the available rainfall is being lost to evaporation.

- **Inefficiencies.** Evaporation only accounts for a part of rainfall use inefficiency. Other factors may limit the capacity of crops or pastures to reach their potential. There are four potential areas of inefficiency:

    1. **Soil** – physical and chemical soil problems may limit productive potential. Chemical factors that limit rainfall use efficiency include low soil nutrient status, nutrient imbalance, acidity, alkalinity and the presence of toxic elements such as aluminium, sodium and manganese. Combinations of these factors may limit the availability of essential nutrients. It is also possible to induce deficiency in one mineral by an excess of another, e.g. an excess of sulphate sulphur can induce molybdenum deficiency in legumes.

       Physical barriers in the soil may prevent plant roots from accessing water and nutrients held deeper in the soil. Hardpans and massive clay subsoils are two examples.
    2. **Plant** – not all plants are equally rainfall use efficient. For example, Rick Young's (pers. comm.) work on the Breeza Plains found Lucerne had a rainfall use efficiency of 4kg/mm/ha/yr while phalaris produced 12kg/mm/ha/yr. Cool season annual grasses in south eastern Australia have reported production levels of up to 28kg/mm/ha/yr. Annual grasses are generally more rainfall use efficient because they rely on producing seed for their long term survival.
       Plant mass is also important in photosynthetic efficiency. The capacity of plants to utilise radiant energy declines rapidly as pasture mass falls below 500kg of green dry matter/ha. Much of the rain that falls on such pastures is used getting the plants to the stage where photosynthesis is optimal. My experience is that graziers who adjust stock numbers to maintain pasture mass in excess of 1,500kg/ha are more resilient in droughts, more profitable and have average stocking rates higher than their neighbours (in many cases, more than twice that of their neighbours).
       Plant physiology has an impact on water use and productivity. C3 and C4 plants have different photosynthetic pathways which affect their capacity to perform under different climatic conditions especially hot, dry days with long sunlight hours. Under these conditions, photorespiration may replace photosynthesis with resultant productivity loss, particularly in C3 plants. Plants with fibrous root systems are generally more efficient at extracting water and nutrients than plants with taproots. Symptoms of K deficiency commonly first appear in annual legumes.
       Some pastures may be dominated by plants that only produce during a part of the year (annual crops). Rain that falls during other parts of the year will not be well utilised because there are no growing plants to use it. RUE may be seasonally high but, in aggregate, low. Croppers may also need to consider rainfall patterns when selecting crops.

3. **Weather** – Temperature and wind run are important considerations. Wheat yields in Australia are determined as much by temperature as rainfall. Wheat is a cool season annual grass which starts to senesce once temperature moves into the 30 – 35 degrees C range. Many of the cool-season annual grasses possess this characteristic. Many warm season grasses also shut down when temperature rises above 45 degrees C, a condition that may apply for most of the day in open rangeland situations.
   Wind run has the capacity to influence the photosynthetic efficiency of plants. Increasing wind speed slows photosynthesis by removing much of the transpired water as evaporation. When plants close their stomata in response to evaporative demand they have lower photosynthetic rates because of a lack of carbon dioxide. Oxygen build-up in the plant leaf may lead to photorespiration under these conditions. At wind speeds of more than 40km/hr, physical plant damage becomes a problem.
   The timing of rainfall events may be important in cropping situations. If a large proportion of the rainfall in the early fallow phase of the cropping cycle is lost to deep drainage, evaporation and inefficiencies, it may be preferable to allow this rainfall to grow cover crops, which can be sprayed out before they set seed, to add to the volume of vegetative residues. If demand for crop commodities is inelastic, any yield losses should be more than offset by price increases.

4. **Animals** – Pasture systems may appear inefficient because of inefficient grazing management. For example, on cold, wet, windy days, without shelter, it may be physically impossible for livestock to eat enough pasture to maintain weight. Wind is an important element in mortality of new born lambs and a lack of shade and shelter can have significant impacts on animal production and fertility. The need to walk long distances to water or poor water quality can significantly reduce the productivity of grazing animals. If pastures are continuously grazed to levels below 500kg GDM/ha, photosynthetic efficiency is affected, meaning that large amounts of rainfall are required to get the pasture to a stage where it uses water efficiently. Inefficiencies in the animal production system may be the reason for apparent inefficiency in RUE.

Conclusions

Micro-economic theory clearly shows that it is not possible to maximise farm profit unless RUE is maximised. To maximise RUE, a number of natural resource management objectives need to be met. Those listed below provide the core natural resource outcomes that would be required to maximise profit and RUE:

- Sufficient ground cover at all times to minimise water loss to run-off and wind and water erosion.
- Sufficient green leaf mass at all times to maintain photosynthetic efficiency.
- A diverse range of annual and perennial grasses, shrubs and trees that enable rain to be used when and where it falls. Water loss below the plant root zone in natural systems can be as low as 0.5% of available rainfall.
- Continuous large surpluses of organic material to improve soil structure, limit evaporation and improve water infiltration.

- Wind protection, shade and shelter to improve the performance of both plant and animal production systems and reduce evaporation.
- Nutrient budgeting to ensure that all nutrients removed by production are replaced. It may also be necessary to balance existing soil nutrient deficiencies if these are limiting RUE.

In short, healthy, bio-diverse ecosystems are required to maximise profitability in agriculture. If RUE is not being maximised, existing management practices are unlikely to be sustainable. The volume of inputs required to maximise RUE is the most cost effective solution to the issue of sustainable farm management. If the volume of inputs required to maximise RUE makes an enterprise unprofitable, that area of land should not be used for production. To maximise RUE in such areas, reverting to pre-existing native woody and non-woody vegetation that has evolved to take advantage of those conditions (nature conservation) may be the most profitable way to utilise that landscape.

Unless land clearing is costless, both economically and in terms of natural resource management, retaining some woody vegetation in the landscape is always optimal. If the demand for agricultural products is price inelastic, land clearing to increase agricultural production imposes a net opportunity cost to all other farmers in that industry.

While the achievement of the above natural resource guidelines does not guarantee profitability (the volume of inputs required to maintain them may lead to a situation where variable costs are higher than income), failure to maintain them unambiguously implies that stocking rate exceeds carrying capacity and profit can be increased by running less stock or cropping less area.

Landscape Resilience

This is about the frequency, duration and amplitude of processes that impact on natural resources and the ways that management influence the speed and magnitude of recovery. Resilience measures the capacity of the landscape to recover from disturbance. Disturbance can take many forms. Changing from grazing to cropping is an obvious example. The greater the number of years of cropping, the longer it takes for the ecosystem to return to its pre-cropping state. If the cropping has reduced the total soil organic carbon level, the system may never return to its pre-cropping productivity.

The factors that affect resilience are the amplitude of the disturbance, i.e. how seriously is the natural resource damaged by the disturbance, the duration of the disturbance event, the frequency of disturbances and the elasticity of the natural resource, i.e. the range of landscape attributes that can buffer the impact of the disturbance and reduce the time taken for the recovery process to be completed.

Landscapes with low slope, inherently more fertile soils and higher rainfall are likely to be more elastic than those with poorer soils and lower rainfall. If the recovery phase is long term, e.g. re-building organic carbon levels, further disturbances may impact the landscape before the recovery from previous disturbance is complete. The resilience of the system can be maximised by adopting management practices that protect the natural resource base. The same management practices that protect the resilience of the landscape also maximise the profitability of the farm business (see above).

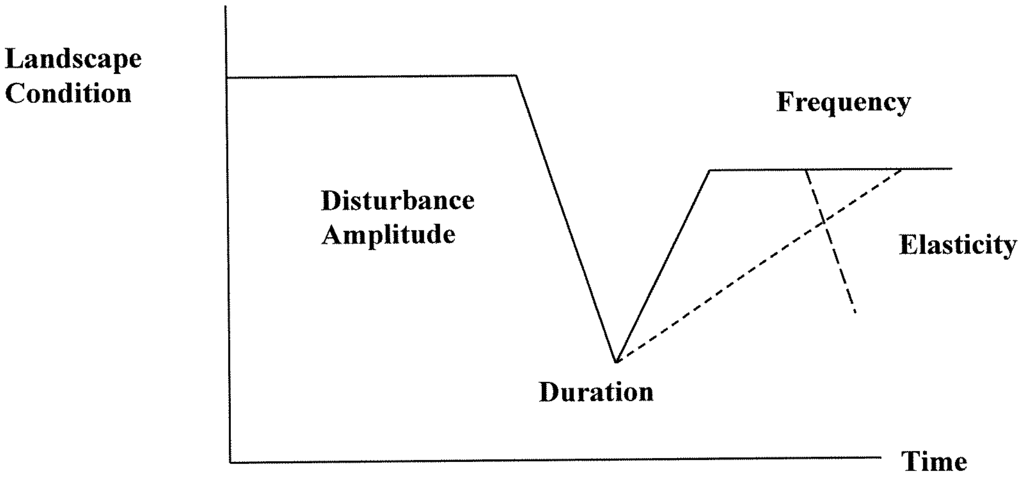

Figure 2: Disturbance and Recovery at a Landscape Scale

Figure 2 is taken from Hutchinson, 2005, and shows the concepts of disturbance and elasticity. The solid line shows what may happen in a drought situation when the landscape is utilised beyond its capacity. This causes quite a large disturbance. When the drought breaks, the landscape begins to recover. If well managed, this recovery may be of short duration and the landscape may return to its pre-drought condition. If the recovery is not well managed, it may take longer to return to equilibrium (dotted line). If the frequency of disturbances increases, one recovery may not be complete before the next disturbance occurs (dashed line relative to dotted line). Evidence from Australian rangelands grazing suggests that, after each disturbance, a new equilibrium has been established, with the landscape in worse condition than pre-disturbance.

The history of agriculture in Australia identifies a number of cultural disturbance events. The influx of livestock to replace the herbivorous marsupials was the first major event and led to the loss of soil structure, changed water cycles and removal of groundcover producing a permanent change in species mix. The disturbances were exacerbated by the introduction and spread of pest animal species such as rabbits, goats and camels, and plants. Broad scale farming and land clearing followed as the capacity of the landscape to support low input grazing diminished. Upon these broad scale cultural changes, short term disturbances such as droughts have been superimposed. Climate change associated with global warming is predicted to increase the frequency of drought in Southern and Eastern Australia (Flannery, 2005). Given the low elasticity of our natural systems, management will need to focus on strategies that minimise the amplitude of drought induced disturbance. The alternative is a long term diminution of landscape productivity.