Report to the Productivity Commission

Tree and shrub thickening in the Murweh Shire

Dr Ian Beale

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See also Appendix:

Discussion on the wider impacts of tree/shrub "thickening" on Queensland grazing lands

This study forms part of the consulting service provided to the Productivity Commission for its inquiry into the impacts of Native Vegetation and Biodiversity Regulation. It should be read in conjunction with Beale and Kenny 2003 (http://www.pc.gov.au/inquiry/nativevegetation/vegetationthickening/index.html).

Literature on issues related to vegetation thickening (including issues raised by Dr Bruce Wilson submission number DR254), is examined further in this study.

1. Rate of Thickening in Murweh Shire.

Despite the existing dominance of woody plants in the mulga lands of eastern Australia, there is good evidence that prior to European settlement most of the mulga was open savanna (Interdepartmental Committee 1969). The initial constraint upon grazing was lack of water, rather than too many trees. Good historical perspectives are provided by the Inquiry into the Condition of Crown Tenants in the Western Division of NSW (Royal Commission 1901), along with the informative and entertaining "A Million Wild Acres" (Rolls 1981) and "The Delicate and Noxious Scrub" (Noble 1997).

Thickening in the Neebine (Charleville –Bollon) mulga areas dates back to the early decades of last century (W. White, Manager, Boatman Station, Australian & New Zealand Land Co. 1965 pers.comm). Jim Gasteen's father took up a soldier settlement block in the Bollon district at the end of World War 1. The ensuing decades were very dry and he reports (Gasteen 1986): "Drought followed drought and in the absence of competition from ground layer species and a lack of fires because there was nothing to burn, inedible shrubs, mulga, cypress pine and eucalypt seedlings began to colonise the bare, open spaces (emphasis added). By the late 1930's shrub regrowth had reached such proportions that some 3 year old ringbarked areas were so unusable and so uneconomic to treat that the usual follw-up treatment of suckering had to be abandoned – some of it still, 40 or 45 years later".

Burrows (1973) concluded from his study of mulga regeneration that stands of mulga with >640 trees/ha prior to clearing (a comparatively low density for mulga) could quickly revert to thick scrub, whatever the final tree number left standing, unless fire or heavy stocking designed to prevent this are imposed. Writing in the same era Cunningham and Walker (1973) reported that "dense mulga regeneration has occurred (in areas of north west NSW) during the past 15-20 years". Thrushton National Park (north of Bollon) was set aside to preserve the 'pristine (sic dense) mulga forest' (see aerial photo in Purdie 1986) in the late 1980's. Yet earlier to this it was a commercial grazing property. Likewise Selwyn Everist (former Qld Government Botanist) informed the author (1965 – pers. comm.) that the site of the mulga clearing study (Beale 1973) was the original Boatman Station horse paddock and was open savanna in the early 1940's[1]. At the time of thinning for this experiment in 1963 there was an initial population of 5570 (SE 11.1%) mulga trees per ha (≈23 years to thick mulga)

[1] Everist did his WWII service at Charleville as a meteorological officer. He also used this time towards developing his encyclopaedic knowledge of mulga (see Everist 1949).

These transformations from open woodland to closed forest are tellingly illustrated by the enclosed photo sequence taken at "Wongalee", 20 kms west of Boatman Station over the past 40-50 years (Plate 1 & 2). [after Burrows 1999].

PLATE 1. Wongalee 1957

Plate 2. Wongalee 1994

Individual Tree Growth Rates.

Everist (1949) reports several tree growth figures for Boatman. One was from a 1" (3 cm) sapling to a tree 20 feet (6 m) high with a trunk of 8" (20 cm) diameter in 20 years. A second was from seed to 12 feet (3.6 m) high in about 12 years. The Queensland Department of Primary Industries maintains several permanently positioned woodland monitoring (TRAPS) sites in the area.

Tree Thickening in Murweh Shire

The author was a pasture research officer at the Charleville Pastoral Laboratory from 1965 to 1998. During this period he traversed the Charleville – Morven road regularly. Mulga regrowth on this road developed from open savanna to thick mulga once the road reserve was fenced to exclude stock in the early 1970's (≈ 34 years to thick mulga)

Spring Hill and Arabella landholdings (along the southern side of the Charleville – Morven road) were both chained about 1970 to increase pasture availability. Arabella has since been re-chained, and Spring Hill could also be. (≈ 34 years from chained to thick mulga).

In summary, thickening of mulga has been recorded since at least the 1940s. Examples given are in keeping with the commonly held landholder wisdom that the recovery period for mulga is about 20 years from drought feeding to again suitable for drought feeding.

It is highly probable that much of the 80+% of the mulga biome considered to be remnant under regional ecosystem mapping has a similar history. Indeed "remnant" is a misleading term when applied to such vegetation, leading Purdie (1986) to note that "as a result of land use (for domestic stock grazing) the Mulga Region ecosystems can in no way be described as "pristine", i.e. identical with their pre-Aboriginal or pre-European settlement state".

In his submission to the Productivity Commission, Bruce Wilson (sub. DR254) correctly points out that "the (pastoral) productivity of the region is in imminent and drastic decline", and has been true since about 1949 at least. The use of broad-acre clearing (including mulga for drought supplementation) and other strategies has allowed management of this problem – in this sense mulga is a commercial species.

Thinning is being proposed as an alternative, but as Burrows (2001, 2002) shows, thinning is a loss-making tree management option in higher rainfall zones than the Murweh Shire, so one would not expect it to "pay" in even more arid areas

The ecological implications of an imposed thinning regime also need to be understood. In mixed species and mixed aged shrub-woodlands it is intuitively obvious that the landholder will thin out what he/she perceives to be most favourable to his/her objective e.g. more 'top feed' or more grass. Following either of these pathways can result in very different woodland structures and composition. For example, the selective removal of palatable mulga from the box-mulga woodlands of the Cobar-Byrock peneplain has led to a vegetation now strongly dominated by unpalatable (to domestic livestock) shrubs (Noble 1997). Clearing on a face, while retaining uncleared areas as 'intact' blocks and strips would better ensure that the integrity of the retained woodland is maintained.

Restriction to lopping of fodder trees may help retain the composition of the vegetation. However lopping is a serious restriction on the commercial viability of the use of fodder trees for drought supplementation and it does nothing to control the thickening of the complete suite of woody vegetation that is occurring.

Inability to manage the thickening of woody vegetation will have three important effects on conservation values in the area:-

1. Overstocking of remaining more open areas, with deterioration in land condition (e.g. Slaughter 2004)
2. Increasing soil loss in the areas of woody expansion - trees are a poor substitute for grass in soil retention (e.g. Gourlay 2004)
3. Decline in cover and food sources for native fauna smaller than kangaroos (e.g. the following quote from Chambers (1988) of an aboriginal perspective of the upper Warrego River area *ca*. 1865:- "--- for brigalow scrub, except for scrub wallaby, which require much shouting and driving, is bad game country ---").

(See also the appendix to this paper for further discussion on vegetation thickening in Murweh).

Other Species

Invasion of other species is well covered in Burrows (1999), Burrows (2002) and in the appendix. But one other observation by a highly respected botanist is worth recording here for both the timescale and wider perspective it adds to the current discussion. Some 66 years ago Blake (1938) noted that "brigalow scrub is slowly but surely extending its range, many changes having taken place within the memory of living men. Both grassland and *Eucalyptus* forest have been invaded and replaced. All stages in the invasion can be seen, and in some older scrubs box stumps are to be found".

2. Basal Area Increases.

Some of the 1960's trial work conducted by personnel from Charleville Pastoral Laboratory recorded basal areas of woody vegetation. Data from one such source (Beale 1971, Beale 1973) is summarized in Table 1. This trial had 3 tree density treatments with 7 replications at 2 locations. Basal area was measured for 16 marked trees per replication.

Table 1. Rates of Basal Area Increases for Mulga 1966 – 1970 (Beale 1971)

Boatman			
Trees/ha	**40**	**160**	**640**
Basal area increase	0.10	0.22	0.39
(Sq M/yr)			
Monamby			
Trees/ha	**40**	**160**	**640**
Basal area increase	0.05	0.19	0.36
(Sq M/yr)			

It appears that Bruce Wilson (sub. DR254) has miscalculated the rates of increase of basal area for both Fensham et al (2003) ((14.1 – 11.84) /44 = 0.05sq m/ha/yr) and Burrows et al (2002) ((12.92 – 11.86)/14.4 = 0.07 sq m/ha/yr).

Both these results approximate the 40 per ha tree density results in Table 1. However Table 1 shows that increasing tree density within this trial produces accelerating tree basal area increase (See Burrows et al 2000, Fig. 3 and Burrows et al 2002, Fig 7 for additional perspectives). These values are also larger than those quoted by Wilson (sub. DR254). The basal area values for 640 trees/ha plots are well beyond those of Fensham et al (2003) and Burrows et al (2002). Converting the values for 640 trees/ha to FPC% by the methodology used by Wilson, the resulting values for FPC % change per year are of 0.83%/yr and 0.78%/yr.

However this conversion to basal area at 1.3metres produces negative values for the initial basal areas at 0.3m in the 40 trees/ha treatments. The estimated values for FPC cover also seem too low. These concerns emphasize the danger of applying relationships developed in higher rainfall areas to semi-arid and arid areas. This is discussed further in the section on State and Transition.

3. Development of a Woody Index Relationship.

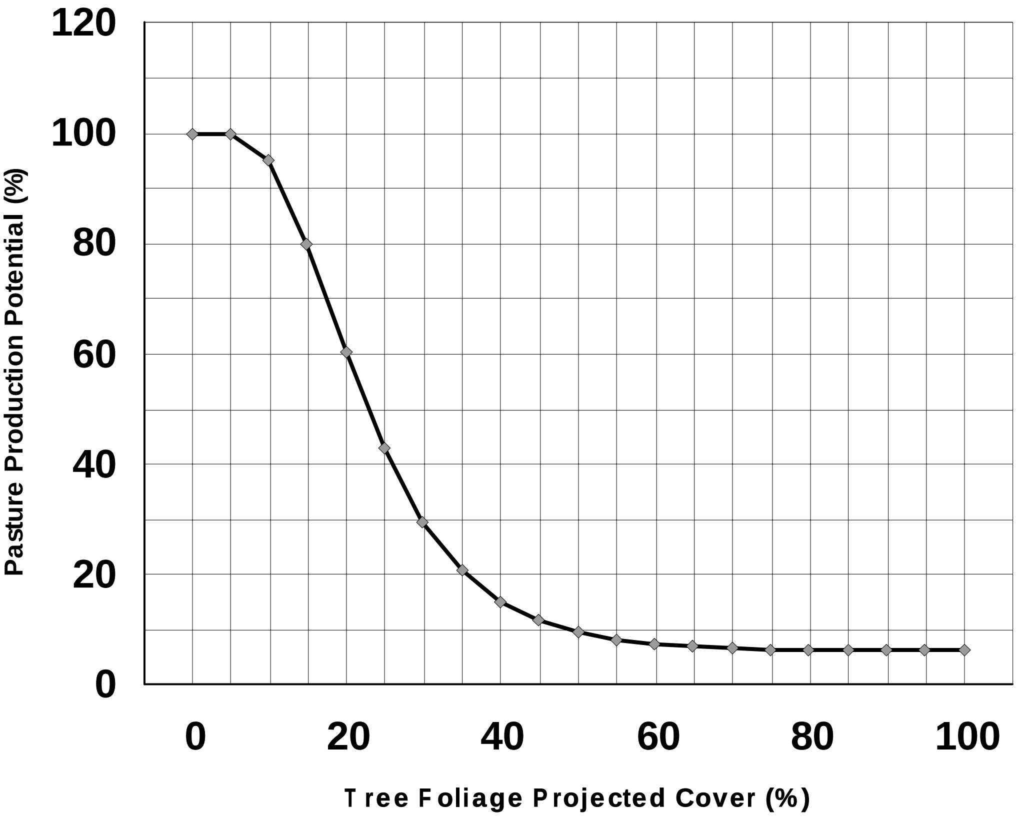
This is derived from sites located in the area bounded by Bollon, Cunnamulla, Mungallala , Quilpie, Adavale and Blackall. These sites had at least paired samples of open and thicker woody vegetation. Measurements included pasture yields and foliage projected cover (measured with a vertical point apparatus as used in the SLATS ground truthing). The WARLUS land system for each site was also recorded. Some 200 of these sites were in land systems commonly associated with mulga. Initial statistical analysis was done with SYSTAT. This was subsequently crosschecked by Dr P. Johnston using COPLOT before being incorporated into the carrying capacity spreadsheet (Johnston *et al* 1996a and b)

The data was fitted to a 5-parameter transition sigmoid growth curve (Grosenbaugh 1965) of the form:-

$$Y=H+A\left(1-e^{-B(X-G)}\right)^{M+1}$$

Where X is the independent variable, Y is the estimated value of the dependent variable and H and A are the upper and lower asymptotes respectively. B provides the necessary curvature and M adjusts the inflection point and G adjusts the value of X so that X-G = 0 when Y = H. For overstorey – understorey relationships, the X origin may be taken as zero, so G = 0 (from Jameson 1967).

Figure 1. Modified Tree Cover - Pasture Production Relationship (Beale unpublished)



Initially the carrying capacity model used a woody index developed by converting the relationship of Beale (1973) to use FPC rather than basal area. Field testing of the Carrying Capacity Model by Cooney (1995) and Crichton (1995) found that the predicted reduction in carrying capacity was too severe at lower levels of FPC. The factor M in the Grosenbaugh equation controls the onset of inflection near the Y axis

(See Figure 1). This relationship provided more realistic predictions when field tested by Cooney (1995) and Crichton (1995). It has since been used on more than 300 property evaluations in the Safe Carrying Capacity Project run by DPI from Charleville. Around 100 of these were of property build-up proposals for financial assistance under the South West Strategy Scheme. Evaluation of such proposals with this model was a requirement of that scheme.

Thus the Woody Index relationship used was derived from on-ground measurements of FPC and herbaceous yield. It has been field tested, and widely used in the carrying capacity project.

The data set also shows that FPC's of more than 50% (and up to 66% for a sample of sites) are common in thickly wooded areas. There can be additional cover from lower storey vegetation.

Indeed Nix and Austin (1973) observed that "in the most favourable environments and particularly the east, mulga occurs as a tree, forming low-open forests or even open forests (trees > 10m tall and with projective foliage cover within the range of 30 to 70%".

4. Development of Estimates of Rates of Cover Change.

These were obtained from scanned and georeferenced aerial photographs by digital subtraction. The areas used were relatively small, and were known to be fairly uniform in topography and land units. The technique was provided by the technical support personnel for the GIS software package used, and is thus (I presume) a standard raster manipulation technique. The technique is very different from that of Fensham et al (2002), who use paired aerial photographs with a grid sampling methodology under a stereoscope. It appears that they apply relationships developed relative to measurements on the current vegetation to the vegetation present in the earlier aerial photograph series. It does not appear that they have verified that these relations apply to earlier vegetation.[2]

The woody index used by Kenny and Beale (2003) was developed from FPC data. As Fensham et al (2002) view aerial photographs under a stereoscope, they are measuring crown cover. The technique used by Kenny and Beale (2003) uses the grey scale values in the aerial photographs, which should be more directly related to FPC. Thus a more open canopy (lower FPC) should have a lower grey scale value. This was not investigated in the study.

Despite this, it is evident that, when the value derived (approximately 1%) is combined with the woody index developed from actual measurements of FPC and pasture yield, the projected time to thicken fits well with historical records of that thickening time listed earlier.

The rate of thickening for FPC between 10% and 40% is not likely to be constant (as Bruce Wilson pointed out in his submission). However, assuming a changing rate of thickening over this region is academic. By the time canopy cover in Murweh Shire

[2] In his submission, Bruce Wilson (DR254) suggested that the rates of cover change from the early 1960's in the Charleville area could be tested by applying the method used by Fensham et al. (2002).

get above 35%, pasture production is seriously depleted from both pastoral and conservation standpoints.

The figure of about 1% annual increment in FPC applies to canopy covers up to about 35%. Canopy covers higher than 35% do increase more slowly (several measured example areas showed about 5% in 24 years, or around 0.2% per year). This is still higher than the figures given for Fensham et al (2003).

Likewise any 'self thinning' (e.g. as a result of extreme drought) only tends to occur when the site potential of the tree population is nearly reached. This usually corresponds to a tree basal area where pasture production is severely depressed, while post drought recovery in tree basal area is generally quite fast, meaning that any boost in pasture production from the self thinning is only transitory. The corollary, that commercial thinning of woodlands 'does not pay' (see attached review), follows for the same reason.

5. SLATS FPC Estimates

In his submission (DR254), Bruce Wilson asserts that the SLATS FPC value for Murweh Shire is for 1997. As I read the SLATS metadata for the 2003 report, field values of FPC were obtained around this time. However estimates of FPC are updated from each new set of satellite data by removing newly cleared areas. Thus it seems that the value we have used is appropriate for 2001. Alternatively, if we started the analysis in 1997 we would still get the values given by Kenny and Beale (2003).

6. State and Transition and pulses of growth.

Semi-arid and arid areas are frequently described as "where things happen slowly". This belief will be supported by measurements between long intervals (e.g. Fensham's 44 years). It will be helped by belief in "the seductive simplicity of Clementsian succession" (Walker 1988), and will be beloved by those seeking a "one size fits all" management philosophy.

However the pattern of change in these areas is actually that not much happens, then things change (and can change rapidly) and then not much happens. Everist (1949) noted pulses of mulga growth from negligible to rapid according to season. This pattern is much better described by the "state and transition" model (Westoby et al 1989, Tropical Grasslands 1994). Thus rates of change of vegetation parameters are likely to be different from those of higher rainfall areas where successional responses might be expected. (See also Appendix attached).

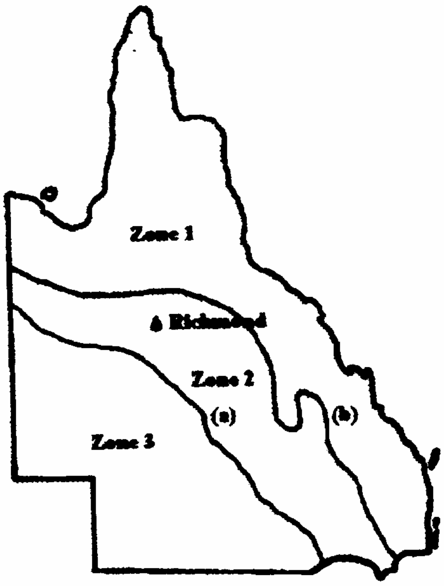


Figure 1. Isohyets of 400 mm mean summer rainfall (November - April) across Queensland for years when the mean value of SOI in spring was (a) more than +5 and (b) less than -5 (Redrawn from Clewett *et al.* 1991).

That the pattern of vegetation response may be even less uniform from humid to semi-arid and arid areas is indicated by the developing field of range ecology at disequilibrium (e.g. Behnke, Scoones and Kervan 1993) .

One possible effect of this on the rangeland areas of Queensland was explored by Beale (1996). It is likely that there are three zones in the Queensland rangelands (See Figure 1 from Beale (1996) above)):-

- Zone 1:- near coastal in which succession is likely to prevail
- Zone 2:- which may swap between successional and disequilibrium depending on the influence of El Nino climatic conditions
- Zone 3:- an arid region in which disequilibrium can be expected

Murweh Shire is in Zone 2, and thus less amenable to the application of relationships developed in higher rainfall areas.

7. Management Considerations.

In his submission (DR254), Bruce Wilson asserts that to explain current foliage protective cover for Murweh, given the estimated thickening in Kenny and Beale (2003), clearing rates must be higher than those recorded by SLATS (1991–2001). However, other factors besides clearing, such as fire, drought and grazing management, affect the foliage protective cover (e.g. Everist 1949, Partridge 1996). Jones and Burrows (1994) presented a State and Transition model for mulga, which encompasses most management outcomes and interactions.

APPENDIX

Discussion on the wider impacts of tree/shrub "thickening" on Queensland grazing lands

1. Tree/shrub thickening

In his submission (sub. DR254) Dr Wilson observed (p.2) that "under BAU thickening will occur on all remnant vegetation, less the amount that has been cleared at a particular time"; and (p.4), "that the occurrence of (tree) thickening in Murweh Shire is not questioned". These statements are endorsed and attention drawn to the fact that, in addition to the mulga lands, there is very strong published evidence that there are few intact forests, woodlands and shrublands in Northern Australia that are not subject to the tree thickening phenomenon (e.g. Royal Commission 1901, Interdepartmental Committee 1969, Rolls 1981, Burrows *et al.* 1985, Harrington and Sanderson 1994, Fensham and Fairfax 1996, Hopkins *et al.* 1996, Binnington 1997, Crowley and Garnett 1998, McCallum 1999, Burrows 2002, Burrows *et al.* 2002, Fensham *et al.* 2002, Lewis 2002, Sharp and Whittaker 2003, Krull *et al.* 2003). [See:http://rangeweb.tamu.edu/archer/– proliferation of woody plants in drylands - a bibliography; accessed 12 February 2004 – for an international perspective].

These published reports of tree/shrub thickening in Australia encompass semi-arid shrublands, tropical and sub-tropical savannas, wet sclerophyll forests, tropical lowlands, Mitchell grasslands, eucalypt woodlands and cypress pine communities. The ubiquity of the response is well explained by ecological theory (see Westoby (1980), Walker and Noy-Meir (1982) and Westoby *et al.* (1989) for international examples) and the special issue of *Tropical Grasslands* [Vol. 28(4) – 1994], presenting State and Transition theory and models based on numerous Queensland case studies.

Proximate causes for such tree/shrub thickening on grazing lands are detailed by Archer (1995a,b), Scholes and Archer (1997), Archer *et al.* (2001), Burrows (2002) and Henry *et al.* (2002). Almost half of Queensland's total land area (174 M ha) supports some degree of tree/shrub cover (Henry *et al.* 2002). About 60 M ha or one-third of the State can be categorised as grazed woodland (Burrows 2002), but this includes around 8 M ha of regrowth from past clearing (SLATS 2003). So the net area of grazed (remnant) woodland subject to tree/shrub thickening should approximate (a conservative) 50 Mha[3].

Once a tree-grass system has "flipped" towards more woody cover the change tends to be unidirectional to ever increasing woody cover over time (Burrows 1980, Whalley 1994), until a new woody plant dominated equilibrium is reached. This has obvious implications for the livestock carrying capacity[4] of grazing lands, as tree-grass relationship curves collated by Burrows (2002) amply demonstrate. The persistence of tree/shrub cover, under current management, is well illustrated by the

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[3] To provide some Australian scaling perspective, the present area of grazed woodlands alone in Queensland exceeds the total area of all cropping+grazing land in New South Wales (Lloyd and Burrows 1988).

[4] Published data detailing the number of domestic livestock currently supported within Queensland's grazed woodland communities (as distinct from those carried on pastures developed from fully cleared areas or native grasslands) are not readily available. However the proportion of tree/shrub cover in each Shire can be derived from the SLATS reports cited by Dr Wilson. Similarly, total livestock numbers for each Shire (exclusive of those in feedlots) are obtainable from ABS data. Tree-grass relationship curves (Burrows 2002), combined with known environmental variables, should then provide a ready and reliable means to apportion livestock numbers in each Shire between those grazing naturally open/induced pastures and those supported within the woodland communities *per se.*

transformation of the Cobar peneplain (NSW) from open eucalypt (poplar box) woodlands when domestic livestock grazing commenced (Royal Commission 1901), to closed shrub woodlands, clearly visible on contemporary satellite images of Australia. This increased woody plant cover has notably persisted over the years, despite a very wide range of seasonal conditions experienced since 1901.

2. Tree/shrub thickening effects on livestock carrying capacity

The GRASSMAN computer package (Scanlan and McKeon 1990) is a counter-part of the safe carrying capacity work of western Queensland (Johnston *et al* 1996a and b). It allows carrying capacity to be estimated once tree basal area is known. This package was initially developed for eucalypt woodlands in central Queensland, with the driving relationship being that between tree basal area (or cover) and potential pasture production. Thus the family of curves cited by Burrows (2002) provide quantitative data that can be directly applied or extrapolated to most grazed woodland communities in Queensland.

Burrows *et al.* (2002) have detailed field based measurements of tree/shrub basal area and their changes over time, utilising a system of permanently positioned monitoring sites (TRAPS transects). Their initial synthesis was for plots shown to be highly representative of 27 M ha of eucalypt woodland in Queensland. Further, the repeat recordings covered a broad range of seasonal conditions, with the first sites positioned in 1982. So the rate of increase in live tree/shrub basal area (and corresponding drop in livestock carrying capacity) can now be projected into the future with some confidence (see Bray *et al.* (2002) for an initial analysis).

Alternatively, a more stochastic approach could be followed by modelling future thickening rates, based on long term climatic records (see Burrows *et al.* 1985, Scanlan and Archer 1991) – since the rate of tree basal area increment is now known for different periods corresponding to different seasonal conditions (Burrows *et al.* 2002). Under either scenario the likely impact of untreated thickening on the Net Present Value of livestock production could be readily estimated for appropriate timeframes.

3. Thinning

Ongoing tree/shrub thickening needs to be managed if the current livestock carrying capacity within Queensland's grazed woodlands (2-3 M cattle equivalents?[5]) is to be maintained. It is often suggested that "thinning" (the selective removal of individual tree/shrubs from thickened areas) can address this problem. Unfortunately this does not appear to be the case (Table 1), at least where the trees involved have no commercial timber value (the most common situation)[6].

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[5] This figure assumes a grazed woodland area of 50 M ha with mean present carrying capacity of 1 cattle equivalent per 20 ha over all the woodlands. See Footnote 1 for suggestions on how this 'ballpark'figure could be more accurately determined.

[6] The reason thinning does not pay is because retained trees grow much faster (less competition) after adjacent siblings are killed. Hence the basal area of the thinned woodland quickly returns to its original state and pasture production is again suppressed. Meanwhile the cost of labour and chemicals to thin out the woodland still has to be met. This quick return to suppression appears to be mostly ignored in

Assumptions for data in table 1 – paddock size 1000 ha; stocking rates are determined by the GRASSMAN model (Scanlan and McKeon 1990) – tree basal area resulting from each treatment (actual field measurements) determines potential native pasture production (Scanlan and Burrows 1990) which is stocked to consume 30% of the pasture on offer; steers enter paddock at 180 kg, leave at 450 kg; average rainfall is assumed for each year of a modelled 15 year timeframe; Net Present Value (NPV) is based on the 15 year time span and a 6% discount rate; interest on herd capital is charged at 10%. [Adapted from Burrows 2002].

Table 1: Response relative to 'control' of various tree clearing treatments on a poplar box (*Eucalyptus populnea*) woodland site in central Queensland.

Clearing method	NPV/ha
Control (intact woodland – initial tree basal area $10m^2$/ha)	
Retain 20% trees scattered over paddock, stem inject the remainder (= THINNING)	($21.00)$^{\phi}$
Retain 20% trees in intact woodland strips – tractor pull and burn the remainder	$47.00
Retain 20% trees in intact woodland strips – treat remainder with tebuthiuron (1.5kg a.i./ha)	$40.00
Retain 20% trees in intact woodland strips – treat remainder with tebuthiuron (1.0kg a.i./ha)	$63.60

$^{\phi}$Negative value

These results strongly suggest that the only way livestock carrying capacity can be economically maintained in thickening woodlands is by fully clearing some areas, while keeping retained trees in intact woodland blocks, clumps and/or interconnecting strips. With such an approach the same tree retention rates (e.g. expressed as tree basal area/ha) can be achieved as in selective thinning, but in a manner that is still profitable to the landholder.

4. Thickening effects on environmental values

A necessary corollary to the present widespread evidence of tree/shrub thickening in grazed woodlands is that these communities were more open in the past. Indeed there is compelling historical and anecdotal evidence of this (see citations in Burrows 2002) along with the quantitative studies referenced in Section 1.

Such 'open' vs 'closed' woodland states have obvious implications for plant and fauna diversity. Crowley and Garnett (1998) have convincingly shown that ti-tree invasion of open woodlands in Cape York is a prime agent threatening the survival of the endangered golden shouldered parrot. In like vein Franklin (1999) has noted that the decline in granivorous bird assemblages in Queensland's 'Desert' woodlands preceded any land clearing activity. This area has always been lightly stocked, while tree-grass competition is greatest in dry, infertile sites typical of this area.

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discussions of drought effects on woody vegetation in papers subsequent to Fensham and Holman (1999).

It is well known that trees lower water tables and run-off as a result of their deep rooting systems (cf. most pasture plants which might replace them). This has been most tellingly illustrated by the effect plantation eucalypts have had in lowering stream flows and water tables following their over planting on South African veldt (Scott 1999); and the proposal to control woody plant cover in the Edwards Plateau to increase urban water supplies for San Antonio and Austin, Texas (Wilcox and Dreuter 2003). Conversely the removal of trees has been associated with rising water tables and salt mobilisation in Western Australia's south west (Bari *et al.* 1996, Beresford *et al.* 2001). This situation is far less likely in tropical/sub-tropical Queensland where, in contradistinction to southern Australia, evapo-transpiration usually exceeds precipitation in the months of highest rainfall incidence (Burrows 1991, Salinity Management Handbook 1997).

Scanlan and Burrows (1990) recorded a significant change in the composition of the understorey flora as tree cover increased. Similar trends have been observed in invertebrate populations (Andersen 1990). As Franklin (1999) notes, insectivorous birds tend to replace seed eaters, while nectar and pollen favouring fauna should increase as tree basal area increases. However, some anecdotal evidence from beekeepers in western Queensland suggests that honey production tails off with increasing tree density. That increasing woody density may be to the detriment of fauna is indicated by this quote from Chambers (1988) of an aboriginal perspective of the upper Warrego River area *ca*. 1865:- "--- for brigalow scrub, except for scrub wallaby, which require much shouting and driving, is bad game country ---".

Thus environmental parameters vary considerably across a broad spectrum of tree/shrub densities and basal areas. What is targeted to be conserved at a eucalypt tree basal area of (say) 4 m^2/ha may be vastly different in quantity and composition at a tree basal area of 20 m^2/ha, if tree thickening proceeds unabated in future. Resulting reductions in stream flow and riparian impacts, especially in non coastal zones, do not seem to have been evaluated under similar scenarios.

5. Conclusion

In his submission (DR254) Dr Wilson has highlighted aspects of tree thickening in south west Queensland and cited quantitative evidence of the phenomenon in other parts of the State. A more general overview is given in Burrows (2002). In effect ecologists are not questioning the ubiquitous nature of tree thickening in our grazing lands, but are simply debating the rate at which it is proceeding[7]. The latter is not surprising given the huge climatic range and differing time spans encompassing individual reports. Likewise most of the discussion over the rate of thickening (e.g Wilson vs Kenny and Beale (2003)) involves different interpretations of remotely sensed/modelled data. Such methods are obviously necessary where there is no history of field based measurements. However Queensland is fortunate in having a comprehensive network of rigorous ground based woodland monitoring sites, established by its Department of Primary Industries. Initial sites were set up in the grazed woodlands over 20 years ago (and earlier for commercial forestry plots) and the database can be accessed to accurately inform the debate (e.g. Burrows *et al.*

[7] Interestingly the published rates of woodland thickening in Queensland are still lower than the 2-5% increase in stand basal area per year reported for woody species in African savannas (Scholes and van der Merwe 1996).

2002). There are also other sites in the mulga region dating from the early 1960's that provide similar data.

More importantly, ecological theory (see Section 1) indicates that under present land use woodland thickening, irrespective of debates about its rate, will proceed until a new woody plant dominated equilibrium condition (or "fluctuating climax") is reached. At this stage, and in the absence of effective ameliorative measures, the present livestock carrying capacity (2-3 M cattle equivalents ≈ 20-25% of Queensland's total sheep/cattle base) in the grazed woodlands will trend to negligible numbers (except in exceptional rainfall years).

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