A REVIEW OF FIRE IN THE MANAGEMENT OF NATIVE PASTURE WITH PARTICULAR REFERENCE TO NORTH-EASTERN AUSTRALIA

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ABSTRACT

The use of fire in the management of the grassy open forests and woodlands of north-eastern Australia is reviewed and discussed in relation to the reports from elsewhere. Fire is used mainly to remove top hamper prior to or at the commencement of the wet season in order to make the new season's growth more accessible. Fire may induce out-of-season growth in south-eastern Queensland following burning in spring when there is adequate soil moisture, and in north-eastern Queensland in late summer when the herbage is maturing but soil moisture not yet depleted. Apart from the important use of fire to form fire breaks the other reasons for burning are largely of local significance only. Fire will continue to be used but pasture improvement will reduce the necessity to burn regularly. Planned burning and conservation of standing forage are suggested to provide low quality feed reserves which may be used in conjunction with urea/molasses supplementation.

INTRODUCTION

West (1965) and Daubenmire (1968) have recently reviewed the world literature on burning as it pertains to pastoral lands. West has paid particular attention to Africa and Daubenmire to North America, while Cooper (1963) has provided an annotated bibliography for Australia.

The recorded history of burning pastoral lands in northern and north-eastern Australia has been relatively short though it is suspected that fires have been a part of the environment for a very long time. Many of these must have been natural and associated with the often violent electrical storm activity of the region but, as witnessed by Mitchell (1845) in central tropical Australia and Gregory (1858) in northern Australia, others were the result of the hunting, warring and sporting activities of the aboriginal inhabitants. However, with the coming of European settlers a little more than a century and a quarter ago, burning became a more frequent phenomenon, particularly in the open forests and woodlands where the rainfall is usually sufficient to ensure carry-over herbage during the dry season.

Although this essay refers mainly to north-eastern Australia, the pertinent work from the Northern Territory of northern Australia is discussed because it is relevant to the northern woodlands of Queensland described by Isbell (1969). Work from other parts of the world is also reviewed in relation to Australian experience.

West (1965) has listed the main reasons for using fire regularly as a management practice in a pastoral system. They are:

1. To remove top hamper in order to increase the availability of new season's growth, and to remove patchiness in unevenly grazed pastures.
2. To stimulate growth at a time when it might otherwise not occur.
3. To control regrowth of trees and shrubs and to clean up fallen timber.
4. To attract animals to areas that might otherwise be left ungrazed.
5. To remove the hazard of wild fires and to establish fire breaks.
6. To control diseases, and pests such as ticks.

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Not all of these reasons can be invoked for burning in any one area but in almost all pastoral areas where burning is regularly practised the level of use of the seasonal production of dry matter is low and much herbage is left to stand over into the next season. For example, in the central coastal area of Queensland Shaw and Bisset (1955) have shown 2-3000 lb per acre dry matter of less than 3% protein content remains on annually burnt grazed pasture at the end of the dry season. Normal grazing accounts for 1/3 to 1/5 of the total seasonal production of herbage only. Miles (1949), also in this area, reports 4500 lb per acre dry matter produced on unburnt pastures with a protein content of about 2% while Norman and Wetselaar (1960) at Katherine, Northern Territory report 1200 lb per acre dry matter of about 2.5% protein from annually burnt pastures. Davis (1959) and Shaw and Norman (1960) have commented that in northern Australia (i.e. Northern Territory and north Queensland), where the dry season is long and severe, burning is usually carried out early in the dry season in an attempt to stimulate a "green pick" of growth resulting from the use of residual soil moisture by the then normally dormant perennial grasses. However, in the southern parts of eastern Queensland burning is primarily for the purpose of removing top hamper and is commonly delayed until after the danger of frost has passed and some rain has fallen. The use of fire in the manner just described has, over the years, resulted in a great increase in the dominance of black or bunch spear grass (*Heteropogon contortus*), especially in the latter area. Shaw and Bissett (1955) and Shaw (1957) consider this dominance to be a severe limiting factor to animal productivity. However, since that time Shaw (1961) has shown that by correcting soil nutrient deficiencies and introducing pasture legumes the need to burn has considerably declined because more of the herbage is eaten.

THE BASIC REASONS FOR BURNING

Burning to remove top hamper

The removal of top hamper in rank, low quality pastures and the elimination of rank growth patches by burning in order to increase the accessibility of new growth is perhaps the most widespread reason for burning. While it is generally stated by graziers that their cattle do better on country which has been burned, no experimental evidence is available to show this is correct.

The least injurious time for burning has been found in South Africa to be at the end of the dry season (West 1965; Cook 1967; Steinke and Nel 1967; and Roux 1969). Botha (1945) considers burning unnecessary, that spring and early summer growth is better on unburnt areas, and that changing from sheep to cattle would largely obviate the need to burn. The change from sheep to cattle in the 1870's in Queensland (Shaw 1957) did not reduce the need to burn, however. In northern Australia, Smith (1960) found the smallest reduction in subsequent herbage production was by burning at the end of the dry season.

Almost all the studies reported that burning reduces the total amount of growth over the ensuing season when compared with unburnt or mown treatments even though growth may be increased in the early part. This is understandable since fire kills off many of the weaker plants in the population (Shaw 1957). This seems of little importance however, as the grazing lands which use fire as a regular treatment, at least in Queensland, are generally undergrazed. Furthermore, Shaw (1957) points to the impracticability of mowing much native pasture as an alternative to burning.

Burning to reduce both top hamper and competing species can assist in the oversowing of introduced species. Stocker and Sturtz (1966) working with native pastures of tropical tallgrass woodlands in the Northern Territory, found that burning shortly after the beginning of the wet season, when the annual, *Sorghum intrans*, has germinated, led to better establishment of Townsville stylo (*Stylosanthes humilis*). This reduced competition from the annuals and allowed later sowing of Townsville stylo when the rainfall was more reliable.

Burning to stimulate out-of-season growth

This may be carried out at either the beginning or the end of the growing season. The response to burning at either time is largely the result of an interaction of temperature with reserve soil moisture. In northern Australia grassland or woodland is commonly burnt at the end of the wet season to prolong the growing season (Davis 1959; Smith 1960; Perry 1966; Shaw and Norman 1970) and no long term ill effects on the vegetation have been observed, perhaps because it is often difficult to burn large areas effectively until well into the dry season (Arndt and Norman 1959).

In Africa it is generally considered deleterious to burn at the end of the growing season (West 1965), but none of these accounts is supported by critically measured data, other than the fact that burning reduced the total seasonal herbage production. This is of little consequence however, as so much herbage is regularly wasted.

There are conflicting reports as to whether burning at the start of the wet season induces spring regrowth earlier than usual. The reviews of West (1965) and Daubenmire (1968) conclude that soil temperatures are often considerably higher on burnt areas than on comparable unburnt areas, and it has often been found that shooting and flowering are earlier. Hulbert (1969) has recently shown that burning a Kansas prairie in spring increased soil temperatures 1-5°C, increased tiller numbers 1.5 to 2.7 times, promoted earlier growth and doubled herbage yields. Jaeger and Jaques Georges (1967) in Sierra Leone found that herbaceous regrowth was stimulated by burning or cutting near the end of the dry season and this was associated with increased soil temperatures. Tothill (1969) also found soil temperatures to be considerably higher following either burning or cutting, and removal of herbage. Germination of buried seeds of *Heteropogon contortus* was greater and earlier on these plots. By using artificial covers it was found that this effect was associated with ground shading and an increase in soil temperature resulting from cutting or burning.

Herbage growth was greater on defoliated than on shaded areas (Table 1).

TABLE 1

The effects of various burn, cutting and cover treatments on spring herbage regrowth and the surface soil temperatures of spear grass native pasture

Treatment*	Mean D.M.+ of spring growth g/m²	Soil Temperature °C** (from Tothill 1969)	
		Mean Max.	Mean Min.
1. Control	44.3	21.3	17.3
2. Burn—Cover A	37.4	20.0	16 3
3. Burn—Cover B	21.5	20.8	16.5
4. Cut—Cover A	46.5	19.9	16.5
5. Cut—Cover B	28.9	20.5	16 8
6. Cut and leave	53.2	21.8	17.8
7. Burn—open	65.4	28.1	17.1
8. Cut—open	86.1	28.5	18 0
Least significant difference $P \leqslant 0.001$	27.2		
$P \leqslant 0.01$	20.3		
$P \leqslant 0.05$	14.9		

* The experimental design has been detailed by Tothill (1969). It involved 1) a control treatment; 2-5) two covered treatments involving burning or cutting (in one the cover used was aluminium foil (A) to interrupt all direct radiation and in the other black plastic (B) allowing transmission of short wave radiation); 6) cutting with the cut material left on the plot; 7-8) two uncovered treatments, one burnt the other cut and herbage removed.

+ The treatments were applied following good spring rain on August 7 but cold drying winds which followed necessitated the application of about 2 in. of water on September 6 with harvesting one month later. At that time all the plots were cut with a scythette at about 1 in. above ground level and the new growth separated from the previous season's herbage, dried and weighed.

** Soil temperatures were recorded from the 0.5-1.0 in. level.

While the effects of light and temperature cannot be clearly separated, and increased light might account for the relatively high production on treatment 6 (cut and leave), the plots with the greatest amount of regrowth were those with the highest soil temperatures.

In contrast, one study near Gayndah in south-east Queensland (Anon. 1959) reported that plots burnt in spring after rain produced only one-third as much green material as unburnt plots one month after burning. Steinke and Nel (1967) in the Sourveld of South Africa reported no stimulation of growth by burning in spring either before or immediately after the first spring rains.

Mowing stimulates growth better than burning (Table 1) (Smith 1960; Jaeger and Jaques Georges 1967; Steinke and Nel 1967). These observations agree with Shaw's (1957) finding that mown plots carried a much denser plant population than burnt plots, which presumes more growing points for initiating growth.

The disputed nature of the spring burning response perhaps rests on the interaction between available soil moisture and soil temperature. In this respect Tothill (1966) has shown in a study of flowering patterns in *Heteropogon contortus* that growth in northern Queensland is unlikely to be limited by temperature but that the start to the growing season is probably determined by soil moisture (i.e. rainfall). In southern Queensland, in years of some winter rainfall, the commencement of spring growth is probably determined by temperature, but following dry winters, like northern Queensland, it is largely determined by soil moisture.

Thus, in southern areas, where the start of the growing season is more likely to be determined by temperature than by soil moisture, it is reasonable to suggest that the removal of ground cover by burning or other means does result in higher soil temperatures; it can stimulate early growth when soil moisture is sufficient. That there are conflicting results and opinions is perhaps due to the differences in soil moisture status of the various areas in relation to the temperature threshold for growth.

The time of burning has also been found to have a marked effect on botanical composition. West (1965) has reviewed the African work which generally showed that burning any time the vegetation was dormant encouraged *Themeda trianda* while burning during the summer growing season reduced it. Davidson (in Roux 1969) found essentially the same response on the Eastern Highveld; that fire controlled the ingress of *Setaria* which became troublesome after areas had been protected from fire for some time. At Frankenweld *Trachypogon* was favoured by winter burning and the recession to *Hyparrhenia* slowed down by regular burning. Daubenmire (1968) in reviewing the North American literature, points out that grasses are little affected by burning if they are in a dormant state, but because of the wide range of environments considered, a great many different responses have been recorded, especially where temperate and tropical grasses are growing together. Anderson, Smith and Owenby (1970) in Kansas have shown that cool season species are reduced by spring burning and the desirable warm season species favoured. In northern Australia Norman (1969) found that the frequency of burning and the rainfall of the years preceding the burn markedly affect the botanical composition. Thus the contributions of *Themeda australis* and *Chrysopogon fallax* to total dry matter yield was negatively related to total rainfall in the two preceding seasons and that of *Sorghum plumosum* positively related. Complete protection from burning resulted in an increase of perennial grasses, particularly *Sehima nervosum*, and annual burning in dry times to an increase in annuals. Furthermore, Norman (1963) found at Katherine that biennial burning was more beneficial than annual burning.

Burning to control woody plant regrowth or fallen timber

Very large areas of the world's grasslands are considered to be a fire sub-climax vegetation, having been derived from shrublands, scrub, forest, woodland or savannah through a history of burning or shifting agriculture including burning. Many such areas are at ecological equilibrium only in the presence of periodic burning. Without this there is a general reversion to brush, scrub or forest. However this reversion is often strongly influenced by the grazing of domestic or wild animals.

Thus, fire is commonly used to control timber or brush growth, and in most cases the accumulated mature herbage is used as the main carrier of the fire. Coaldrake (1961) has discussed the use of fire in maintaining a grassy understory to the grassy forests and woodlands of the coastal lowlands of Queensland. Without fire shrub encroachment becomes progressively greater and the consequences of wild-fire more disastrous.

To some extent the time of burning is dictated by the phenology of the species it is desired to control. Krupko and Davidson (1961), in a study of the invasion of the bush *Stoebe vulgaris* on sandy soils of the Highveld of South Africa, where burning and heavy grazing have been discouraged over the past 25 years, have shown that seedlings can be eliminated by spring burning of the grassland. Mature plants can be controlled only by repeated spring burning combined with heavy grazing, which achieves a kill only indirectly due to the effects of burning. The time lapse since the last burn and the amount of material not grazed and allowed to accumulate are two important factors determining the intensity of the burn. West (1965) points out that where the reason for burning is to suppress bush and prevent encroachment, the controlling effect usually increases with the frequency of burning for a time. However Riney (1964) has found in Rhodesia that, because of insufficient fuel, frequent fires are usually not hot enough to control bush, and furthermore they may eliminate or weaken perennial grasses which results in invasion of annual grasses and scrub. De Vos (1969) commented that infrequent and hot fires are often necessary to maintain grassland against invasion of shrubs.

In Australia one of the reasons for burning is that it helps to control regrowth of eucalypts, other shrubby species, and to consume fallen timber resulting from ringbarking or poisoning. However only a small amount of fallen timber is removed by grassland burning as witnessed in the many areas where annual burning for 50 years or more has not effectively removed all fallen timber.

Jacobs (1951) has pointed to the exceptional ability of eucalyptus to regenerate from lignotubers and epicormic buds and that forestry experience in the summer rainfall areas of Australia has shown that fire and grazing cattle are important factors in controlling seedling and lignotuber regrowth. There are many areas where both fire and grazing have failed to contain such regrowth but there are also large areas where regrowth has been negligible for many years.

Walker (unpublished) considers the open forests and woodlands receiving more than 25 in. precipitation per year to have a relatively small regrowth problem. He also points out that the potential for regrowth in the southern Queensland part is from lignotubers largely and the northern Queensland part from seedlings. Since these areas are usually burnt annually (Shaw 1957) it is difficult to separate the two effects of burning and grazing. Tothill (1971) has shown for one area in sub-coastal south-east Queensland that where open forest/woodland has been cleared for more than 50 years, grazing has a far greater effect in controlling *Eucalyptus* and *Acacia* regrowth than burning. Close inspection of this area reveals a considerable population of lignotubers which are kept grazed to the level of the surrounding herbage.

It appears that fire on its own is of limited effectiveness in controlling woody regrowth or shrub encroachment in north-eastern Australia. Since the vegetation has evolved in the presence of fire many of the species are fire resistant or require fire for their regeneration, and then the regeneration may provide a greater problem than the original stand of vegetation. Often the quoted usefulness of fire for vegetation management is largely or wholly due to some other factor such as grazing.

Burning to attract animals to isolated areas

With the closer subdivision that has come to much of the pastoral lands, burning to attract animals is not now widely used. There are disadvantages in such a practice as when the area burnt is insufficiently large to maintain the extra animals attracted to it, severe overgrazing may ensue. In Australia watering points are generally a greater limiting factor to the animals' foraging area than the state of the feed. Strategic development of watering points has to a large extent solved the problem for which this practice might be used.

Burning to control wild fires and provide fire breaks

Where there are large areas which seasonally exhibit a cycle of vigorous herbage growth followed by maturing and haying-off, burning will always be practised to form fire breaks or buffer zones against adjacent terrain which cannot or may not be adequately controlled.

Burning to control diseases and ticks

While it has been claimed in the past that burning might have provided some measure of control of pests and diseases in contaminated pastures it is unlikely that this could be practiced regularly with any success because the times of maximum infestation are usually times of lowest burning success.

Burning and its effect on soil fertility

The ash residue resulting from burning native pasture has been found to be 12.6% by Miles (1949) in central coastal Queensland. Assuming no losses of nitrogen or phosphorus during the burn, about 1.5-3 lb and 1-2 lb/ac respectively would be returned to the soil via the ash. However, Norman and Wetselaar (1960) have shown about 90% of the nitrogen to be lost to the atmosphere in the burn. No value is given for phosphorus. At Katherine, only about a quarter of a pound of nitrogen is therefore returned per acre. These values are so low as to be inconsequential for plant growth, except perhaps in the earliest stages of seedling establishment.

West (1965) states that American workers generally hold there is some stimulation of growth due to the mineral nutrients from the ash. In this respect Kucera and Ehrenreich (1962) have shown slightly higher values of calcium, magnesium, potassium and silica in the ash of plants from burnt areas than those from unburnt ones. Moore (1960) in Nigeria found higher values of total soil nitrogen, nitrate nitrogen and available phosphorus on burnt areas than on unburnt areas, but he suggested this difference could have arisen from the different botanical compositions resulting from the treatments.

THE FUTURE USE OF FIRE

To the pastoralist fire has been and is a useful and important tool. Just as the other operations of a pastoral enterprise are planned, so too should burning be a planned aspect of management, the basis for which can only be determined by individual circumstances. By far the greatest problem of the native pasture areas is the wide seasonal fluctuation in the quality and quantity of the forage. The first big step in achieving greater animal production is to iron out as far as possible or practicable these fluctuations. This will automatically have the effect of reducing the need to burn regularly (Shaw 1961). On a limited scale fire will be important in preparing for pasture improvement, elimination of patchiness, even promotong "out of season" growth in particular areas and seasons, and in wild fire prevention. It may also be important in maintaining a desirable balance of species within a pasture.

Where drought is a recurring threat to animal production the needless or automatic burning of all mature herbage each year is no longer wise since even low quality herbage can be used to maintain cattle if supplemented with urea-molasses licks (Alexander, Daly and Burns 1970). While the regular use of such licks for the annually recurring period of low quality feed is questioned as being profitable in the long run compared with pasture improvement (Loosli and McDonald 1968), this practice is being increasingly used by pastoralists as a means of intensifying grazing management in northern Queensland (Gillard, personal communication). Thus the benefits of feeding urea-molasses could well come, not so much from their direct effects on the animals, but from the greater flexibility of management possible. The impact of this on native pastures which are/being upgraded through the introduction of legumes such as Townsville stylo, where a fairly critical level of grazing management is required, could be considerable. Burning can only be avoided if some form of pasture improvement leading to greater use due to improved herbage quality, or feed supplementation is practised.

A system of strategic burning coupled with planned conservation of standing dry roughage is likely to be the best course of action for those lands not being developed to any significant extent. For such a system to be effective fire must be controlled on a regional basis by organized grazier co-operation. As indicated by West (1965) this has been achieved effectively in other parts of the world.

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