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A basis for planning fire to achieve conservation and protection objectives adjacent to the urban interface

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ABSTRACT

The use of planned fire to achieve both protection and conservation objectives in bushland adjacent to developments is a major challenge to land managers. Here we develop and present some simple conceptual models that may help to resolve this problem. By presenting these models we anticipate that they may be further developed in a quantitative manner.

INTRODUCTION

The selection of fire regimes to meet multiple land management objectives remains one of the principal problems facing fire managers and scientists. The problem is perhaps most acute in those lands dedicated for conservation which abut urban, industrial or rural development. Humans are a source of unplanned (UPF) and planned (PF) fires, the latter being employed mainly to alleviate the threat posed to humans by the former. The interaction of these two types of fire will substantially influence both protection and conservation.

Debate is generated by the use of PF to manipulate fuel quantities in order to provide human protection (e.g. McMahon *et al.* 1984). Concurrently there is concern that disturbance regimes in areas managed for conservation have been substantially altered in the recent past (Hobbs and Hopkins 1990) and that some form of PF may be needed for conservation in specific systems (e.g. Saxon 1984). The objective of conservation is to maintain biotic diversity and the processes that are associated with biota (Western 1991). In practice, within discrete areas such as reserves, this translates into maintaining populations of species (i.e. avoiding extinctions).

There are outstanding examples where the use of PF is directly targeted at conservation objectives (Christensen and Maisey 1987). Often strategies for the use of PF are carefully derived to achieve both conservation and protection objectives (Sneeuwjagt 1989). Sometimes, however, conservation is used as an *ad hoc* justification for PF operations directed at protection (Good 1985). Is the sort of PF needed for protection the same sort needed for conservation objectives? How much fire, if any, do we need to inject into an area to conserve biodiversity?

Despite improvements in knowledge of fuels and aids to management in the last 10-15 years, community debate about the management of fire and particularly the use of PF continues. Should there be more PF or less? How much is needed within a landscape to protect an adjacent urban interface? Is a form of PF required for conservation purposes and if so can a single PF operation or program be planned that fulfils both protection and conservation objectives? The answers will depend on the physical location and extent of PF operations in any particular landscape.

Strategies for use of PF in particular areas are often intuitive (Sneeuwjagt 1989), despite the element of sophistication afforded by modern databases, geographic information systems, fire behaviour models and methods for integrating these tools. Formal relationships between the use of planned fires, protection and conservation in landscapes have not been explicitly developed in a quantitative manner. Such an approach may quantify the relationships and assumptions that often lie behind the use of PF in landscapes and assist with the comparison of options.

Here, several conceptual models are presented which summarize ideas that could lead to a quantitative basis for evaluating the contribution of PF to protection and conservation.

We use the Sydney area as a background to illustrate our ideas. There the interface of urban development with bushland is extensive (a scale of $>10^3$ km in length) with much of the bushland composed of fire-prone shrub/woodlands on sandstone soils (Benson and Howell 1990).

THE ROLE OF PLANNED FIRES IN PROTECTION

How effective is PF for hazard reduction in limiting wildfire spread, particularly to an interface? There are few case studies that objectively deal with this question (e.g. Underwood *et al.* 1985; Buckley 1992; McCaw *et al.* 1992). Here we discuss the concept of protection (probably the inverse of hazard) at the interface as a function of the amount (area) of fire prescribed for hazard reduction in adjacent bushland.

For a landscape such as a reserve that has an extensive urban interface, the degree of protection afforded to the interface will be some function of the area subjected to PF for hazard reduction; Figure 1a illustrates the simplest abstract case. We assume that if nearly the whole area is subjected to PF, protection would be close to maximum, whereas if little of the area is treated, protection would be minimal. Between these extremes the size and location of individual PF operations in relation to factors such as fuel type, physiographic features and proximity to the interface will determine the nature of the relationship between protection and total extent of PF. Here we postulate two functions (Fig. 1b) which reflect different and more realistic configurations of PF. If PF is concentrated on aspects with highest fire potential (e.g. steep slopes and high fuel loads), both at the urban interface and in strategic buffers more remote from the interface, it is arguable that the 'efficiency' of protection will be greater (curve I, Fig. 1b); i.e. protection is greater per unit area of land treated. There is resultant low hazard immediately adjacent to the interface.

The lowest efficiency may correspond to scattered distribution of PF operations on inappropriate aspects, low fuel loads and places very remote from the interface, leaving dangerous conditions immediately adjacent to the interface. The last point is important as it presumes that there is some risk of UPF passing through PF areas and reaching the interface. In the case of this second scenario (curve II Fig. 1b), the outcome is that a large area of PF is needed to achieve a high level of protection.

These scenarios can be illustrated informally using an example (Fig. 2) of a severe wildfire in the Brisbane Water National Park, near Gosford (about 80 km north of Sydney) on 23 December 1990. This fire took place under extreme weather (Sydney FFDI = 83, maximum temperature = 40 °C, maximum windspeed = 46 km h^{-1}, relative humidity = 14 per cent) and resulted in the destruction of several houses in the town of Pearl Beach. The path of the fire included a number of areas that had burnt less than 5 years prior to the wildfire (Fig. 2), including the entire valley behind the town (burnt 13 months before). The wildfire spread downhill in this valley. Prior, recent fires probably reduced the level of damage sustained in the town compared to that likely under higher fuel levels.

The outcome of alternatives in this example can be imagined. Given the weather, would more or less protection to the town have been provided by;

(i) a zone of intensively managed fuels, extending several hundred metres around the perimeter of the town;

(ii) a more diffuse distribution of recently burnt patches (but equivalent in area to those in Fig. 2) before the wildfire;

(iii) more extensive (greater area) fuel management by PF remote from the town?

These alternatives would be likely to produce different functions when presented in the form of Figure 1 and thus could be formally compared.

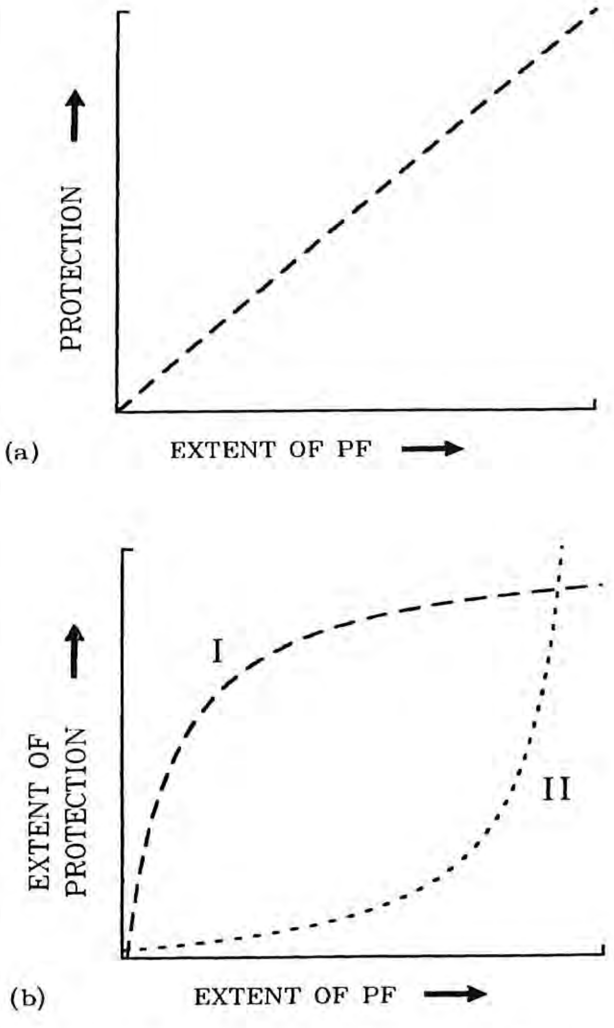


Figure 1. (a) Protection at the interface is presumed to be postively related to the extent of planned fire (PF) in an adjacent landscape. (b) Two forms of this relationship (curves I and II) indicate the sensitivity of the relationship to the location and configuration of areas of PF in the landscape.

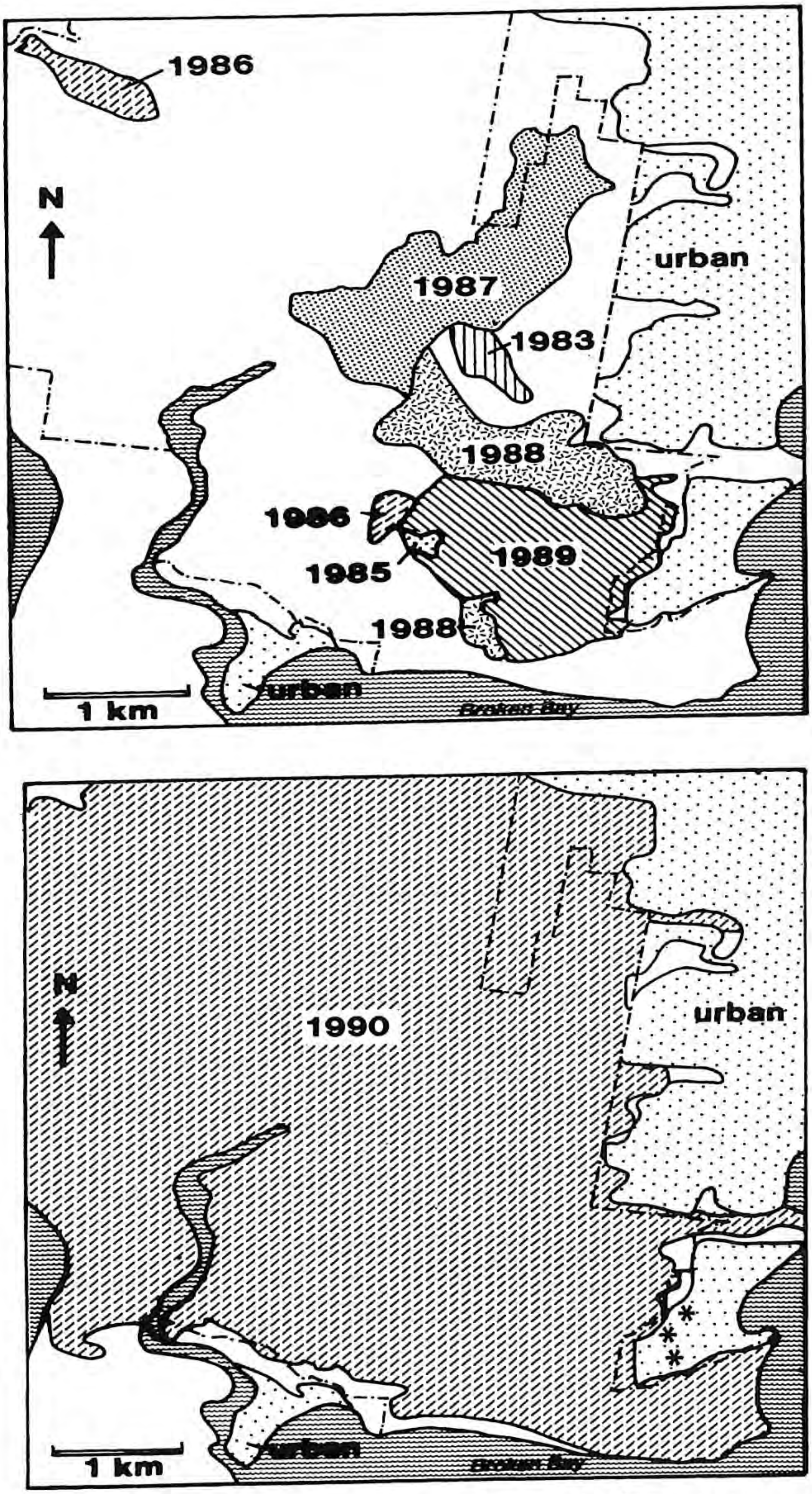


Figure 2. Maps showing pre-fire condition and extent of a major wildfire (December 1990) in the Brisbane Water National Park north of Sydney which resulted in property destruction (denoted by ✱ *) in the town of Pearl Beach. The direction of headfire spread was from north-north-west.*

THE ROLE OF PLANNED FIRE IN CONSERVATION

Specific guidelines and objectives for fire management for conservation are often lacking for particular areas (Good 1981; Press 1989). Management by default concentrates on individual species, usually because they are rare or have been studied. However, this can be detrimental to co-habiting non-target species (e.g. Keith, this volume).

How do we frame guidelines for the management of groups of species? For the plants of fire-prone woodlands and shrublands of the Sydney region, empirical evidence (Cary 1992; Morrison *et al.* 1995) suggests that there is a relationship between fire regime variability and the number of species in a site (Fig. 3). Variability of fire frequency is of particular importance in determining floristic diversity in this flora (Cary 1992; Keith and Bradstock 1994; Morrison *et al.* 1995).

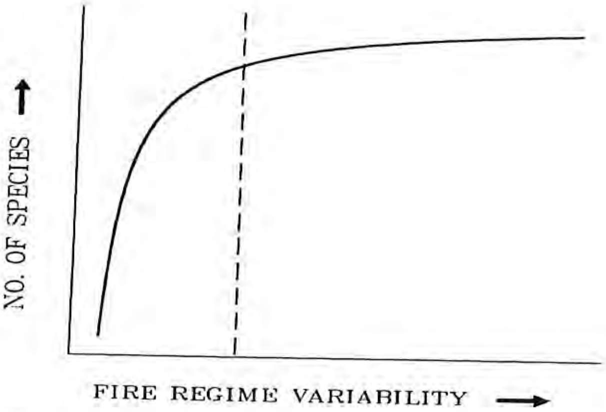


Figure 3. Number of plant species at a site level is postulated to be a function of fire regime variability in fire-prone shrub/woodlands of Sydney. Fire regime variability exceeding a threshold (dashed line), will maintain species numbers at or near their maximum.

Given the importance of fire frequency we would define a non-variable or uniform regime as consisting of successive fires spaced identically in time. In the shrubland and woodland communities around Sydney the evidence suggests that such a uniform fire frequency (low variance in frequency) may result in the eventual elimination of species irrespective of whether the regime is composed of short (<10 years), moderate (10-30 years) or long (>30 years) intervals between fire. Note that each fire frequency scenario affects species in different categories according to life history, though the net result in each case is similar: i.e. a reduction in number of species. It follows that to maintain all species, a mixture of fire intervals of different length (high fire frequency variance) is required, including the occasional incidence of a very short fire interval. The mechanisms behind this are more fully explained by Keith (this volume) and Keith and Bradstock (1994). It is important to note that these conclusions apply at a fine level of scale (e.g. in stands and sites).

From Figure 3 it is possible to define a threshold for fire regime variability which demarcates different levels of species presence at sites. Fire-management to maintain high numbers of species at a site would therefore be aimed at keeping fire regime variability above this threshold. Note that we postulate that a wide range of fire regime variability (or permutations of intervals between fire) is compatible with maximum or near maximum species presence. Definitions of these fire regime thresholds for some Sydney sandstone communities are provided in Bradstock *et al.* (1995).

IMPORTANCE OF FIRE FREQUENCY

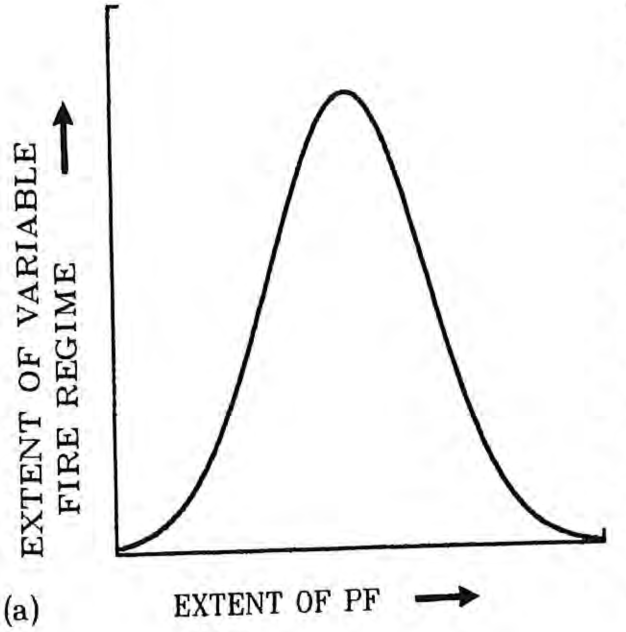
Given that it is possible to define the level of fire regime variability needed to maintain plant species at a fine scale, what role do planned fires play in contributing to this variability across a landscape? It is likely that fire regime variability at this level of scale will be some function of the area covered by planned fires in that landscape.

A model is presented in Figure 4 which relates the spatial extent of fire regime variability (e.g. the proportion of sites in which species are maintained close to the maximum) to extent of planned fires. The landscape is assumed to be composed of a matrix of many sites. This assumes that a regime of UPF prevails in the landscape, the nature of the model being highly dependent on the characteristics of UPF and most importantly the interaction or overlap between PF and UPF at particular sites.

We predict (Fig. 4a) that when PF extent is low then UPF is predominant in the landscape. A proportion of sites will therefore be subjected to relatively uniform fire regimes and species presence in those sites will be reduced. As the extent of PF increases, an increased proportion of sites (greater area) will be subject to fire regimes with sufficient variability to maintain species numbers close to the maximum. This comes about in several ways through the interaction of UPF and PF. Unplanned fires in extreme conditions will burn through areas subject to PF (e.g. Fig. 2). Such areas are therefore subject to a high chance of a short interval between fires.

Conversely in some situations the presence of a PF will limit the extent of an UPF by moderating its spread rate and extent. Thus UPF will not reach some sites, changing the fire frequency in those sites to a more variable state than would have prevailed without PF. The model postulates that there is a level of PF extent that optimizes this overlap effect and thus optimizes fire regime variability across a maximum number of sites in the landscape. The model will be sensitive to the locality of PF in a landscape as well as extent of PF (Fig. 4b). For example, there are often defined wildfire paths in particular parcels of land according to patterns of ignition and weather (Minnich 1989). The placement of PF in relation to these paths will determine overlap effects.

We postulate that as PF extent increases beyond the optimum level either uniform PF regimes may become predominant, or the overlap between PF and UPF may become too extensive and repetitous through time, resulting in fire regime uniformity over an increasing proportion of sites.



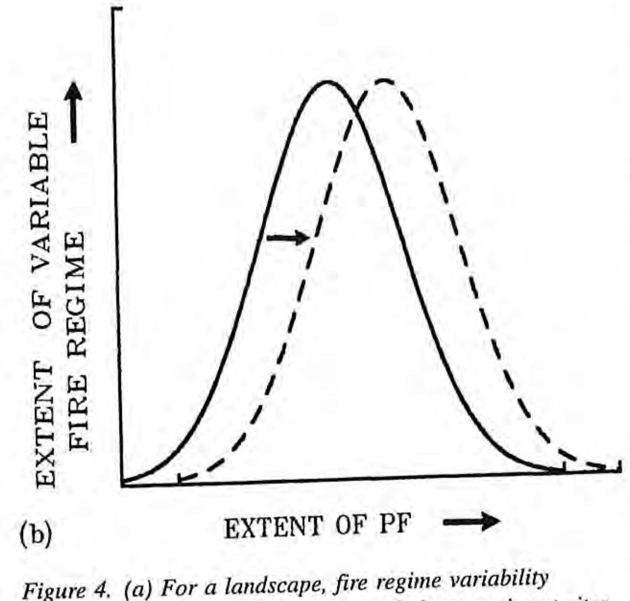


Figure 4. (a) For a landscape, fire regime variability sufficient to maintain high numbers of plant species at sites, will be some function of the extent of PF. (b) The relationship presumes that a particular regime of unplanned fire (UPF) prevails in the landscape. The effect of a shift in UPF (broken line) on that relationship is shown.

A MODEL TO EVALUATE THE DUAL ROLES OF PLANNED FIRE

We have suggested how the contribution of PF to protection and conservation objectives can be formally evaluated on a common basis (areal extent of PF). If we are to know whether the sort of PF needed for protection is the same as that needed for conservation, we need to merge the separate strands developed above. Such a model is given in Figure 5 illustrating different scenarios. We present these as alternatives which may represent the situation in a landscape at some point in time. The most important feature of these models is the relativity of the pairs of curves with respect to the horizontal axis.

The first example (Fig. 5a) illustrates a situation where an optimal solution for both objectives is difficult to achieve. If protection is pursued as a priority then conservation will be sub-optimal (PF extent will exceed the conservation optimum). In the second example (Fig. 5b) the PF optimum for both objectives coincides. Note here that there is a fairly wide range of PF values that produce near optimum solutions for both objectives. In the third example (Fig. 5c) both objectives coincide but protection is achieved more efficiently. We may be tempted to earmark this as the ideal management scenario for an area. A variant is given by the fourth example (Fig. 5d), notable because protection is maximized at a lower level of PF extent than conservation (the inverse of the first scenario) with the implication that further PF can be targeted solely to achieve conservation.

We could define a sub-optimal level of fire regime variability in the landscape as being an acceptable conservation objective provided that it is sufficient to conserve species within that landscape. Irrespective of the level of fire regime variability that is acceptable in terms of conservation, this approach allows us to think about how much PF will contribute to that variability.

Undoubtedly, further examples could be generated and their sensitivity to factors such as change in UPF paths and location of PF could be explored. At this stage we stress the value of using this approach to look clearly and objectively at the consequences of management actions. Which example applies to a particular parcel of land? How will it vary over time as PF is used? How can the use of PF be adjusted to produce a better outcome for both objectives? The answers to these questions beg quantitative solutions to this model.

Many of the tools for producing a quantitative solution are available. For example, fire spread models in conjunction with data on terrain and fuels can be used to produce scenarios from which a quantitative relationship between area of PF and protection (e.g. Fig. 1) can be developed for a given parcel of land, presuming certain wildfire scenarios. Some aspects of the problem, however, require further work. In particular, we need to know more about:

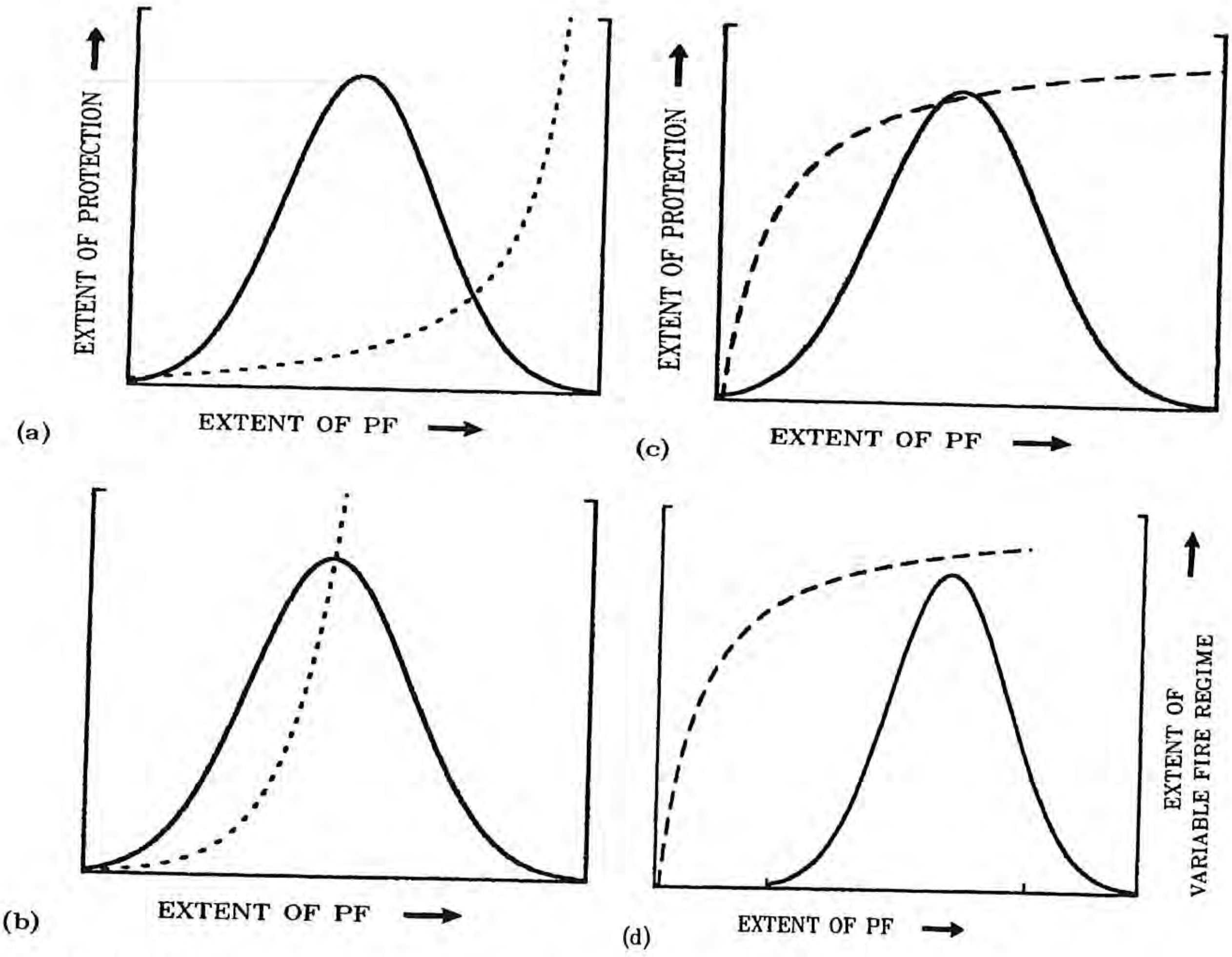


Figure 5. A model with examples (a,b,c,d) depicting different relationships between PF extent and conservation (solid line) and protection (dashed line).

(1) the definition of fire regime thresholds for local or 'site' scale extinction of functional groups of species that correspond with identifiable vegetation communities;

(2) the interaction between PF and UPF as a determinant of UPF spread.

The latter element is important and, as noted, is an understudied part of fire science. The issue of overlapping fires, particularly at short intervals, is pivotal.

Underpinning the use of PF in many conservation and protection programs is the assumption that PF interacts with UPF to truncate UPF spread, intensity and extent. While the injection of planned fires will undoubtedly alter the nature and extent of unplanned fires, the actual limits of such an effect are largely unknown for many systems.

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