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〈 **Review** 〉

Fire and Rangeland's Management in India

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ABSTRACT: Fire, usually a detrimental factor makes changes in commonly structure and functions when it is practiced properly. In countries like Australia, South Africa, Japan and Texas in USA etc., fire is used as a tool to manage the natural ecosystems in productive condition on the basis of ecological approach. However, in developing countries like India there is effective measure to use and control fire in rangelands. This review provides knowledge on changes in sociological characters of plants, biomass profile, cycling of materials and strategy to use fire for the shaping of communities in different rangelands located in India and other countries. Further, the informations furnished in this article will be more useful for the forest managers, planners of rangelands and administrators in countries like India and tropical countries with similar bioclimatic conditions to prepare appropriate management plans where the fire is an integral factor.

Key words: Biomass, Fire management, Forest fire, Nutrient cycling, Phytosociology

INTRODUCTION

Fire, always a powerful factor, destroys / designs community structure in majority of rangelands. The effects of fire on communities depend on season of burn, frequency and intensity of fire, velocity of wind, moisture content of air, type of plant species in the community, whether annuals or perennials and the macro-climatic zone where the fire has happened. Besides, the changes in community composition made by individual species, all functional attributes like flow of energy, availability and rate of transfer of nutrients between the tropic levels, the sequence of food chain, complexity of food web, biodiversity status, rate and direction of community succession and finally the degree of homeostasis are vigorously influenced by fire in ecosystems (Daubenmire 1968). Management of communities in fire pruned rangelands is habitat specific and depends on many external and internal factors (Show and Clarke 1994). Many workers have been interested on fire concerning grazing land, nitrogen fixers, minerals, nutrient uptake, etc. This review deals with the aspects like fire regime, fire effects on phytosociology, biomass structure and nutrient cycling in the rangelands, role of fire as a management tool in shaping vegetations and ecology of fire influenced rangelands in and over India.

FIRE REGIME

Fire in a rangeland may be either wild or prescribed. Wild fire is often not desired due to difficulties in post-burn management. On the other hand, prescribed burning has a role to play for many rangeland managers. A number of steps viz., preburn planning, the burning operation and postburn management are required to conduct any prescribed burning (Bailey 1988). When developing a burning programme for a game ranch, the most important factors to consider are the reasons for burning and the appropriate fire regime to be applied (Trollope 1990). The fire regime refers to the type and intensity of fire, and the season and frequency of burning. The dry fuel load accumulated during summer in the grassland patches of forests is one of the origin places of fire and from there it can enter easily into the forests of deciduous and semi-evergreen types (Paulsamy 1992). Joshi (2003) also pointed out that forest fires of short-to medium-return intervals are quite common during summer seasons in Garhwal Himalaya.

Effect of fire on grasses is largely determined by season of burn, size of plant, amount of dead material, growth form, species, precipitation and whether it is an annual or perennial (Wright 1985). Fire season is likely to be the dominant feature of any prescribed fire regime and is directly amenable to management. Griffin and Friedel (1984, 1985) found that winter fire was effective in reducing fuel and was easily controlled. It maintained or improved the composition of pasture plants palatable to cattle. A summer fire significantly decreased the grass component while increasing the proportion of forbs, particularly unpalatable species. Rainfall, season of burning and reduction of cover appeared to be important factors in controlling the composition of post-fire herbage. There was no im-

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portant effect of fire on nutrients in either season of burning. Pressland *et al.* (1986) favoured burning of native vegetation following good rainfall seasons for effectively decreasing the density of some useless woody weeds growing in the mulga (*Acacia aneura*) rangelands of Queensland. This judicious timing of fire also resulted in minimal damage to pasture species as well as post-fire loss of carrying capacity. Long term community responses to altered fire regimes should be predictable from a basic understanding of individual species response to fire (Hodgkinson 1986).

PHYTOSOCIOLOGY

Most rangeland communities are resistant to fire but are not necessarily stable. Significant changes in structure and composition may occur. Mall and Mehta (1978) noted higher density value in the burned plot when compared to control plot. Further, burning resulted in enhanced tillering and increased percentage germination of the seeds. The response of plants to fire is species specific. Interestingly it has been noted that the dicot weeds in general and the Asteraceae member, *Anaphalis subdecurrense* in particular significantly enhanced its quantitative ecological characters in the post fire communities of subtropical grasslands of Anaimalais (Paulsamy *et al.* 1995, 1996, 1997a, b, c). Similarly, in the same grasslands, the fern, *Pteris aquilina* responded parallely with the dominant grass, *Chrysopogon zeylanicus* to annual summer fire by improving its ecological characters and it is found to have some clues for the preparation of management plans (Paulsmay *et al.* 1995 a, 1995 b). On the other hand, Paulsmay *et al.* (2001) reported that the species like *Impatiens tomentossa, Drosera peltata, Osbeckia parviflora, Emelia sonchifolia, Lecanthus peduncularis* and *Lobelia nicotianifolia* are fire threatened medicinal herbs in the grasslands of Anaimalais and they need immediate attention for conservation.

Fire also affects the seed pool in soil and it varies according to species. Fire can enhance the number and diversity of forbs because they have hard seed coat that can be scarified by fire (Wright 1985). Shaw (1957) and Tothill (1969) cited a number of factors favouring the dominance of black spear grass in Queensland. The sharply pointed seeds become buried in the soil and are protected from fire. Fire reduces the basal cover of competing species and stimulates seed germination whereas the established black speargrass plants are resistant to fire. Hassan and West (1971) reported a significantly lower seed pools in some taxa such as *Bromus tectorum, Agropyron* spp. and *Poa* spp. on the burned plots six weeks after fire.

The sprouting response of the rhizomatous grasses generally increases immediately after fire (Wright 1985, Pandey 1988). In the early stages of post-fire growth and under certain conditions, individual plants of *Triodia wiseana* achieved a larger size than *T. basedowii* due to its sprouting response (Casson and Fox 1987). Paulsamy (1992) observed that the sprouting of perennial grasses in general and the dominant grass of the community, *Chrysopogon zeylanicus* in particular is significant over the unburned grasslands in Anaimalais, India.

Fire is a natural phenomenon in the evolution of plants in the pastoral areas. Qualitative evolution of the grasses was more homogeneous in burned plots than in unburnt savanna of Ivory Coast (Abbadie 1985). Populations of most of the Queensland's native plants are capable of surviving in certain fire regimes and may benefit from burning (Anderson and Pressland 1987). In the semi-arid regions of western United States, burning reduced *Bromus* density, allowing forbs and *Sitanion* to successfully compete for growing season precipitation. Whisenant and Bulsiewicz (1985) observed that spring burning of mixed-grass prairie in the Badlands National Park at Western South Dakota, USA significantly reduced Japanese brome density for the first growing season, but returned to its original density by next year. Paulsamy *et al.* (2003b) reported that the grasses and legumes in the high level grasslands of Anaimalais, Western Ghats, Southern India improved their ecological importance significantly by annual summer fire. However, the 'other forbs' in the post fire communities have lost their importances. Fire is often used in combination with other range improvement techniques in the management of grasslands. In the Juniper communities of Texas, prescribed fire is generally used in combination with other range improvement techniques which reduced the Juniper canopy cover, allowing herbaceous vegetation to increase. Noble *et al.* (1986) reiterated that the changes in community structure are not due to fire alone because the interaction of grazing pressure and rainfall regime before and after fire determine the overall ecological impact. Andrew (1986) found that the pasture degradation was arrested if burning was used with grazing in the monsoon tall grass pasture. The species, *Calluna vulgaris* responded well to grazing and other types of management practices including fire (Gimingham 1989). Due to the discontinuity of such management practices, there was a replacement of *Calluna* by other species in the grasslands of Texas, USA.

BIOMASS

The biomass of grasses, forbs and litter and the relative abundance of different life-forms were highly coupled with the burning cycle. Abrams *et al.* (1986) found that live biomass was greater on burned than unburned low land sites. Biomass of the graminoids was 40 percent lower whereas that of forbs and woody plants was 200~300 per cent greater in the unburned than in the annually burned site of Kansas tall grass prairie. Studies of Andariese and

Covington (1986) for more than two years on the understorey response following both wild fire and prescribed burning in Arizona ponderosa pine showed a general trend towards increased production. Harniss and Murray (1973) also reported a higher production from rhizomatous grasses on burned plots than that of controls for about 30 years. Pandey (1988) observed growth stimulation of both shoot and root components in a *Dichanthium annulatum* dominated grassland after burning. However, the belowground biomass showed a considerable decrease. Research shows that, when correctly practiced, burning can maintain the vegetation in a productive condition with minimal habitat deterioration (Gimingham 1985). Britton *et al.* (1987) stressed the importance of adequate soil moisture at the time of burning to achieve higher production. In south-western New South Wales, Australia, a three year sequence of above-average rainfall immediately following burning in either spring, autumn or winter resulted in a substantial increase in species richness and herbage dry matter production (Noble 1989). In the grasslands of Varanasi, India, the summer burning prior to rains resulted in higher production and thereby the greater recovery rates of biomass compared to winter burning (Pandey 1988). The burned area of Arapaho Prairie, Arthur County, Nebraska initially had more aerial phytomass than the control. However, in later stage, the burned area had statistically lower phytomass production (23% less) than the control (Morrison *et al.* 1986).

Garza and Blackburn (1985) discussed the effect of burning season on the production. In the Post Oak Savanna of Texas, burning in early winter favoured the growth of forbs, whereas spring burning tended to favour the production of grasses. Herbicide treatment and burn-herbicide combination were recognized as suitable management practice for an increased buffel grass (*Cenchrus ciliaris*) standing crop (Mayeux and Hamilton 1983).

NUTRIENT CYCLING

The importance of various nutrients in determining pasture production or quality varies from soil to soil. Deficiencies of nitrogen or phosphate are probably most widespread, though other macronutrients such as magnesium, potassium and sulphur can be limiting in many soils (Snaydon 1987). One way of making good these deficiencies is through prescribed burning. Increase of mineral salts with burning has already been well documented (Daubenmire 1968, Viro 1974, Fox 1980). However, Paulsamy *et al.*(1993) reported that the minerals like phosphorous and potassium did not get change after fire in the grassland soils of Anaimalais, Western Ghats, India. Another effect of burning is that the nutrients are changed to simple, water soluble salts that are immediately available to plants. Leaching out of the easily soluble phosphate before the restoration of equilibrium between different electrolytes in the soil is also possible (Viro 1974).

Hobbs and Schimel (1984) concluded that fire in the sagebrush-grassland and mountain brush communities increased the rate of nitrogen mineralization and presumably the availability of nitrogen to the vegetation. Manian *et al.* (2002) reported that the free N_2 fixer, *Azospirillum* increased its population considerably in post-fire grassland communities. They also noted the increase of nodulation in the legume, *Atylosia trinervia* after fire in the Kundah platau of Nilgiris, southern India which consequently increased the N_2 status in post-fire community. Wells *et al.* (1979) reported that nitrogen fixation, both symbiotic and non-symbiotic was more prevalent following fire, with general increases in P, K, Ca and Mg. The increased root exudates of burned grasslands create a favourable environment for the growth of N_2 fixing and P-solubilizing microorganisms (Senthilkumar *et al.* 1995). Curl and Truelove (1986) pointed out that under the conditions of high temperature during fire with consequent low soil moisture followed by wetting, increased the root exudation which in turn enhanced the population of microbes like N_2 fixers and P-solublizers. Jalaludin (1969) generalized that the decomposers like *Trichoderma* and *Penecillium* are the pioneers in tropic soil after fire. Lynch and Panting (1980) explained that the management practices like burning increased the total carbon accumulation in soil and in turn it increases the size and activities of soil microbial biomass. There was generally no direct loss of soil nutrients except for the volatilization of nitrogen and sulphur (Vogl 1974). With low fire intensities, however, these losses to atmosphere was probably minimal (Griffin and Friedel 1984). The nitrogen losses are often recovered through precipitation and increased actions of nitrogen fixing plants, particularly legumes (Burton 1972), soil algae, bacteria and certain fungi (Stewart 1967). The accumulation and rate of transfer of nutrients between the components of ecosystem is one of the most useful parameters to measure the community development (Odum 1971). Paulsmay *et al.* (1995a) found that the fire influenced grassland communities of Anaimalais, Western Ghats, India recorded significantly rapid uptake /release rate of certain nutrients like nitrogen, phosphorous and potassium.

The nutrient content of grassland plants on burned sites tended to be higher (Daubenmire 1968) or relatively unchanged (Lloyd 1971). Nielsen and Hole (1963) even noted symptoms of nitrogen and phosphorus deficiencies in unburned grassland plants. At pre-forest savanna of Ivory coast, Abbadie (1984) observed the maximum concentration of nitrogen in the aerial living parts of plants just after fires which decreased regularly thereafter upto the following fires. Shoot phosphorus also decreased in the second half of the growing season in the annual burned reed vegetation of Zuidelljk Fleveland polder which was coupled with an increase of rhizome phosphorus (Linden and Van der 1986).

A few workers have questioned the increase of mineral pool in the rangelands after fire. In the Queensland grasslands, the stimulation of grass growth after burning was presumed to be due to higher soil temperatures rather to a release of available nutrients in the ash (Anderson and Pressland 1987). No evidence of any effect of fire on the phosphorus, potassium, calcium, magnesium, sodium and aluminium content of soils has been recorded after 28 years of veld burning at Ukulinga (Cass and Collins 1983). White and Grossman (1972) have reported a decline in calcium, magnesium, potassium and sodium concentrations and in the base saturation of soils in which the grassland was burnt annually for 37 years. According to Christensen (1977) there was no clear cut evidence that increased uptake of nutrients by plants occurred as a result of fire. Some increases of tissue concentration of nutrients were measured but they may simply have been a function of tissue age.

FIRE A MANAGEMENT TOOL

Fire is primarily used on rangeland to manipulate plant populations, maintain habitat for animals, improve forage quality and production and increase fire proof vegetation preventing damaging wild-fires. Vegetation management which, while being of considerable antiquity, is still widely practiced at the present time. Burning of woody material, if properly done, has the added advantage of promoting rapid regeneration and encouraging the development of a new supply of young nutritious green shoots (Gimingham 1985).

The greatest potential use of fire will be in wildlife management since many wild-life preserves, refuges and hunting grounds still support native grasslands. Most of the national parks of Africa, for example, contain various grasslands and or savannas and have management programmes that include fire as an important and often essential tool (Hill 1971, Van Rensburg 1971). Komarek (1971) in summarizing the effects of fire on wildlife habitats in south- eastern United States pointed out that grasslands and early stages of brushland, maintained by controlled burning, provide the diversity of flora necessary for healthy wildlife populations. In Anaimalais of Western Ghats, Southern India, the forage yield of grasslands are increased drastically by fire which in turn is more useful for the benefit of wild animals (Paulsamy *et al.* 2003a). Hence, patch-wise rotational burning is advocated for sustained availability of fodder and habitat for wild animals in that areas. The use of fire for habitat manipulation for both wild and domestic animals is common, for example, deer and cattle in California (Hendricks 1968) and sheep and grouse in Britain (Ward 1972).

Fire has been shown to be an important tool in the management and control of bush encroachment in grazing rangelands (Bastin 1991). Major vegetative and edaphic changes are taking place in range ecosystems where fire has been excluded (Wright and Bailey 1982). Reduction in the occurrence of fire since European settlement is considered to be the major cause of shrub increase (Hodgkinson 1987). The tree and shrub invasion is occurring in the forest steppe area of Eurasia (Walter 1985), the aspen parkland of Canada (Bailey and Wroe 1974), the tall grass prairie of the Central United States (Bragg and Hulbert 1976) when prescribed fire is not regularly imposed. In the management of the grassland biome, fire is deliberately excluded only from those sites in which successional development to scrub or forest is being encouraged (Tainton and Mentis 1984).

The ecological status of Indian grasslands has been a debatable point. Champion (1936) considered that the climax vegetation of India would be either forests or deserts. He also expressed the opinion that nowhere in India is grassland of climax type and they are all existing due to biotic activities like lopping, burning, shifting, cultivation and grazing of the forests for the last several thousands of years. Singh and Krishnamurthy (1981) also concluded that the tropical grasslands of India are seral in nature, owing to their origin to deforestation or abandoned cultivation. They are maintained at various successional levels in different parts of the country mainly due to biotic factors like grazing, harvesting and man induced fire. The occurrence of annual summer fire every year in the Grass Hills of Anaimalais, Western Ghats maintained the ecosystem in a highly productive seral stage (Paulsamy *et al.* 2001). The differences in the habitat complex (including the edaphotope and macro- and micro-climate), age and mode of origin and intensity of biotic operations result in an array of very diverse grassland communities (Singh 1976), though, at places they may attain the status of a disclimax (Misra 1959).

Ranganathan (1938) studied the ecology of the shola grassland vegetation of the Nilgiris plateau and he believed that the Nilgiris grasslands are 'climatic climax' and these grasslands have been in possession of their territory for centuries and are entitled to be called stable association whatever the factors that ensure their stability might be. Bor (1938) opined that once we admitted the existence of grazing and burning in an area, we could not apply the term 'climatic climax' and so these grasslands should be considered as 'biotic climax'. Champion (1939) also felt that these grasslands are not climatic climaxes as they are caused by periodic fires.

Ecopyrological(ecothermotical) investigations of Indian grasslands are limited (Trivedi *et al.* 1981, Pandey 1988, Vinod Shankar and Trivedi 1988, Paulsamy 1992, Paulsamy *et al.* 1995a, b, 1996, 1997a, b, c, 2001). Working in a *Dichanthium annulatum* dominated grasslands, Pandey (1974a) found an increase in the live biomass of grasses and forbs as a result of burning. To this increase, he attributed the fertilizing effect of nutrients released in ash. Some of the major consequences of fire were elimination or invasion of certain species, and alteration of the relative frequency and growth characteristics of certain species (Pandey 1974b). Summer burning prior to rains showed promising result for a higher and there by greater recovery rate of biomass compared to winter burning (Pandey 1988). The recurring fire during every summer in the grasslands of Anaimalais maintains the elevated biomass every year (Paulsmay *et al.* 1997b). Paulsamy *et al.* (1997c) further reported that the index of dominance was increased with concomitant decrease of species diversity index in the summer fire influencing *Chrysopogon zeylanicus* dominated grasslands of Anaimalais, India.

Mall and Mehta (1978) recorded a significant increase in the live green aboveground biomass following burning in a tropical grassland of Ujjain. On the other hand, the grazed and annually burnt *Sehima* grassland showed decreased annual average biomass, net community production and stability than that of the protected one (Vinod Shankar *et al.* 1975a). Nevertheless, in a *Sehima-Dichanthium* cover, the combination of burning and grazing proved to be a good tool for increasing the potentiality of range grasses as the burning removes the rank growth deposited near the sprouting buds and exposes those to environment while the grazing stimulates these buds and ultimately the vigour increases. The increase in plant height and tiller number of *S. nervosum* in every year grazing plot, may be the cause of stimulation of apical buds through animal trampling. The severe effect of these factors (burning and grazing) damages or destroys the buds resulting the decrease in plant vigour. Overall vigour of the species went down, if the grasslands were left unused as in control treatment (Trivedi *et al.* 1981). In Kundah rangelands of Nilgiris, Western Ghats, Senthilkumar *et al.* (1998) reported that the aboveground and litter productions and turnover rate of aboveground parts were increased significantly after summer fire. However, in their observation, belowground counter part remain unchanged after fire. In addition, they have noted the significant higher contribution of legume biomass to the total community after fire in the same grasslands.

In general, control of fire in rangelands used to improve the species diversity, well established food web and stability (Paulsamy 1992). Public involvement and awarness about the rangeland fire are more important for the effective control of fire. Netalkar (1997) in a case study at Bapeli region of Karnataka forests proved the effective control of fire by involving the local people. Paulsamy (2003) stated that ecological approaches must be necessary for the development of any fire control measures to protect the biodiversity and ecological balance as well. For the pre-suppression of fire, number of methods are practiced depending upon the environment . Show and Clarke (1994) explained the application of various fire breaks like natural breaks, existing roads, trails and tracks, cleared fire breaks, tree covered breaks and fire lines for the pre-suppression of fire. Construction of vegetational fire breaks as fire barrier is getting vital importance in terms of biodiversity conservation and maintenance of ecological balance (Rasmussen *et al.* 1986, Perara 1992). In the high hills of Nilgiris of Southern India, vegetational fire breaks of 5 × 1.5 m size constructed by using certain evergreen shrubs like *Berberis tinctoria*, *Elaeagnus kolaga* and *Rhodomyrtus tomentosa* effectively control the spread of fire (Paulsamy *et al.* 2003c). In addition, they have evaluated that due to higher fire retardant capacity, the fire belt made by the species, *Rhodomyrtus tomentosa* was highly effective in comparison to other two species in the same area of Nilgirs, southern India.

CONCLUSION

In tropical regions, the fire generally disturbs the natural development of the communities towards maturity, thus maintaining them at seral stage. These fires influenced disclimax vegetations support a rich fauna. However, uncontrolled wild fire often destroys vast tracts of grasslands within a short period, depriving fodder to the dependant herbivores. This can be averted by prescribed rotational burning, taking into account the phenology of the vegetation and the fodder needs of the fauna. Pre-seasonal controlled fire can also serve as an effective management tool to check the devastating wild fire. Suitable vegetational fire breaks may be employed to control and regulate the surface fire so as to preserve the seed pool, woody vegetation and biodiversity.

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