The Use of Fire as a Management Tool on the Curtis Prairie

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INTRODUCTION

At the University of Wisconsin Arboretum, Madison, fire has been used as a management tool to maintain our prairies for over 20 years. During the 1930's and 40's the necessity and importance of fire in maintaining biotic communities was so slighted, indeed downgraded, that to propose fire as a useful tool in the early 1950's required a great deal of insight and clear objective interpretation of carefully regulated experiments. This paper reviews the development of the Curtis Prairie and some of the research efforts that have given us the information needed to understand the role of fire in the tall grass prairie.

The primary management goal of the University of Wisconsin Arboretum is to rehabilitate or artifically establish as many of the native Wisconsin biotic communities as possible. As a result the Madison Arboretum is different from most arboreta in that it is a collection of communities rather than horticultural plantings. The Arboretum's 1,240 acres include over 31 different biotic communities; some are natural, whereas others have been restored over the 37 year history of the Arboretum.

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FIG. 1. Fire on the University of Wisconsin Arboretum Prairie.

the frequency of many introduced weeds and greatly enhancing the prairie species.

At 5 year intervals, a grid of meter square quadrats that are located 50 feet apart are used to determine the composition of the prairie. The first survey was done in 1946 and at that time the Curtis Prairie was essentially a bluegrass field with a few prairie species growing in it. In the first survey a data sheet was used that contained only 10 prairie species as these were the only species that were abundant enough to be included in the study. In subsequent years this data was worthless as a result of the increase in numbers and dominance of other prairie plants. The 1961 survey showed that portions of the Curtis Prairie were similar to native prairie stands in terms of the number of indicator species and in the summed frequencies of the prairie species (Cottam and Wilson 1966).

Table I provides the general pattern of changes in frequency that have occurred on the Curtis Prairie since its establishment. These results show that the frequency of the dominant grasses, big and

TABLE 1. FREQUENCY OF PLANT SPECIES IN CURTIS PRAIRIE, STAND A, 1951 AND 1961*

	Frequency	
	1951	1961
Prairie Species		
Achillea millefolium	44	55
Ambrosia artemisiifolia	79	53
Andropogon gerardi	6	44
Andropogon scoparius	—	47
Asclepias verticillata	59	61
Eryngium yuccifolium	1	69
Helianthus grosseseratus	—	5
Lactuca canadensis	48	84
Liatris aspera	2	37
Monarda fistulosa	53	73
Ratibida pinnata	6	32
Rudbeckia hirta	—	3
Silphium terebinthinacium	2	21
Solidago gigantea	—	3
Solidago nemoralis	—	81
Solidago rigida	—	8
Sorghastrum nutans	—	68
Other Species		
Agrostis alba	—	8
Aster pilosus	71	31
Pastinaca sativa	32	11
Poa compressa	79	97
Solidago altissima	32	48
Weeds		
Agropyron repens	29	11
Oxalis stricta	54	44
Poa pratensis	60	13
Trifolium repens	74	43

* Data of Cottam and Wilson 1966. (In Lussenhop 1971)

little bluestem (*Andropogon gerardi, A. scoparius*), Indian grass (*Sorghastrum nutans*), and many of the prairie forbs including the goldenrods (*Solidago* spp.), yellow cone flower (*Ratibida pinnata*), and especially the rattlesnake master (*Eryngium yuccifolium*) substantially increased in frequency between 1951 and 1961. In addition, many of the troublesome weedy species such as wild parsnip (*Pastinaca sativa*) and Kentucky bluegrass (*Poa pratensis*) markedly declined.

The Curtis Prairie gently slopes from the west, where the maximum elevation of 925 feet is reached, to the northeast at minimum eleva-

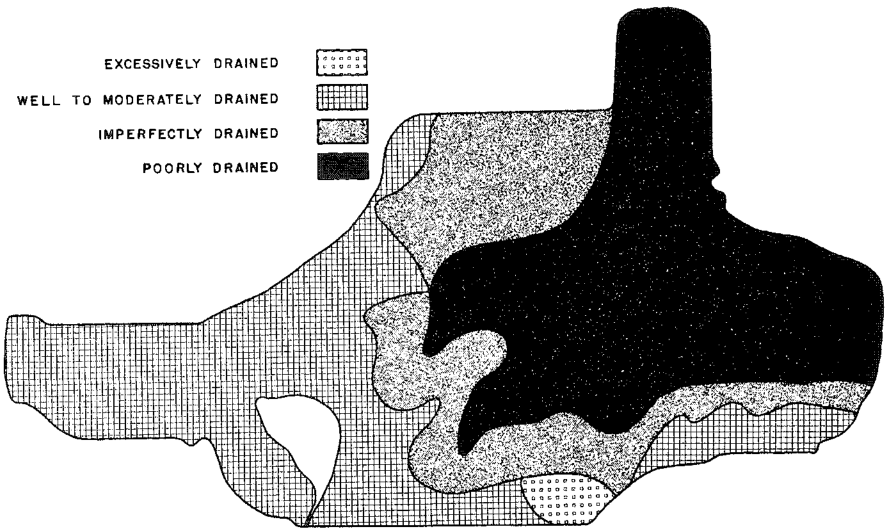

FIG. 2. Soil drainage pattern in the Curtis Prairie.

tion of 865 feet. Figure 2 shows the soil drainage pattern in the Curtis Prairie. The west end of the prairie is well-drained to moderately well-drained while the eastern end is poorly drained. The drainage pattern is essentially from the southwest to the northeast.

The vegetational pattern in the Curtis Prairie in 1966 and 1971 is shown in Figures 3 and 4. These maps were prepared by calculating a Continuum Index Value (Curtis 1955) for each quadrat in the 1966 and 1971 censuses and then using synographic mapping techniques to delineate community types. Prairies composed of all wet prairie indicators will have a CI value of 100, mesic prairies have a value of 300, and all dry prairie indicators in a community would result in a CI of 500.

Based on the drainage and soil moisture pattern, the communities show a reasonable delineation. Comparison of 1966 and 1971 CI maps of the Curtis Prairie show that there is a slight shift to lower CI values. Studies on the Greene Prairie (Anderson 1968) revealed that after the initial establishment the species segregated themselves according to their optimum moisture regime. Thus changes in com-

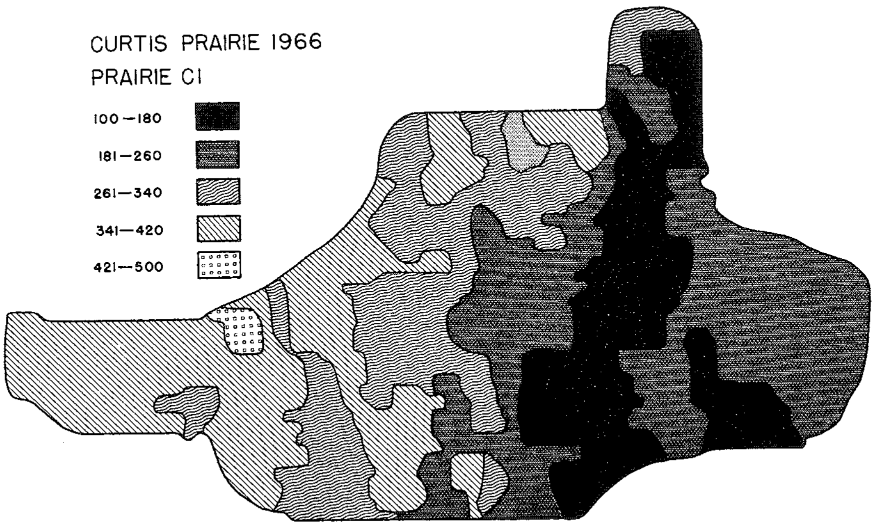

FIG. 3. Vegetational pattern in the Curtis Prairie, 1966.

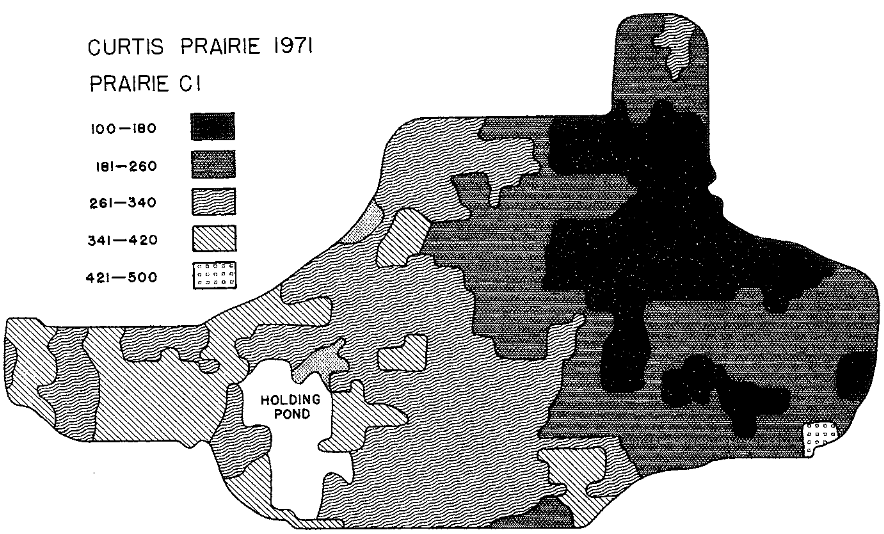

FIG. 4. Vegetational pattern in the Curtis Prairie, 1971.

position within any given area might be expected to continue as the species make a more complete adjustment to the environment.

Since the 1940's there have been several studies of the effect of prairie fires on a range of topics that include soils, soil arthropods, and spiders (Hole and Nielsen 1963; Lussenhop 1971; Riechert and Reeder 1971). The soil on which the Curtis Prairie was established had its genesis under forest cover rather than prairie. Studies begun by the soil scientist, Francis Hole, in 1956 revealed during the agricultural era, which lasted about 90 years (1840's to 1930's) the forest soil lost about 20 tons of organic matter per acre. That amounts to about 26 percent of the organic matter contained in an undisturbed forest soil. However, during a 19 year period, from 1940 to 1959, the prairie restored 12 tons of organic matter or 60 percent of that lost (Nielsen and Hole 1963). Based on his work, Professor Hole believes that a prairie soil is slowly forming under the Curtis Prairie. However, it is estimated an A1 horizon in a prairie soil can form in 500 years and a textural B horizon in 4,000 years (Arnold and Riecken 1964). Because burning enhances the productivity of the tall grass prairies, it also increases organic matter and nitrogen in the soil.

Studies of invertebrate response to fire has shown that burning reduces the diversity and limits the number of soil arthropod individuals. Soil arthropod diversity is related to the quantity of litter and rate of decomposition. Fire reduces the amount of litter and also increases the rate of nutrient turnover; to this extent it limits soil arthropod diversity (Lussenhop 1971).

Organisms that occur below the soil surface are well shielded from the fire because of the soil's insulating properties. During a prairie fire, surface temperatures of up to 200°C were recorded for 70 to 140 seconds. However, at depths of 0.5 and 1.0 cm in the soil, temperatures were unchanged (Riechert and Reeder 1971).

Immediately following fire, predatory spiders and soil arthropods that are resistant to dessication were found to increase (Lussenhop 1971; Riechert and Reeder 1971). However, arthropods which are unable to escape the fire by getting under the soil or other protective objects such as stones, frequently are killed by the fire. For this reason it has been recommended that a portion of small prairies be left

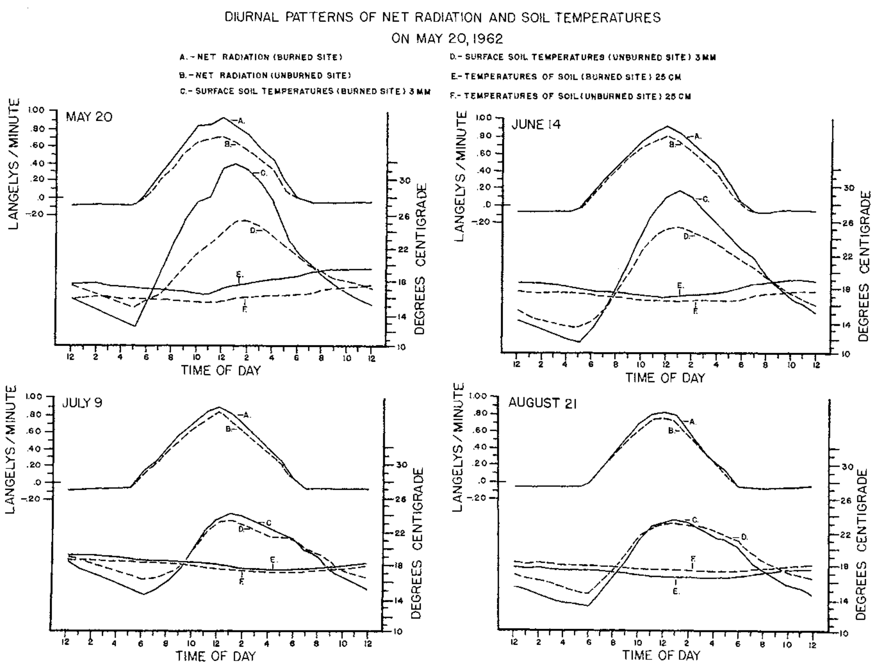

FIG. 5. Net radiation and soil temperatures for 4 days during the growing season on the Curtis Prairie.

unburned each year to permit some of these more fire-sensitive species to survive. This recommendation seems reasonable, as during presettlement times, the large prairie tracts undoubtly had sizeable areas that were missed by fire and where the fire susceptible species may have persisted and then reinvaded the burned tracts during the next growing season.

During the past 5 years, two studies on the Curtis Prairie examined the causative mechanism for increased productivity of the prairie following burning. The first of these studies examined net radiation patterns and soil temperatures at the surface and 25 cms into the soil. Figure 5 shows these measurements for 4 days that span the major portion of the growing season.

During the spring, daytime temperatures were substantially warmer on the burned prairie than on the unburned. The blackened surface readily absorbed energy while on the unburned prairie the litter layer retarded soil warming and its lighter color reflected back some of the radiant energy. However, at night, the lack of a litter layer on the burned surface allows it to cool much faster than the surface of the unburned prairie. While these conditions persist to some degree throughout the growing season, they are most pronounced in May and early June before much vegetative cover has developed on the burned site (Brown 1967).

Total production of above ground biomass was 4,180 lbs/acre on the unburned site compared with 8,478 on the burned. It was hypothesized that conditions for growth were more favorable on the burned site especially during the spring because the soil warmed up faster, extending the growing season. During May, the shoots on the burned area were exposed to favorable temperatures for photosynthesis during the day and at night the cooler temperatures near ground reduced nighttime respiration. It was reasoned that the reflective litter surface on the unburned site increased the energy load on the leaves once they emerge above the litter and this resulted in unfavorable leaf temperatures. Leaf temperatures were predicted from net radiation measurements but no measurements of leaf temperatures were made (Brown 1967).

This work was continued by Peet (1971). She measured reflectance, air temperatures at 5 cms above the ground, leaf temperatures and net primary productivity of big bluestem using gas exchange methods. Her results also showed that the burned prairie presented more favorable conditions during the spring, but the actual differences in leaf temperatures were not as great as those predicted by the method used by Brown (1967) and that the reflected energy from the litter surface could not account for the differences in leaf temperatures. However, the litter surface did reduce wind movement and this could be an important factor in raising leaf temperatures on the unburned site during the early part of the growing season. As a result, leaf temperatures during midday were nearer the photosynthetic optimum, about 26°C for big bluestem, on the burned than on the unburned site.

Both of these studies pointed to the importance of early spring growth conditions. By 31 May 1971, the burned prairie had 21.8 g/m^2 while the unburned prairie had only 0.6 g/m^2 of above ground biomass (Peet 1971). The extended growing season and the more optimal conditions for net photosynthesis in the early spring on the burned site are important factors in the increased productivity of burned prairies in the midwest.

Since the establishment of the Curtis Prairie in 1935, there have been 4 Masters and 6 Doctoral theses, as well as 16 published papers resulting from studies carried out in the Arboretum's prairies. Many of these scientific works have had a significant impact on recent ecological thinking. However, the Curtis Prairie has played an equally important role in educating the general public in the Madison area about fire ecology and its significance to the prairie community. The Arboretum is essentially surrounded by an urban area of nearly 200,000 people, and the objections raised to our prescribed burning program are presently minimal. For the past 8 years, the Arboretum's prairies have served as an outdoor classroom for thousands of school children. This educational program has more than paid for itself in understanding and good will. Today, elementary school children are taught the concepts of fire ecology that were rejected 15 years ago by leading ecologists throughout the country. Nonetheless, recent concern about air pollution has emphasized the need to educate the public about the difference between natural smoke and that which is produced by factories and automobiles.

In 1953, when Walt Disney was filming the "Vanishing Prairie", he sent his crew to photograph the burning of the Curtis Prairie as this was the only place in the world where anything even approaching the spectacle of a primeval tall grass prairie fire could be found. Since that time, there have been other major efforts made at restoration but it is fair to say that more has been learned about prairie ecology through the restoration of the Curtis Prairie than any other.

The future of the Curtis Prairie and the whole of the Arboretum is not secure. Recent expansion of the West Beltline Highway, that parallels the southern boundary of the Curtis Prairie, has caused serious erosion and siltation problems. About an acre of the prairie was lost when a settling pond was built to capture the sediment from the beltline during construction (Fig. 4). We are also threatened by other urban development and a growing number of visitors who are not sufficiently educated to properly use a natural facility such as the Arboretum. Solutions to the current problems that the Arboretum now faces cannot be solved by more publications in scientific journals; public support and understanding must be expanded.

Our Tour Program and publications of books, such as "A Guide to the Arboretum Prairies" (Riech 1971) have helped. Many people have learned to love the prairie, to appreciate its diversity, and understand the role of fire in this community. It is this knowledge that give the Arboretum and the Curtis Prairie a chance for survival in the future.

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