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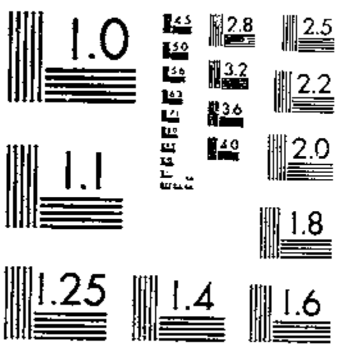

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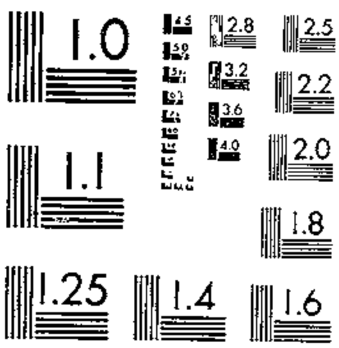

MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

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UNITED STATES DEPARTMENT OF AGRICULTURE
WASHINGTON, D. C.

EFFECTS OF FIRE AND CATTLE GRAZING ON LONGLEAF PINE LANDS, AS STUDIED AT McNEILL, MISS.[1]

By W. G. WAHLENBERG, *forester, Southern Forest and Range Experiment Station, Forest Service*, and S. W. GREENE, formerly *associate animal husbandman, Bureau of Animal Industry*, and H. R. REED, formerly *assistant agronomist, Bureau of Plant Industry*[2]

CONTENTS

INTRODUCTION

Grazing of cattle in the longleaf pine (*Pinus palustris*) forests of the South has been a practice of long standing. The virgin forest was typically open and parklike and supported a cover of coarse grass. This wild grass, which was frequently burned over in winter, supplied the main forage for the descendants of the cattle imported by early Spanish settlers. The original forest was largely clear cut in lumbering operations, and the lands are now characterized by thrifty second-growth stands in discontinuous groups and patches still leaving much open, unimproved grazing land.

Owing to protection from fire this pure longleaf type of forest is rapidly shrinking in area as loblolly pine (*Pinus taeda*) encroaches from the north, slash pine (*P. caribaea*) from the southeast, and sometimes hardwoods from the creek bottoms. Without attempting to go into the relative merits of longleaf pine versus other species having less ability to withstand fire, it can be stated that where the change in composition is acceptable, continued exclusion of fire is very essential. Whether any grazing should be practiced on such areas is open to some

[1] Submitted for publication September 21, 1938.

[2] Field work on the forestry phase of this study was started by R. D. Forbes and E. W. Hadley and carried forward by L. J. Pessin and W. G. Wahlenberg. H. I. Harris, Bureau of Animal Industry, assisted in the field work with cattle and in the final compilation of the cattle data. V. L. Harper assisted with the final report. The Mississippi Agricultural Experiment Station cooperated by providing the steers and the farm facilities necessary for feeding, dipping, and weighing the animals.

doubt, since grazing on wild lands of the South in the absence of burning has yet to be proved practicable. Certainly the practice of winter burning to improve the forage is one of long standing, nearly all grazing on the unfenced open range in the past having been accompanied by fires to remove the accumulations of dead grass. Furthermore, the incompatibility of timber growing and cattle grazing seems obvious where either of these two industries is to be conducted under intensive management. Young trees cannot withstand the constant trampling of cattle, nor will forage grow where the overhead forest canopy becomes closed (*66*).[3]

There are still relatively large areas of open longleaf pine forests, however, where only nonintensive management, if any at all, is practiced. These areas may be open now because of forest denudation or because of poor tree-growing soil. On these tracts longleaf pine growing and cattle grazing might be advantageously combined. There is likewise the possibility that cattle grazing might be employed in young stands on better-stocked areas and better sites prior to the time the trees develop overhead shade and needle litter to the point where forage is shaded and smothered out.

Before the question of dual use of longleaf pine forest land for growing timber and grazing cattle can be settled, numerous factors must be considered. First and most important is the question of fire. Is fire necessary for wild forest-range management, and if so, what is its effect on longleaf pine? Then there is the question of the effect of grazing itself on longleaf pine. What is the probable effect of grazing or burning on watershed values where soils are highly susceptible to erosion or regulation of water run-off is of primary importance? Considerable longleaf pine land, however, lies outside this zone. According to the recent southern forest survey, 8 million of the nearly 22 million acres on which longleaf pine is 75 percent or more of the forest growth consists of so-called flatwoods—areas too nearly level to be subject to erosion regardless of surface treatment. Much of this land is unfenced open range, largely undeveloped but essential to rural economy.

To answer some of the questions concerned with dual use of forest land for growing longleaf pine and producing forage for cattle an experiment was set up in 1923 at McNeill, Miss. to determine the effects of annual burning and cattle grazing on (1) the reproduction, survival, and growth of longleaf pine, (2) the forage of unimproved woods pastures, and (3) the soil. The study of the soil was included because of the attention this subject has received from those who sought to discourage widespread burning of forest lands in the South.

REVIEW OF LITERATURE

A study of the literature has served to show that the ancient conception of the dual use of land for forestry and livestock has persisted in various countries to the present day; that, in spite of conflicting interests, nonintensive management for dual use may still be practical under certain conditions; that where this is so consideration should be given to fire as a tool in such management; and that if fire is in use or being considered, the observations of others on how such fires affect trees, livestock (domestic or wild), and soils, are pertinent to the problem of proper management.

[3] Italic figures in parentheses refer to Literature Cited, p. 47.

In the western United States early attempts to harmonize grazing and forestry involved schemes for deferred and rotation grazing (*19*, *50*) but no use of fire. The production of timber has required certain adjustments in the grazing management of western ranges (*35*), but livestock grazing continues to be one of the principal sources of income from western national forests, and has been recognized as a factor in decreasing the number, intensity, and area of accidental fires (*28*).

Jennings and Crosby (*36*), speaking of the flatwoods country of South Carolina and Georgia and the Coastal Plain of Alabama and Mississippi, stated in 1929 that beef-cattle production in the piney woods section is connected largely with lumbering, turpentining, reforestation, and large holdings of land. In their opinion, where the menace of the cattle tick has been removed, the best utilization that can be made of large areas of this part of the South is a combination of growing timber and producing beef cattle. These authors advocate the solution of the problem by perpetual institutions, such as corporations or the States themselves, through the adoption of programs that will make the land pay its own way while growing back to timber, through the sale of beef calves and yearlings. In 1933 Chapline and Campbell (*11*) concurred in these views; speaking of forest ranges in the South, they observed that the grazing of livestock on native forage produced on forest lands furnishes a livelihood or supplemental income to a substantial portion of the rural population and in some instances provides a current return to the landowner to meet carrying charges. They concluded that timber growing and adequately controlled livestock grazing seem to represent a dual use which can contribute substantially to economic use of forest lands.

Regardless of injury to trees or soil it has long been the custom to use fire on forest areas to aid in obtaining wild game or in raising domestic livestock. In South Africa, according to Staples (*57*, *58*), grass burning is apparently of very ancient origin, "having been practised by the natives before the advent of the white farmer for much the same reasons as it is done today."

In North America the Indian practice of burning the woods to facilitate hunting is clearly recorded (*5*, *43*). Hammond (*25*), writing of South Carolina in 1882, stated that the early settlers in this region were stock raisers and kept up the Indian practice of burning off the woods during the winter. The destruction of the undergrowth by this means favored the growth of grasses, and numerous herds of almost wild cattle and horses found abundant pasturage; the uplands were covered with a large growth of yellow pine, and a deer might have been seen in the vistas made by their smooth stems a distance of half a mile. But in 1882, according to Hammond, after the discontinuance of spring and autumn fires, an animal could not be seen 15 paces because of the thick growth of oak and hickory that had taken the land.

Charles Lyell (*39*) published observations on the difference between hardwoods and longleaf pine in relation to woods fires. Visiting Tuscaloosa, Ala., as early as 1846, he found the hills covered with longleaf pines and noted that their preponderance in relation to hardwoods was locally attributed to the grass burning practiced by the Indians. He noticed that the bark of the hardwoods was such as to make them much more susceptible to injury, and he marveled at the profusion of reproduction on burned areas. In 1889 Long (*38*) pointed out the different significance of forest fires in the North and South, being confident that fires had a vital part in the survival of the longleaf pine forest under natural conditions. Ten years later Pinchot (*48*), writing for the National Geographic Society, spoke of the outstanding resistance of longleaf pine seedlings to fire. In 1907 Schwarz (*51*) pointed out that the destruction of longleaf pine seedlings 2 or 3 years old by surface fires had been somewhat exaggerated and misunderstood. As early as 1913, Harper (*26*) stated that if it were possible to prevent forest fires absolutely the longleaf pine—one of our most useful trees—would soon become extinct.

The ideas of these early observers (1849–1913) made little or no impression on the expanding conservation movement of the present century. Fire damage was so conspicuous and its benefits so subtle that exclusion of fire was favored rather than its controlled use. Hence forest fires were regarded either as an unmixed evil or else as a double-edged weapon so dangerous in the woods as to deserve unqualified condemnation.

It remained for Chapman (*12*) to reopen the subject in 1926, when he reported on certain experiments at Urania, La., and recommended periodic use of fire in growing longleaf pine. His study, although based on more systematic observation than preceding ones, failed for some time to stimulate further research on fire as a management tool. Meanwhile, additional records of its damaging effects continued to accumulate (*17*). In 1931 Greene (*21*) expressed views on the ecology of longleaf pine as affected by fire that were currently regarded as revolutionary, although they were largely restatements of the ideas of early writers (*26*). Later Chapman (*13*) stressed the then unpopular idea that fire is essential to the proper development of longleaf pines and the permanence of longleaf pine forests. In view of the conflict between these statements and the teachings favoring exclusion, men charged with the protection and management of large forest properties in the longleaf pine region have found the problem definitely two-sided and perplexing. There was no assurance that a controversy over the burning policies in the southern United States could be decided as definitely against light burning as it appeared to have been in the case reported by Bruce (*8*) in California.

Further information on the fire situation in the longleaf pine region of the South was published in 1935. Bickford and Bull reported a particularly destructive accidental fire in Louisiana,[4] and Eldredge (*20*) pointed out the insufficiently recognized and appalling danger of attempts to exclude fire completely from similar stands of timber in southern Georgia. On the basis of extended experience as a manager of forest properties, Eldredge reached the conclusion that lack of mastery of the fire situation in the South is the outstanding obstacle to the progress of forestry in the longleaf-slash pine region. The same year Demmon (*18*) published a review of the manifold effects of fire, both injurious and beneficial, in longleaf pine stands under different conditions. A year later Chapman (*14*) published further details of his work with longleaf pine at Urania. He found bare soil the most

[4] A report on the fire of September 17, 1932, on holdings of the Urania Lumber Co. Fire weather and hazard are indicated by these conditions: No rain in previous 12 days; daily maximum temperatures 86° to 97° F., averaged 90° for the period and 98° at the time of the fire; wind brisk, and "rough" unburned during the previous 19 years. Briefly the results may be indicated as follows: The longleaf pine second growth, consisting of 900 pole-sized trees per acre, was all killed. Of the virgin longleaf pine seed trees, 95 percent were killed. For further details of the forest fire experience of this lumber company, a pioneer in forestry endeavor in the South, see the report in the Journal of Forestry, vol. 33, pp. 351–357, 1935.

favorable natural germinating bed for pine seeds. A mat of native grass resulting from 3 or more years without fire was most unfavorable as a seedbed, frequently causing complete failure of longleaf pine reproduction. He demonstrated the fire resistance of seedlings 1 to 3 feet high by placing tissue paper around the terminal buds. The tissue remained unscorched through a grass fire which burned off the pine needles to within 3 inches of the buds. Of this class of seedlings winter fires killed less than 1 percent, but fire on a hot windy day in March killed 35 to 50 percent. He observed that controlled winter fires killed back competing vegetation consisting of other species of pine, hardwoods (including blackjack oak, *Quercus marilandica*), and shrubs the survival of which will suppress and kill longleaf pine seedlings. Chapman concluded that longleaf pine naturally thrives and grows in pure stands on areas subject to burning at intervals of 2 to 3 years.

Some such interval between fires seems to have prevailed during the establishment of most of the second-growth longleaf pine timber in the South. Extensive, well-stocked, and thrifty stands of such timber occur in southern Alabama. The reduction or elimination of fire when the trees were in the sapling stage resulted in increased growth.

Now the timber is in the pole state, and one of the veteran woodsmen (*55*) in charge of fire protection and conservation has reported on the advisability and feasibility of using controlled burning as an economical means of protecting this fine timber from unwanted fires.

Working in northern Florida, Osborne and Harper (*44*) confirmed Chapman's early results on the seedbed preference of longleaf pine. By direct seeding of replicated plots screened against the ravages of birds and rodents, they found that burning before seed fall was beneficial. With predators excluded, the "catch" of longleaf pine was increased whether the burning was immediately before seed fall or a year before.

Not a great deal about the use of fire in the forest can be learned from experience in other countries. It is interesting, however, to note recent developments related by Pring (*49*) in many parts of the Punjab, a Province of India, where the forests of chir (*Pinus longifolia*) resemble our longleaf pine, and the climate also is similar to ours. After years of attempted exclusion of fire, controlled winter fires are now used at intervals of 3 years to minimize the effect of incendiary fires during the hot season (*23*), and this in spite of recognized disadvantages, which include damage to the pines, a change to coarser and less nutritious grasses, and, in hilly country, increased erosion. Research by Nicholson in India, as reported by Stebbing (*59*), led to conclusions favoring controlled winter burning. He found that except for some loss of nitrogen the effect on fertility of clay soils was favorable, and on other soils at least temporarily beneficial. Efforts to protect from fire are concentrated on areas in process of regeneration. Yet when such areas were burned over, injuring and killing some young trees, the growth of other trees was stimulated. Enormous reduction in damage from accidental fires is expected from controlled burning in India. Stebbing admits no doubt but that—

> rigid and perpetual fire protection in many moist tropical forest areas is not only a waste of money, but absolutely inimical to the regeneration and in some cases to the very existence of the more valuable species.

Troup (*62*) refers to an article by Smythies (*56*) also reporting on conditions in India. In his experience, areas that are brought under fire protection after years of burning tend to regenerate in great profusion, whereas on areas that have been successfully protected from fire for many years, natural reproduction is becoming more and more difficult to obtain, doubtless owing mainly to the thick accumulation of needles with its adverse physical and chemical effects. Smythies also concluded that successful regeneration is possible under the most favorable conditions without fire protection. From Switzerland, Hess (*31*) reports detailed observations indicating the beneficial effects of burning on soil reaction and composition, and concludes that fire can be utilized in silviculture for the natural reproduction of forests.

The changes that take place in the type of forage or in species of forage plants, depending on the use or nonuse of fire with or without grazing, have had very little consideration from experimental workers until recent years. A number of experiments at widely separated points but under somewhat similar conditions have thrown light on this effect of fire on forage. Hole (*34*) in 1911 stated in regard to the coarse savanna grasses of India that fire alone is rarely capable of killing out the species and is directly beneficial in clearing away inedible material, in enabling cattle to gain easy access to the young palatable shoots, and in increasing the production and accelerating the growth of the latter at a season when fodder is usually scarce. Other observers of grassland burning in India (*9*) wrote in 1932 that the higher the rainfall the more likely burning is to be useful. They observed that high rainfall encourages ligneous versus herbaceous vegetation and that fire is the best method of rectifying this balance between the two; that yearly burning in March since 1928 has not only not caused *Andropogon contortus* to deteriorate but on the contrary has enabled this grass to make a uniform growth everywhere, providing early feed for cattle Hensel (*29, 30*) in 1923, comparing burned and unburned pastures in Kansas for a period of 4 years, stated that it appears reasonably well established that vegetation actually starts earlier on burned areas than on similar areas not burned; that burning does not decrease the total number of plants but does have an influence on composition. As far as Kansas grasses are concerned, Hensel found that the change in composition has, if anything, been in favor of burning, and that in the first 4 years burning has not caused weeds to spread. *A. scoparius*, which in Kansas increased following burning, was one of the predominating grasses on the pastures used in the present experiment. Working in South Africa in a region somewhat similar to the southern United States, Bews (*7*) described certain types of forage plants that are notably resistant to fire. Phillips (*47*) writing of east Africa and South Africa found that while fire discouraged certain plants it favored other species to an extent that made them indicators of frequently burned areas. In 1926 and 1929 Staples (*57, 58*) indicated the effects of burning and nonburning on the principal native forage grasses in South Africa. He noted that the botanical composition of natural grassland may be much influenced by burning. Winter burning, according to Staples, was found to encourage the more valuable climax grassland species, and summer burning, the inferior pioneer species. Winter burning in addition to "cleaning up" a pasture was found to favor the development of native legumes and perpetuate the local association of clump grasses, thus preventing unfavorable changes from taking place. The nutritive ratio of the herbage on the burned as compared with the unburned grassland was regarded as the more suitable for the production of milk and wool and for the growth of young animals. The favorable effect of fire on legume growth has been noted by Sellards et al. (*52*) in Florida.

Welton (*66*) in 1929 found in Ohio that forage produced in the shade was lower in both quantity and quality than that produced in the open. Hart, Guilbert, and Goss (*27*) reported from California in 1932 that in the year following burning the phosphorus content of forage samples collected from a burned area nearly doubled that of samples from an unburned area, but there was much less difference the second season after burning. Neal and Becker (*42*), in 1933, reported that analyses of wire grass collected from burned and unburned areas in Florida showed a much higher content of ash and crude protein in the samples from the burned area. This difference tended to decrease from March to July.

The condition of forage vitally affects wild as well as domestic animal life. Many species of grass found palatable by cattle are grazed also by deer, and quail consume quantities of the seeds of legumes common on southern ranges. Quail are well recognized as a byproduct of possible commercial value from longleaf pine cut-over lands. It is now becoming more apparent that while indiscriminate burning may be detrimental to game animals, the complete and extensive exclusion of fire may so modify environment as to be still more detrimental.

Stoddard (*60*) has called attention to the use of fire in his research on the production of quail in southern Georgia, where he has shown that winter fires of the creeping type, coming after legumes have shed their seeds, increased the thrift and abundance of perennial legumes. He has recommended (*61*) the carefully controlled use of fire on quail and wild turkey ground. He states that it should be used at the proper season (not in summer) and under proper weather conditions for the definite purpose of regulating cover and increasing food supply for the game birds. So used it is a necessary tool and essential feature of quail management. Stoddard found that perennial legumes, an important source of winter and spring food for quail, were smothered out by the mulching effect of accumulations of unburned grass.

THE EXPERIMENTAL AREA

The field work of this experiment was conducted at the Mississippi Agricultural Experiment Station, established for study of land-use problems in the Gulf Coastal Plain. In 1923 cooperation started at McNeill between the Forest Service, the Bureau of Animal Industry, and the Bureau of Plant Industry, certain lumbermen and timberland owners contributing to the first cost of the necessary fencing.

The experimental area [5] has an elevation 230 feet above sea level, the topography being very gently rolling upland, typical of at least the southern portion of the upper Coastal Plain. An average rainfall of about 60 inches a year provides ample moisture for growth. The main soil types are fine sandy loam classified by the Bureau of Chemistry and Soils as Norfolk, Orangeburg, and Ruston soils. In texture and

[5] S½ sec. 5, T. 5 S., R. 16 E., Pearl River County, Miss., about 2 miles southeast from McNeill. This land, leased 1923-33, is now a part of the Harrison Experimental Forest administered by the Southern Forest Experiment Station, New Orleans, La.

forest. The surface soils are loamy fine sands or light-textured fine sandy loams underlain by friable fine sandy clays of yellow, red, and reddish yellow, respectively. Unlike the loessal soils of northern Mississippi these soils are not extremely susceptible to erosion unless denuded of vegetation.
consistency, they are representative of the well-drained types of soil in the Coastal Plain which were originally occupied by longleaf pine

The original stand of longleaf pine, 75 to 100 years old with a few older trees, was boxed for turpentine about 1900 before being harvested for timber. In the winter of 1902-3, 8,000 to 10,000 feet board measure per acre of virgin timber was cut. A few additional trees were later removed for piling, leaving about 10 scattered seed trees per acre.

This was more trees than were left on many cut-over areas, but many of them were small and suppressed, with crowns insufficient for seed production. During 20 years, however, these inferior trees developed into seed trees capable of regenerating the forest. Meanwhile second-growth stands developed on certain parts of the area from advance reproduction already on the ground and started active height growth about 1906. The seedlings originating in 1924 and later (the ones studied intensively in this project) had to compete with stands of grass considerably heavier than those under virgin timber. The grass type, in which prairie beardgrass (*Andropogon scoparius*) and slender beardgrass (*A. tener*) predominate, is typical of extensive areas from Texas to western Florida. It differs from the flatwoods grass types in Alabama and Georgia, in which less palatable species of *Aristada* often predominate, and is not typical of plant associations on the deep sands of Florida.

As a part of the open range, the experimental area had been lightly grazed and burned over nearly every year during the fall and winter up to January 1923, when it was fenced and placed under protection. In the absence of natural barriers to fire and grazing, the entire tract is believed to have received uniform treatment before being fenced. The general character of the land at the beginning of the experiment is shown in figure 1 and plate 1, *A*.

A woven-wire hog fence was built around 320 acres. To aid in dividing this tract into four comparable experimental areas, a careful survey of the pine reproduction and second growth was made by the Forest Service, and an intensive survey of the soils by the Bureau of Chemistry and Soils. The tract was then divided into two 150-acre pastures, comparable as to soils and forest cover, one to be burned over annually and the other protected from fire. The remaining 20 acres was divided into two fairly comparable 10-acre ungrazed check plots, one to be burned and the other protected. Provision was made for systematic periodic measuring of results as follows: Cattle weights monthly; survival of tree seedlings twice a year; plant succession and forage values annually; and development of second growth by 5-year periods. In addition to the regular work, supplementary studies have been made of soil. In 1928 four one-half-acre sample plots were added for observation of the development of second-growth pine stands.

Within the 320-acre area 54 sample plots of 0.01 acre each were established in1923 for study of forest reproduction and forage growth. These plots were 66 feet long by 6.6 feet wide, rectangular, and marked

A, Ungrazed and unburned check plot—an opening typical of most of the grazing areas in this study; numerous small seedlings are hidden in the grass beneath scattered seed trees; in the background is a well-stocked sapling stand. *B*, Technique of locating the tiny longleaf pine seedling under a mat of grass and litter; quadrat corners marked by permanent stakes and seedlings by wire pins with a bit of rag at the top, which on ungrazed plots were left in place from year to year; a low movable bridge prevents injurious trampling by the observer. (F224897.)

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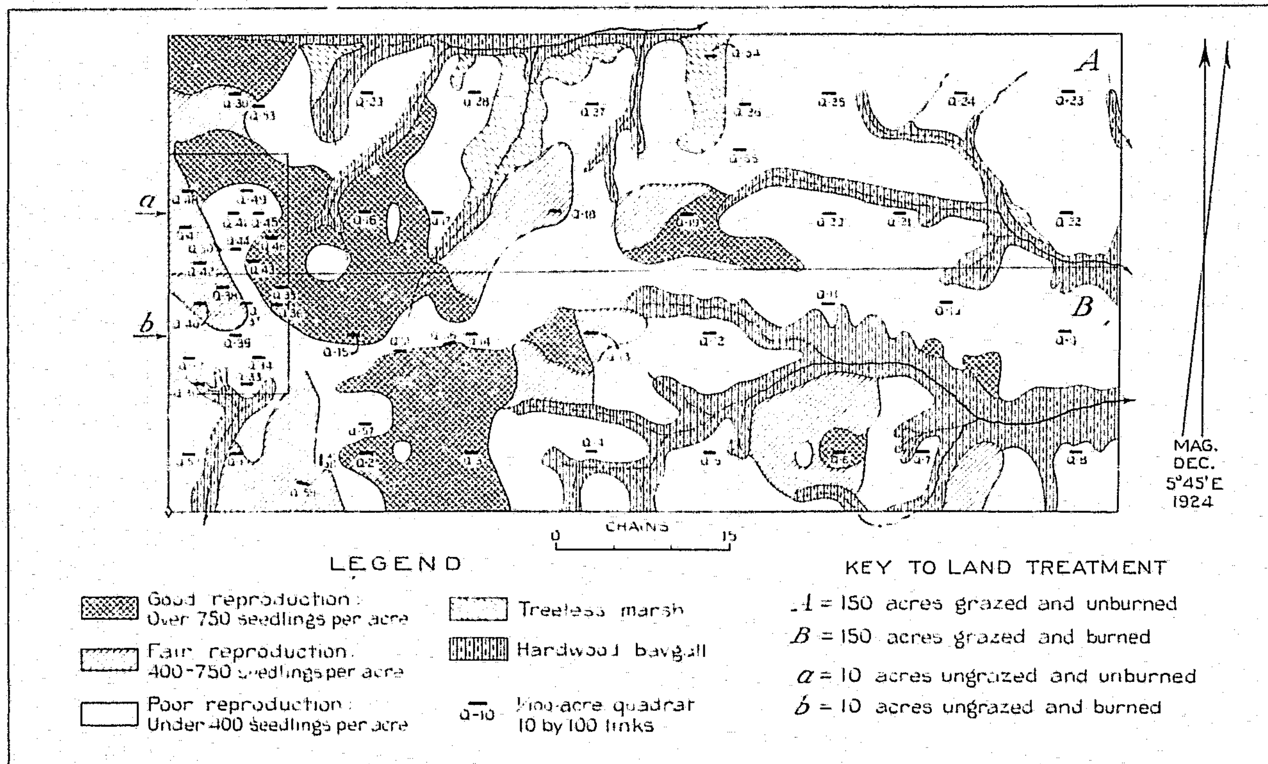

FIGURE 1.—Reproduction map of experimental area, McNeill, Miss.

with a permanent stake at each corner (pl. 1, *B*). A map of the living pine seedlings on each plot, made every year before the grass was burned, was carefully revised about 3 months after each fire. In this way a continuous record was kept of individual seedlings of known age. Except in well-advanced second-growth stands, no thorough study was made of seedlings originating prior to 1924. Plots Q-55 to Q-59 were established in 1928 and were used solely in studying the 1927 crop of seedlings.

The seasonal start and finish of grazing on the pastures each varied by several weeks in the different years. The average dates were April 5 and November 8, giving a grazing season of about 7 months.

The annual controlled burning of the south half of the area was done in January or February each year. The earliest date was January 10 and the latest February 27, the average date for the 11 fires (1923-33) being February 10. Although local cattlemen usually do some firing as early as December, the experimental burning was carried out in such a way as to simulate the most general local practice. Very windy days and damp weather were avoided, the former for safety, the latter in order to be able to obtain a fairly clean burn in one operation. Fires were set at midday and often were as severe as could be produced from one season's accumulation of grass and litter. Although all extensive and partly isolated blocks of pine upland were ignited, no attempt was made to ignite smaller areas that failed to burn. Following a typical fire in 1932 these scattered unburned spots were mapped (not including those in hardwood areas) and found to amount to 13 percent of the total. Such areas accumulated a larger amount of grass fuel by the next year and hence, except for closely grazed spots of carpet grass, seldom escaped at least biennial burning.

EFFECTS ON LONGLEAF PINE STANDS

OLD-GROWTH AND SECOND-GROWTH TREES

The old-growth and second-growth trees were examined for any effects of burning and grazing on growth and seeding. Cone-count records from several hundred trees made in 1927, 1929, 1931, 1932, and 1933 did not reveal any difference in cone yields that could be ascribed to annual burning.

Extensive diameter measurements of the old-growth trees made in 1927 and again in 1933 did not disclose any difference in growth for that period as a result of burning. This was not surprising, since the crowns were above the defoliating effects of ordinary fires.

Growth data from the second-growth trees were taken during the period 1928-33. Differences in the dominant portion of the stand for a 5-year period, as shown in table 1, were less than in the stand as a whole. Increases in average height, diameter, and basal area, as well as in total cubic volume, were all greater on the unburned plots in both total and dominant stands, in spite of apparently more favorable initial densities on the burned plots. At the start the trees averaged larger on the burned than on the unburned plots. The nearly one-half inch greater diameter growth on protected plots in the dominant stand[6] is possibly less significant than the contrast in height growth. Dominant trees on the burned plot grew 3.1 feet, or 23 percent, less during the 5 years than those protected (fig. 2). The computed total volume of peeled wood per acre in the dominant stand at the start, in 1928, was 183 cubic feet on the protected plot as against 233 cubic feet on the burned plot, yet the volume increase of the dominant stand was 362 cubic feet on the protected plot as against 299 cubic feet on the burned plot.[7]

Corresponding with the 23-percent reduction in height growth at McNeill, Cary (*10*) observed the rate of height growth of young

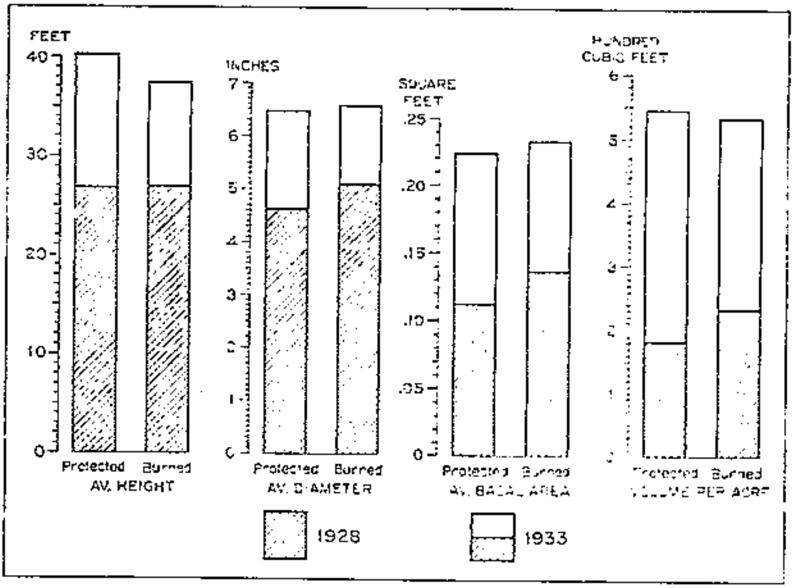

FIGURE 2.—The effect of annual burning on the development of dominant stands of second-growth longleaf pine, during a 5-year period.

timber to be reduced by 20 to 25 percent by annual winter burning. The retardation in growth of longleaf pine as a result of continued light burning has also been shown by MacKinney (*40*).

Table 1 also shows a perceptible but probably not statistically significant benefit from grazing. Such a difference, if it is real, would seem reasonably well explained by the reduction in the amount of grass fuel and hence in the height of flames.

[6] This result from sample-plot work was checked against a similar contrast in growth rates on 299 scattered second-growth trees measured in 1927 and 1933 in connection with cone counts. The latter determination (on an ungrazed area) showed diameter growth in 6 years of 2.12 inches on burned land and 2.48 inches on unburned land. The difference of 0.36 inch in favor of protection had a standard deviation of 0.05 inch, signifying that the probability of this difference being due to chance was slight.

[7] In computing these volumes, the possibility of woods burning having affected the bark of the trees was not considered. Later determinations of bark thickness on these trees showed that bark was slightly, but consistently, thinner for the burned plot (*68*). The mean difference in single bark thickness on 700 trees, 2 to 8 inches in diameter, was 0.033 inch, plus or minus a standard error of 0.001 inch. The resultant bias of 0.066-inch diameter inside bark at breast height (double bark thickness) would not change the estimate of volume of peeled wood by more than 2.5 percent. The effect of fires on bark thickness was only two-thirds as great here as in a study at Lanes, S. C., reported by MacKinney (*41*).

TABLE 1.—*Effect of burning and grazing on second-growth stands of longleaf pine, as shown by differences in height, diameter, basal area, and volume per acre, 1928 and 1933* [1]

Basis of measurement and condition of plot	Unburned versus burned plots					Ungrazed versus grazed plots				
	1928	1933	Growth		Basis, trees	1928	1933	Growth		Basis, trees
DIFFERENCES IN AVERAGE HEIGHT										
All trees in stand:	*Feet*	*Feet*	*Feet*	*Percent*	*Number*	*Feet*	*Feet*	*Feet*	*Percent*	*Number*
Protected	16.9	29.4	12.5	74	659	17.7	28.7	11.0	62	464
Unprotected	17.6	26.3	8.7	49	373	16.6	27.7	11.1	67	568
Dominant stand:										
Protected	26.8	40.3	13.5	50	152	27.1	38.9	11.8	44	152
Unprotected	26.9	37.3	10.4	39	141	26.6	38.9	12.3	46	141
DIFFERENCES IN AVERAGE DIAMETER BREAST HIGH [2]										
All trees in stand:	*Inches*	*Inches*	*Inches*	*Percent*	*Number*	*Inches*	*Inches*	*Inches*	*Percent*	*Number*
Protected	2.9	4.2	1.3	45	659	3.1	4.4	1.3	42	464
Unprotected	3.4	4.5	1.1	32	373	3.0	4.3	1.3	43	568
Dominant stand:										
Protected	4.6	6.5	1.9	41	152	4.8	6.4	1.6	33	152
Unprotected	5.1	6.6	1.5	29	141	4.8	6.6	1.8	38	141
DIFFERENCES IN AVERAGE BASAL AREA										
All trees in stand:	*Square feet*	*Square feet*	*Square feet*	*Percent*	*Number*	*Square feet*	*Square feet*	*Square feet*	*Percent*	*Number*
Protected	0.0464	0.0989	0.0525	113	659	0.0548	0.1060	0.0512	93	464
Unprotected	.0623	.1087	.0464	74	373	.0503	.0998	.0495	98	568
Dominant stand:										
Protected	.1129	.2245	.1116	99	152	.1231	.2248	.1017	83	152
Unprotected	.1379	.2338	.0959	70	141	.1269	.2335	.1066	84	141
DIFFERENCES IN VOLUME PER ACRE										
All trees in stand:	*Cubic feet*	*Cubic feet*	*Cubic feet*	*Percent*	*Number*	*Cubic feet*	*Cubic feet*	*Cubic feet*	*Percent*	*Number*
Protected	260	888	628	242	659	256	721	465	182	464
Unprotected	263	631	368	140	373	266	797	531	200	568
Dominant stand:										
Protected	183	545	362	198	152	212	552	340	160	152
Unprotected	233	532	299	128	141	202	525	323	160	141

[1] Unburned plots had been protected from fire and burned plots burned annually for 5 years previous to first measurement. The figures are average measurements from a grazed half acre and an ungrazed half acre. Ungrazed plots had been protected from grazing, and grazed plots grazed annually, for 5 years previous to first measurement. The figures are averages from a burned and an unburned half acre. The number of trees shown as the basis for computation thus indicate the number per acre found in the field, minus seedlings less than 4½ feet tall and a very few trees of abnormal form. Measurements of all trees in stand, other than for volume, include additional trees as follows: Unburned, 5; burned, 22; ungrazed, 11; grazed, 16. These were mostly small suppressed trees not destined to survive long enough to affect the volume of commercial products.

[2] 4½ feet above ground level.

SEEDLING STANDS

SURVIVAL OF SEEDLINGS

The longleaf pine seed crops of 1924 and 1927 alone furnished sufficient seedlings to supply an adequate base for studies of survival. The scanty germination from other seed crops was mapped, but the seedlings were not numerous enough to show significant trends. Unimportant also were the occasional seedlings of other pine species.

The well-recognized tendency of slash pine under the influence of protection from fire to migrate slowly from swamps to better-drained soils was observed but not specifically studied.

Although no counts of longleaf pine cones were made in 1924, 1 year after the experiment started, the yield of seed appeared heavier than in any subsequent year. In 1927, a definitely lighter seed year, the cone crop averaged 24 cones per tree. In that year, by counting

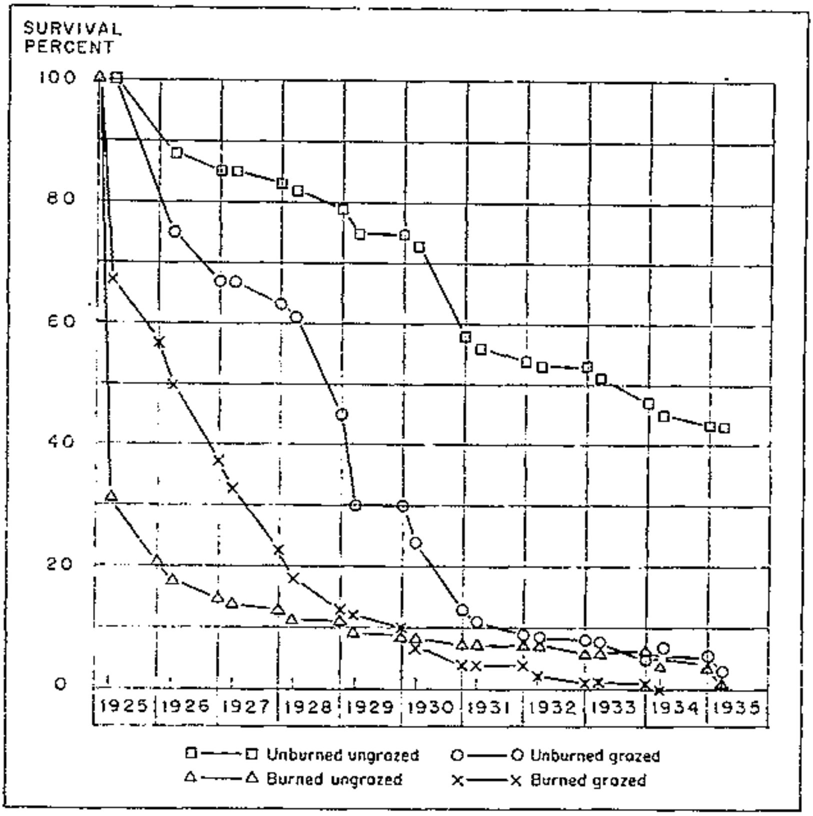

FIGURE 3. Survival of 1924 seed crop of longleaf pine seedlings. Plotted points indicate two examinations each year, before and after fire.

and cutting seeds that were caught in traps, it was estimated that between 71,000 and 82,000 good seeds per acre fell on most of the area.

The main facts in the life history of the two significant crops of longleaf seedlings (1924 and 1927) that occurred during the course of these observations are shown numerically in tables 2 and 3. The trends of mortality of the two seed crops under different treatments are indicated in figures 3 and 4.

TABLE 2.—*Survival of longleaf pine seedlings from seed crop of 1924* [1]

Overwood or grass type and treatment	Area basis for counts	Original stand per acre, 1925	Survival			Stand per acre in 1934 [2]
			1926	1930	1934	
Open—no overwood:	*Milacres*	*Seedlings*	*Percent*	*Percent*	*Percent*	*Seedlings*
Burned pasture	152	16,850	59	11	0	33
Burned ungrazed	62	15,302	32	15	7	1,143
Unburned pasture	117	15,145	74	30	4	624
Unburned ungrazed	56	18,714	90	82	53	9,929
Advance reproduction:						
Burned pasture	49	6,439	33	4	0	20
Burned ungrazed	25	10,120	3	1	0	40
Unburned pasture	46	10,326	93	35	7	717
Unburned ungrazed	37	7,835	76	55	21	1,676
Seed trees:						
Burned pasture	9	6,000	67	6	0	0
Burned ungrazed	12	35,417	6	0	0	83
Unburned pasture	17	17,588	52	17	1	176
Unburned ungrazed	7	33,571	91	67	24	8,143
All conditions together:						
Burned pasture	210	13,956	57	10	0	29
Burned ungrazed	100	10,420	21	9	5	740
Unburned pasture	180	14,144	75	30	4	606
Unburned ungrazed	100	15,730	88	75	43	6,750
Native grass:						
Burned pasture	163	14,575	59	12	0	37
Burned ungrazed	89	17,652	20	9	4	787
Unburned pasture	158	14,032	79	33	5	654
Unburned ungrazed	93	15,978	88	75	43	6,946
Carpet grass:						
Burned pasture	44	7,643	1	0	0	0
Burned ungrazed	0					
Unburned pasture	5	24,600	2	1	0	0
Unburned ungrazed	0					

[1] The data shown separately for native grass and carpet grass are from a regrouping of the same milacre plots used in the classification of overwood conditions. The area basis shown for the results in grass is smaller than that for all conditions together, because certain milacres in transition from one type to another could not be included in the analysis of effects of grass.

[2] After 10 fires on the burned areas.

TABLE 3.—*Survival of longleaf pine seedlings from seed crop of 1927* [1]

Overwood or grass type and treatment	Area basis for counts	Original stand per acre, 1928	Survival		Stand per acre in 1934 [2]
			1929	1934	
Open—no overwood:	*Milacres*	*Trees*	*Percent*	*Percent*	*Trees*
Burned pasture	152	6,150	4	0	0
Burned ungrazed	63	5,330	10	0	0
Unburned pasture	117	6,692	44	2	154
Unburned ungrazed	56	8,804	16	18	1,625
Advance reproduction:					
Burned pasture	49	10,380	0	0	0
Burned ungrazed	25	1,200	30	0	0
Unburned pasture	46	3,173	47	1	43
Unburned ungrazed	37	3,405	48	7	243
Seed trees:					
Burned pasture	9	2,220	0	0	0
Burned ungrazed	12	28,000	1	0	0
Unburned pasture	17	9,294	39	1	118
Unburned ungrazed	7	11,714	74	21	2,429
All conditions together:					
Burned pasture	210	6,909	2	0	0
Burned ungrazed	100	7,018	7	0	0
Unburned pasture	180	6,098	43	2	122
Unburned ungrazed	100	7,010	59	17	1,170
Native grass:					
Burned pasture	164	7,630	2	0	0
Burned ungrazed	95	7,340	7	0	0
Unburned pasture	193	4,632	55	3	135
Unburned ungrazed	96	7,000	58	17	1,167
Carpet grass:					
Burned pasture	46	4,710	3	0	0
Burned ungrazed	5	1,000	0	0	0
Unburned pasture	16	31,000	16	0	0
Unburned ungrazed	1	7,000	86	43	3,000

[1] See footnote 1, table 2.

[2] After 7 fires on the burned areas.

Early in 1926, after the first growing season, the survival of seedlings originating from the seed crop of 1924 clearly showed a detrimental effect of fire. Under average conditions of overwood (table 2) the percentage of survival for the unburned ungrazed plots exceeded

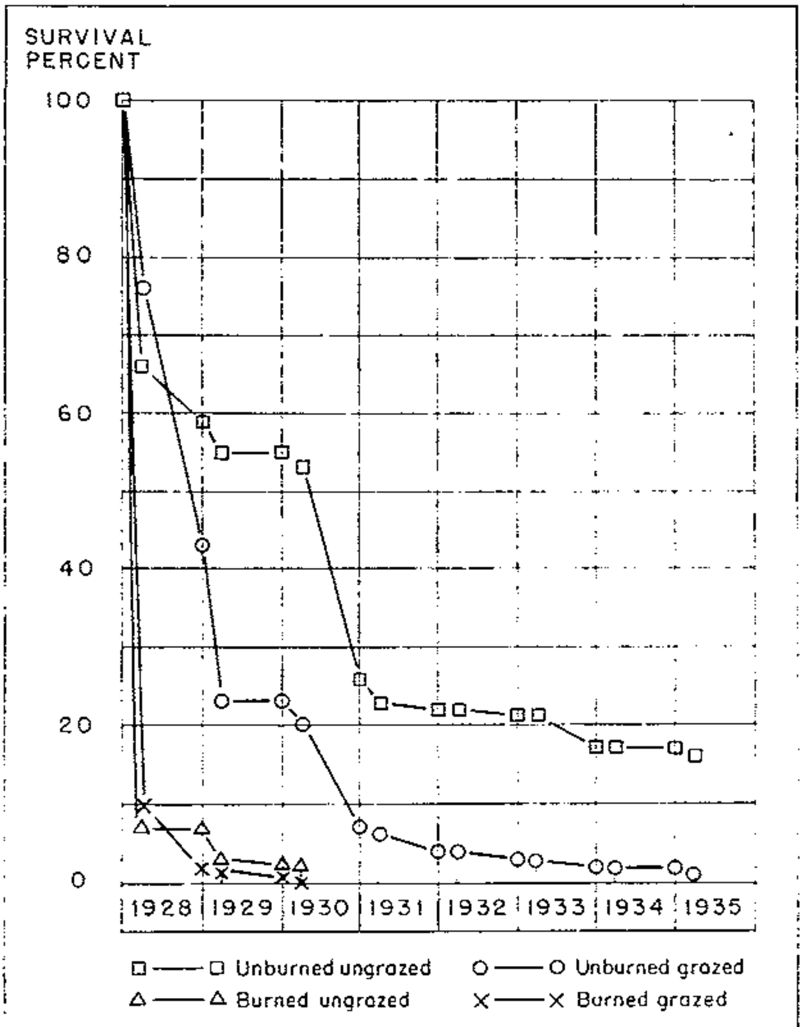

FIGURE 4. Survival of 1927 seed crop of longleaf pine seedlings. Plotted points indicate two examinations each year, before and after fire.

that of the burned ungrazed plots by 67 percent. The difference on the pastures was not so great (18 percent), but still clearly in favor of the unburned area. Similar differences in early survival were noted for the seedlings of the 1927 crop under average overwood conditions in 1929 (table 3). The survival percentage for unburned land exceeded that on burned land by 52 percent where there was no grazing, and by 41 percent on the pastures. These first fires were less detrimental on the pasture, apparently because grazing removed some of the grass fuel, thus reducing the intensity of the fire.

Regardless of grazing, however, the resistance of yearling or younger longleaf pine seedlings to fire is usually very low. The mortality of 3-month-old seedlings (of the 1927 crop) after the first fire was more than 90 percent whether grazed or not (fig. 4), leaving less than 1,000 seedlings per acre on the burned plots, or less than enough for satisfactory regeneration even in the absence of any further detrimental effects (burning, grazing, or disease). Thus destruction by fire was quite prompt and decisive in this case.

The seedlings from the seed crop of 1924 suffered less from their first fire, and as the initial stands were much denser the remaining stands appeared adequate for regeneration, barring excessive injury in subsequent years. As is indicated in figure 3, mortality of 3-month-old seedlings of 69 percent on the burned and ungrazed plot left about 6,000 seedlings per acre, and of 33 percent on the burned pasture about 9,000 seedlings per acre.

Later (in 1934) the survival of seedlings was 43 percent for the 1924 crop in its tenth year and 17 percent for the 1927 crop in its seventh year on unburned and ungrazed land. For each of the other three land treatments (and for each of the two crops of seedlings) survival averaged in all cases not over 5 percent, which amounted to less than 800 seedlings per acre.

Grazing also reduced the survival of longleaf pine seedlings (tables 2 and 3 and figs. 3 and 4). On burned land the reduction of inflammable material by grazing reduced fire damage in most places enough to balance the grazing damage, so that there was little difference in survival. In the early years these survival differences were not always large or entirely consistent. Later, probably because the seedlings still remained in the grass stage, the grazing damage accumulated to the extent that it stood out more clearly on both unburned and burned land. In resultant stands seedlings were uniformly most numerous on areas both unburned and ungrazed.

Browsing by the cattle probably injured a few of the smaller seedlings, but on the whole browsing injury appeared entirely negligible except under heavy grazing or on carpet grass areas, all of which were closely grazed regardless of stocking. The larger and older seedlings develop a heavy plume of resinous foliage that is avoided by cattle. It was the indirect effect of grazing, through trampling and compacting of soil or other factors, that became evident as time went on and the seedlings remained in the stunted condition.

It was observed in taking the field records that most of the grazing injury was indirect. Direct mechanical damage to seedlings from browsing the needles, breaking or injuring buds, stems, or bark, was rare, and appeared entirely negligible except under conditions of heavy stocking as in 1928 (one steer to each 5 acres), or on areas where cattle habitually concentrated.

Discussion of the tendencies in early survival has so far been based largely on the experimental area as a whole, regardless of a wide range in overwood conditions between the various sample plots. Native grasses, with prairie and slender beardgrasses predominant, cover most of the area, though small patches of pure stands of grazed carpet grass (*Axonopus compressus*) crowded out the native species in many spots.

On the carpet-grass areas the pine seeds germinated satisfactorily, but generally they failed to survive even the first growing season. Five years after germination all 1927 seedlings in grazed carpet-grass areas were dead. Seedlings of the 1924 crop surrounded by carpet grass were 98 percent or more dead the first year and entirely gone at the end of 10 years on all plots. Mortality is ascribed to grazing and trampling by cattle. Having insufficient fuel, these carpet-grass areas failed to burn over, but they were invariably grazed so closely that the pine seedlings were killed. Thus it appears that grazing and reproduction of longleaf pine on carpet-grass areas are not at all compatible.

Openings on the experimental area occupied by native grasses covered roughly two-thirds of the intensively studied plots. Survival percentages differed somewhat between the open areas and the other conditions shown in tables 2 and 3, but the same general trends held true. By the end of the tenth growing season more than half (53 percent) of the 1924 stand of seedlings in open areas was still surviving on the ungrazed, unburned plot, whereas less than a tenth (0 to 7 percent) of the original stands survived the other three treatments. Of the 1927 seed crop, seedlings on the burned pasture succumbed in all types after the third fire, and those on the ungrazed plot failed to survive the fourth fire (fig. 4). Survival on unburned open areas in 1934 was 18 percent for complete protection, 2 percent on the unburned pasture, and zero on the burned plots.

While seedlings under seed trees may be valuable if kept alive until removal of the larger trees makes room for them to grow, the forester is most vitally concerned with the problem of raising pine seedlings that come in in open portions of the forest. It seemed essential therefore that special consideration be given to the relative rate at which open areas filled in with new seedlings. Seed crops of several different years contributed to the establishment of the seedling stand. Therefore the combined effect of longleaf pine seedlings which came in during the course of the experiment, regardless of the seed crop from which they originated, was determined on the intensively studied field plots by the stocked-quadrat method (*24*) in order to determine the rate of filling in openings. Each milacre quadrat (0.1 by 0.1 chain) with one or more seedlings regardless of age was recorded as stocked. Four or more ages were represented by seedlings originating from seed crops in 1931, 1927, 1924, and earlier years. The percentage of the total number of previously unoccupied quadrats found to be stocked at any time indicated the current degree of success in regeneration of open areas. Only current success is indicated, because indeterminate numbers of these seedlings are not permanently established and those that do not survive may or may not be succeeded by the establishment of new seedlings.

This method was applied to those portions of plots in the survival study classed as free of overwood in 1930. Thus confined to areas with room for more trees, the rate with which the openings were being regenerated was observed without regard to density of the new stand. Trends in this filling-in process are shown in figure 5. The influx of new seedlings subsequent to the 1924 seed crop tended to sustain the proportion of the area thus fully stocked. This influx was composed of rather short-lived seedlings, however, since the curves show only temporary peaks, as in 1927 and 1931. The position of the curve on any date represents the net result of gain and loss in percentage of total area occupied at the time. After the fire of 1933 the percent of stocking of open areas with longleaf pine seedlings was as follows: Burned pasture, 25; burned-ungrazed area, 41; unburned pasture, 61;

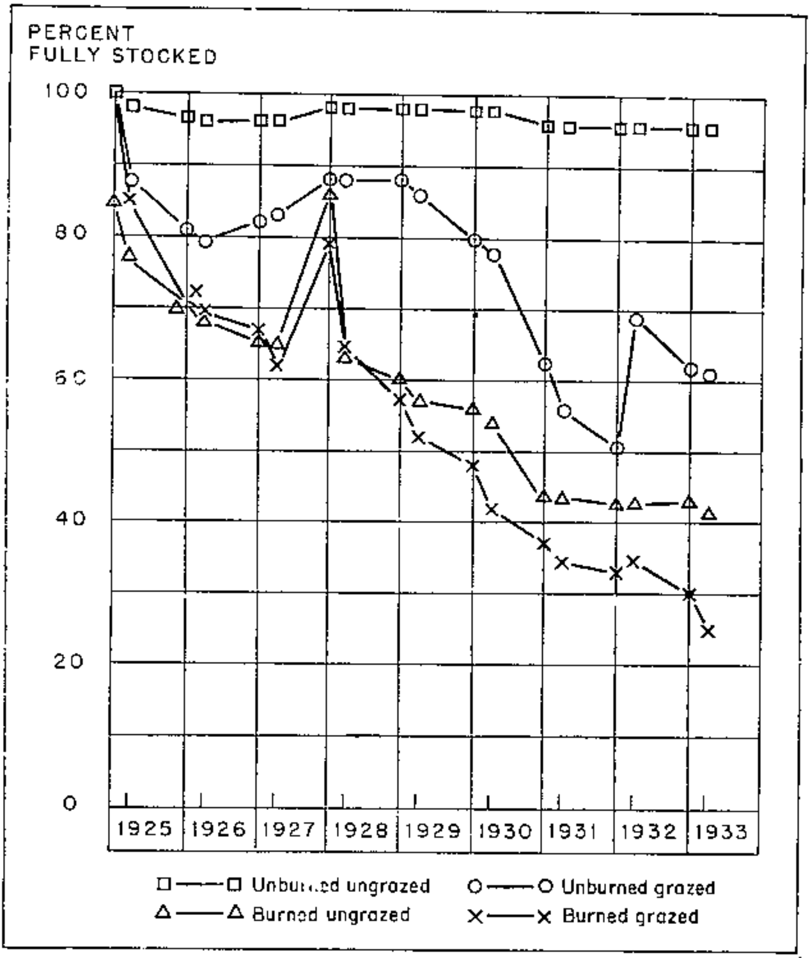

FIGURE 5.—The proportion of open areas fully stocked with longleaf pine seedlings from the 1924 and subsequent seed crops, as affected by burning, grazing, and protection therefrom. Plotted points indicate two counts each year, before and after fire.

and unburned-ungrazed area, 96. These results rank in the same order as the total survivals shown in tables 2 and 3.

SIZE OF SEEDLINGS

So far the different land treatments have been compared on the basis of the relative survival of seedlings from two principal seed crops, with some reference to the rate at which forest regeneration might be expected to encroach on open areas. Whether these open areas will actually fill in with trees depends of course upon whether seedlings become permanently established and grow. The preponderance of survivors now on the plot completely protected from grazing and burning will have little significance if the seedlings are unable to grow enough to emerge from the grass. After more than 13 years no seedling of the 1924 crop had made an appreciable start in height growth. Dimensions of the stems of some of these seedlings measured with micrometer calipers in tenths of inches in 1933 are given in table 4. The average size of seedlings was larger on the burned areas than on the unburned areas. The seedlings on grazed areas were found to be smaller than on ungrazed areas whether burned or not.

TABLE 4.—*Stem development of longleaf pine seedlings of 1924 crop in the grass stage as affected by land treatment, 1933*

Conditions of study	Basis, seedlings	Average seedling				Tallest seedling		Thickest seedling	
		Mean diameter	Mean height	Basal area at ground	Volume[1]	Diameter	Height	Diameter	Height
Seedlings 8½ years old:									
No fire:	*Number*	*Inches*	*Inches*	*Square inches*	*Cubic inches*	*Inches*	*Inches*	*Inches*	*Inches*
Ungrazed plot	811	0.44	1.18	0.152	0.060	0.8	3.5	0.9	1.5
Pasture	177	.39	1.02	.119	.041	.3	2.3	.7	2.0
After 9 annual burns:									
Ungrazed plot	103	.63	1.32	.221	.097	.8	3.1	.8	3.1
Pasture	29	.46	1.14	.168	.063	.6	2.0	.6	2.0

[1] Stem volumes were cubed as cones.

In January 1937, when the surviving seedlings, now 12 years old, were again measured, 573 on the unburned plot averaged only 1.53 inches high and 0.47 inch in diameter at the ground level. The smallest was a puny specimen only 0.3 inch high and 0.2 inch thick, while the largest was 7.3 inches high and 1 inch thick. The 54 survivors found on the burned ungrazed plot were somewhat larger, averaging 2.41 inches high and 0.65 inch thick. The largest one was 5.7 inches high, 1.1 inches in diameter, and apparently on the verge of active growth. The typical seedlings in both burned and unburned plots, however, remained severely stunted (fig. 6).

Among the numerous causes, other than burning and cattle grazing, that commonly contribute to stunting and death of longleaf pines in the grass stage, hogs, brown spot disease (*Septoria acicola*), grass competition, and soil conditions are major factors. In the present study, only burning and cattle grazing were thoroughly and systematically tested, though brown spot was recognized as a major influence. Insects were not a major factor although a sawfly (*Neodiprion lecontei*) was unusually abundant in 1932 and caused defoliation of numerous longleaf pine seedlings in the grass.

The possible effect of grazing in increasing the brown spot disease, through reduction of grass and consequent greater exposure of the smaller seedlings to infection, appears to have been negligible. The effect of fire in reducing infection, on the other hand, was obvious. After 10 years of annual burning and exclusion of fire, random samples taken in October 1933 revealed the status of this disease to be as shown in figure 7. The proportion of diseased and dead foliage, as shown on the horizontal axis of the chart, represents the degree of infection or condition of individual seedlings. The number of seedlings in this condition, in terms of percentage of total plants, is shown on the vertical scale. Thus 14½ percent of the seedlings had the degree of infection most commonly found on the protected plot, or 35 percent, whereas 37 percent of the seedlings on the burned plot were typically less than 5-percent diseased. The average amount of infection was 34 percent on the unburned area, and less than half as much, 13½ percent, on the area burned annually. The disinfecting action of fire seems to be clearly reflected.

The larger size of the 1924 seedlings on the burned plot may be ascribed in part to retardation of the brown spot disease by fire, and in part to the relatively higher mortality of the smaller seedlings on the burned area, which left only the larger ones for measurement, thus raising the average size. The seedlings on the unburned plot, the larger ones even more than the smaller ones, were badly infected with brown spot, which was doing a more thorough job of defoliation than was annual fire.

The brown spot disease was serious also 20 miles west of McNeill, at Bogalusa, La., where it was regarded as epidemic. Intensive

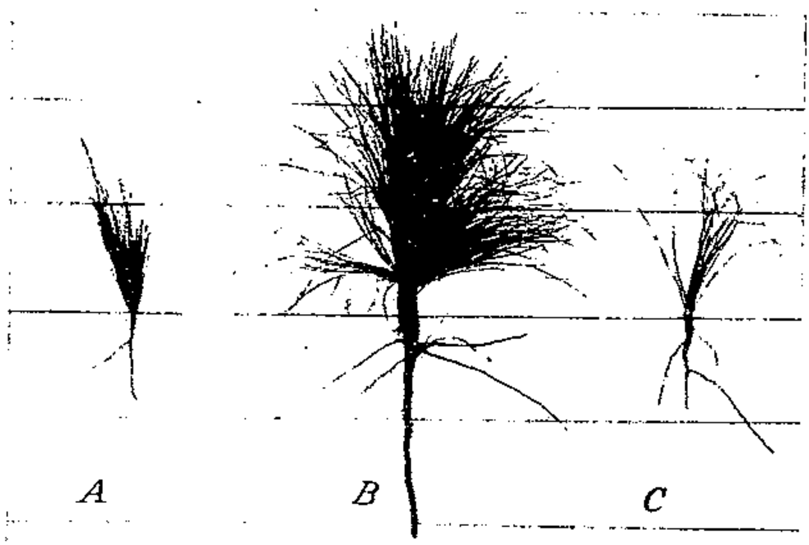

FIGURE 6.—Typical longleaf pine seedlings that grew under different burning conditions on the McNeill study area. The horizontal lines are 6 inches apart. The taproot of each tree is broken at the lower end. *A*, A typical 9-year-old seedling from the burned check plot, less than half an inch in diameter and, without any definite terminal bud, still unprepared for active height growth. *B*, A seedling from an adjacent area exposed to irregular periodic burning (not annual) during its early years, a type commonly regarded as 5 years old; it has a diameter of approximately 1 inch at the ground line and illustrates the general development necessary before the longleaf pine seedling can begin active height growth. *C*, A seedling from the unburned check plot of the same age as *A*; its lack of development was due to the effects of the brown spot needle disease.

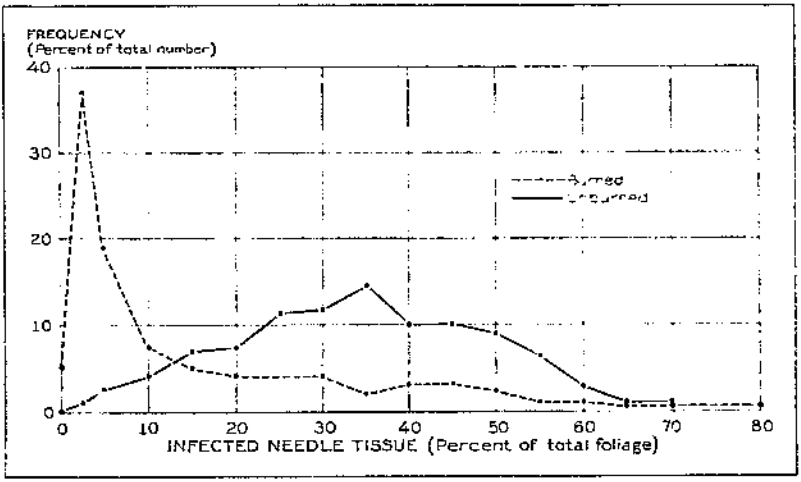

FIGURE 7.—Frequency of infection by brown spot needle disease and percent of infected needle tissue of longleaf pine seedlings on burned and unburned areas after 10 years of annual woods burning. Each curve is based on 200 representative seedlings in the grass stage selected at random and examined in October 1933.

studies were made by Siggers (*53*) there and at numerous other points. A similar situation prevailed also on the Parker plots at Urania, La., which were utilized by Chapman in some of his early work (*12*).[8] Less severe stages of the disease were observed on the Chapman forest area at Urania in 1931, where only a negligible amount of foliage was infected 4 years after fire.[9] This relatively light infection of a tract in the same general vicinity as the Parker plots illustrates the local occurrence of epidemics of brown spot disease.

Siggers' research (*54*) has shown that a single fire greatly reduces the effects of disease in the first season following and often to a lesser extent in the second season. This reduction in disease permits the development of seedlings as a result of the retention of foliage through a second season.

Few, if any, of the surviving seedlings in the native grass areas of the McNeill study area, all badly stunted regardless of the land treatment, can be expected to begin normal height growth in the near future, because after more than 12 years they have attained only about half or two-thirds the size necessary before active growth can start. In a separate study[10] it has been shown that although some longleaf pine seedlings may become 1 inch in diameter at the surface of the ground, and a few of them slightly larger, without growing actively in height, the great majority of them—regardless of age—do not make the normal spurt in height growth until they attain a ground diameter of at least 1 inch. This is the best single criterion of the imminence of normal active height growth. The general development necessary before the longleaf pine seedling can begin active height growth is shown in figure 6, *B*.

[8] The McNeill and Parker areas were both examined by P. V. Siggers by identical methods and at the same season of the year. The McNeill unburned area averaged 34 percent in October 1933, after 10 years' exclusion of fire, whereas the Urania area averaged 32 percent in October 1931, 6 years after a fire.

[9] Examinations made by P. V. Siggers, October 1931, by standard method.

[10] WAHLENBERG, W. G. DENSE STANDS OF REPRODUCTION AND STUNTED INDIVIDUAL SEEDLINGS OF LONGLEAF PINE. U. S. Forest Serv., South. Forest Expt. Sta. Occas. Papers 39, 16 pp., illus. 1934. [Mimeographed.]

Thus even though the heavy seed crop of 1924 germinated in profusion, producing an abundant stand of normal seedlings, the surviving seedlings slowly stagnated until, after 12 years, the failure of this 1924 crop to develop, regardless of the treatments tried, was obvious. Too frequent scorching and loss of foliage, the ravages of brown spot, and the competition of grass appear to have been the main causes. The outstanding fact, then, is the failure of both annual burning and the complete exclusion of fire to permit the development of longleaf pine seedlings.

The earlier reproduction of longleaf pine, however—those seedlings that became well established before the experiment started—has developed in recent years both under annual burning and complete exclusion of fire, and whether grazed or not. The apparent reason for this difference in response is that when the seedlings reached 2 or more feet in height they were highly resistant to any further serious injury from brown spot, grazing, fire, smothering by debris, or competition of any other vegetation except larger trees. The larger second-growth pines on the experimental area emerged from the grass about 1906. Whether or not these developed trees went through a long period as stunted seedlings could not be determined. It has been shown by Pessin (*45*) that the total age of longleaf pines unfortunately cannot be ascertained even by miscroscopic observation of cut sections. Recently he has reported (*46*) that 12-year-old, badly diseased and stunted longleaf pine seedlings in Louisiana showed prompt recovery and phenomenal growth as soon as the causes of stunting were removed.

EFFECTS ON THE FORAGE COVER

In the longleaf pine region of the South, winter burning to remove what is locally spoken of as a "rough," has been practiced for a long time with little thought of any harm that might be done. Following such disposal of the dry, dead portions of the grass growth of the previous season, together with the fallen pine needles (or pine straw), it was evident to every observer that the burned woods greened earlier and that cattle had a very decided preference for the burns and would not graze the rough in the early spring unless forced to it. Cattlemen have often said that they burn in order to green up the grass and get earlier pasture. In some sections a succession of unburned patches is left so that the cattle and sheep can pick forage out of the rough while the burns are greening, after which a clean burn of the remainder of the woods is made. No apparent harm to the native grasses has resulted from this winter burning. Local cattlemen have considered this practice essential as a form of pasture or range management and also believe that it reduces the number of ticks, redbugs, and snakes. The timber owners and cattlemen agree that annual winter burning is a means of protection against the summer and fall fires that are so destructive to both grass and merchantable timber where the litter has been allowed to accumulate and provide fuel. In the early days, except where turpentining was in progress and the turpentine operator wished to burn over his own woods because of the special care required, burning by cattlemen was regarded by the timber owner as a convenient arrangement which saved him the expense of burning his own land.

It was only when thought was given to the need for forest reproduction and growth that serious objection was made to grass burning and the value of the practice was questioned. Opponents of burning claimed that it did not actually give earlier grass. They also claimed that the stands of grass were reduced and that the best grasses and legumes were prevented from spreading and improving the pasture. It was argued by many people that the region would not reforest at all to longleaf pine if the cattlemen were allowed to continue burning the woods. Up to 1923, when the present experiment was established, there was a dearth of published factual material. In view of the importance of the question, it was evident that exact information obtained by experiment in the longleaf region was much needed.

DESCRIPTION OF PASTURES

The division of the experimental area, which has already been described, gave two pastures of 150 acres each, the south pasture being burned annually and the north pasture protected from fire throughout the experiment. The hardwood swamps and open pine areas available for grazing are shown in figure 1.

The pine reproduction ranged from poor to dense but was much more abundant than that commonly found on cut-over lands. The scattered growth of oaks and other hardwoods associated with the pine was considered average for the length of time since cutting.

The native forage plants were typical of virgin lands in southern Mississippi, as shown by a careful strip survey of Pearl River County [11] in which the experimental tract was located. The predominating stand was made up of prairie beardgrass (*Andropogon scoparius*), a broadleafed clump grass, and slender beardgrass (*A. tener*), a narrow-leafed clump grass.[12] Both of these grasses are grazed readily by cattle, specially early in the season and where close grazing has encouraged a lush growth. Neither should be confused with broomsedge (*A. virginicus*) or "wire grass," an indefinite term applied to various grasses of low grazing value. The local wire grass is *Muhlenbergia expansa* and is not the same as the wire grass of the eastern range of longleaf pine. Numerous other grasses were found in scattered stands but were not abundant enough, separately, to make up an important part of the forage growth. Fifty-four species of native grasses were collected from the experimental area and identified. (See Appendix, p. 51.)

At the beginning of the experiment the 2 pastures were mapped to show the extent of pine second growth in the following classes, depending on density of stands: Forty-six acres had more than 750 saplings per acre about 20 years old, under which the grasses were already being shaded and smothered out by the pine straw; 32 acres had between 400 and 750 saplings or seedlings per acre of a smaller size but large enough to offer some competition to forage growth; 160 acres had less than 400 pines per acre and these had not made sufficient height growth to shade out pasture grasses; 62 acres were occupied by hardwoods in swamps where no forage was produced. Most

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[11] The strip survey, made by H. R. Reed in 1932, covered an area of 510,000 acres by examination strips spaced 6 miles apart and extending the width of the county. Examination plots were located at each one-eighth of a mile on these strips and plots were examined by the same methods used on the plots in the experiment here reported. The data are unpublished (1933).

[12] Grass specimens were identified in A. S. Hitchcock's office, National Herbarium, U. S. Department of Agriculture. Legume specimens were identified by Roland McKee of the Division of Forage Crops and Diseases, U. S. Department of Agriculture.

of the grazing was on the 192 acres of poor or fair pine reproduction at the beginning of the experiment, and this area, free from dense shade and straw fall, was gradually reduced during the period of 11 years of grazing. It is evident that the pasture was an inferior one as compared with newly cut-over pinelands and that not as good gains could be expected from the cattle as might have been obtained on the same area during the 20-year period immediately following the cutting of the virgin timber. However, it was possible to divide the area in such a way as to equalize the conditions on the 2 pastures quite satisfactorily for purposes of comparison.

Along old log roads several patches of carpet grass had become established, but these were estimated at the start of the experiment to amount to only about 3 acres in each pasture. Carpet grass, an introduced turf grass, is relished by cattle and has a much higher carrying capacity per acre than the native clump grasses, to which it is preferred after midsummer. Two other introduced grasses, Bermuda grass (*Cynodon dactylon*) and Dallis grass (*Paspalum dilatatum*), were found on the pastures but were not important. Twenty-five species of native legumes, mostly perennial, were well distributed and did not occur in pure stands. Very little of the introduced annual lespedeza (*Lespedeza striata*) was present. These forage plants are discussed in more detail in the section on composition of forage.

CATTLE USED AND METHOD OF GRAZING

Since the variable factor in this experiment was the use of fire, all other controllable factors were held the same on both pastures.

Either native cattle or Herefords crossed with the native cattle and raised locally were used throughout the experiment. For the first two grazing seasons it was necessary to use breeding cows. From 1925 until 1933, 2- to 4-year-old steers were used. The average weight when put on pasture was 561 pounds. The steers were fattened for market each winter and replaced by other steers purchased locally. The cattle were divided as equally as possible for breeding, weight, and condition each year.

For the first 5 years grazing was maintained at one head for each 10 acres, a commonly accepted rate. During the sixth year the rate of grazing was doubled to one head for each 5 acres. During the seventh, eighth, and ninth years the rate of grazing was one head to each 7½ acres. During the tenth and eleventh years the rate was again reduced to one head to each 10 acres. The average rate of grazing was one head to each 8.9 acres, although a considerable portion of the area used produced no forage.

For dipping and weighing, the cattle from both pastures were handled at the same time, being driven about 2 miles to central headquarters each time. Weighing was performed regularly at 28-day intervals during the experiment, except when it was necessary to dip for fever ticks at 14-day intervals.

From 1923 until 1929 the animals were dipped only enough to keep them fairly free from ticks but not with the intention of eradicating the ticks. In 1929 dipping under Federal tick eradication supervision was compulsory, and the cattle were dipped regularly each 14 days throughout the entire grazing season. The dip used during 1929 was stronger than that previously used.

In 1929 it proved necessary to give the cattle of both pastures supplementary feeding of cottonseed meal during the last 2 months of the season, but no extra feed on pasture was supplied to the cattle during the other years of the experiment.

The beginning of the grazing season varied from March 2 to April 24, the average being April 5. During the early years of the experiment the cattle were not turned on pasture until it was considered that the unburned pasture would support them, or from the first to the middle of April. In this region the native grass is available earlier on burned than on protected pastures, and each year until 1932 the burned pastures would have supported the cattle several weeks before the grazing season was actually started. The cattle were left on the pastures each year as long as the forage would carry them without heavy losses in weight, and were removed after the first killing frost, the average date being November 8. The number of days of grazing varied from 196 to 252, with an average of 217 days, or approximately 7 months.

Salt was kept before the cattle at all times and a mineral mixture containing lime and phosphorus was supplied in boxes where the cattle had free access. Water was supplied in each pasture from natural streams.

COMPOSITION OF FORAGE

A number of factors influenced both the quantity and quality of the forage produced on the two pastures and also the type and composition of forage cover. The increases or decreases of each species, showing its relative proportion on the plots from year to year, were determined by estimating the percentage of the total herbage made up by the species at each annual examination. At each examination a record was made of the density of all grasses for each plot in terms of percentage of the plot actually occupied by grasses, a solid stand being considered as 100 percent. Various mechanical methods for recording the plant growth on the plots were tried, but on account of the large number of species considered and because the density of the grasses caused intermingling, mechanical methods were discarded and the visual method of estimating by successive small areas of the plots was adopted. The estimates were made consistently by the same worker during the entire progress of the experiment.

The percentages for increases and decreases of herbage give the proportional changes in the botanical composition for each condition without respect to the total yield of forage. The density percentages give a measure of the proportion of the area for each condition without respect to the composition of the forage.

Data were taken on 54 species of grasses occurring on the plots, but only 3 of these were abundant enough to be important for cattle grazing—the 2 predominating beardgrasses and carpet grass. Carpet grass never reached a relative abundance on either pasture of more than 10 percent of the herbage, but increased fast enough under grazing to be considered a factor in maintaining the carrying capacity of the pastures.

In order to determine differences in quality of forage as affected by burning, samples of the two principal grasses were collected in 1929 and again in 1931 from open areas where shade was not a factor and

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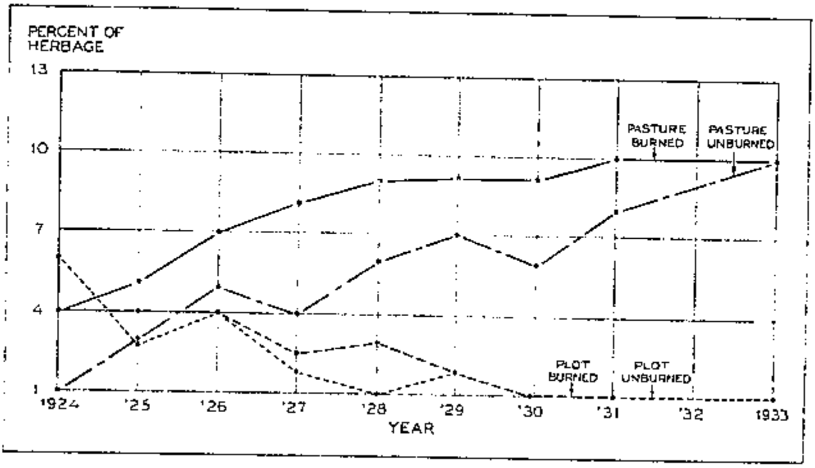


FIGURE 8.—Percent of herbage of carpet grass on burned and unburned pastures and ungrazed plots, 1924–33.

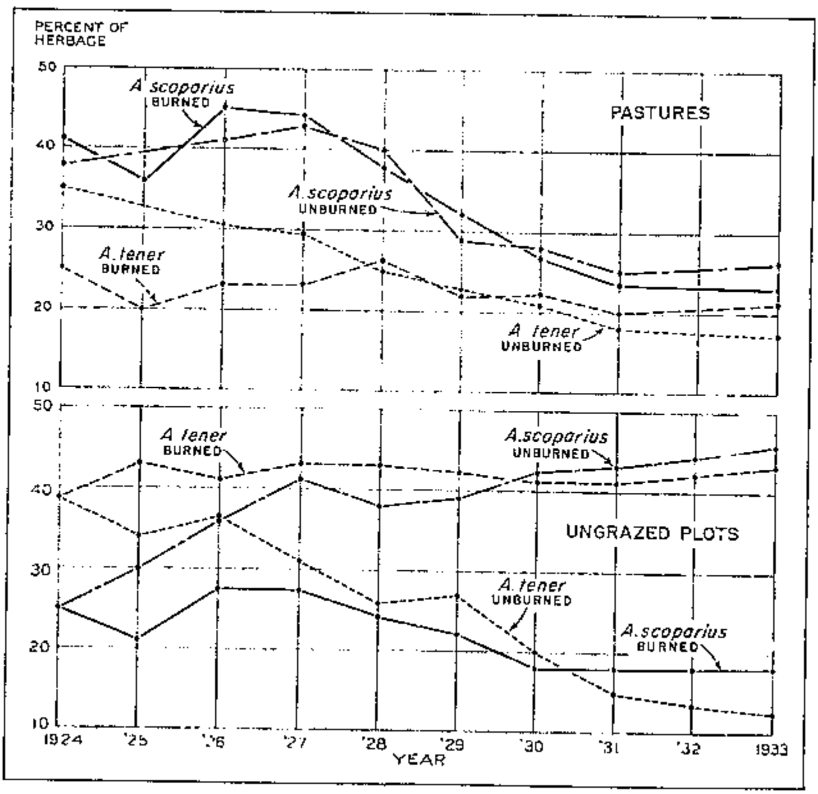


FIGURE 9.—Percent of herbage of beardgrasses on burned and unburned pastures and ungrazed plots, 1924–33.

analyzed for chemical composition. Composite samples were made by cutting the current growth from a large number of random locations and mixing. Samples were taken from April to June during the flush of the early season's growth.

In making the estimates of percentages of herbage, only the grasses were considered and no counts of the legumes were made until 1931, so that the record of the legumes covers relative abundance after different conditions of treatment, rather than increases or decreases. The counts made thus represented the number of individual plants that occurred on the intensive study plots after 9 years of burning or fire protection.

Table 5 gives the relative percentage of herbage of the 3 species of grasses considered at the first examination in 1924 and at the final examination in 1933, and the density of all grasses. Figures 8 and 9 represent graphically the annual changes that occurred in the percentage of herbage made up by these grasses under the 4 experimental conditions. These data were obtained from the 54 intensive study plots each 0.01 acre in area.

TABLE 5.—*Changes in proportion of the principal grasses and in density of stands of all grasses, 1924–33* [1]

PASTURE

Grasses	Burned			Unburned		
	1924	1933	Difference	1924	1933	Difference
	Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
Prairie beardgrass	41	23	−18	38	26	−12
Slender beardgrass	25	21	−4	35	17	−18
Carpet grass	4	10	+6	1	10	+9
All other grasses	30	46	+16	26	47	+21
All herbage (density)	62	21	−41	79	22	−57
UNGRAZED PLOTS						
Prairie beardgrass	25	18	−7	25	46	+21
Slender beardgrass	39	43	+4	39	12	−27
Carpet grass	4	1	−3	6	1	−5
All other grasses	32	38	+6	30	41	+11
All herbage (density)	73	30	−43	79	18	−61

[1] Averages based on fifty-four 1/100-acre intensive study plots.

The data show that there was a considerable reduction in the quantity of forage produced on the unburned as compared with the burned areas. Where dense stands of longleaf pine reproduction occur the fallen pine needles will, if left unburned, eventually eliminate all grass and legume growth, as illustrated in plate 2. The forage is also being slowly reduced on both the burned and unburned areas through competition for light, moisture, and plant food as the stands of pines increase and occupy more space. On both burned and unburned pastures the areas only fairly well or poorly stocked with seedlings or saplings furnished most of the grazing because their open character permitted a luxuriant growth of grass. A comparison of the forest-type map (fig. 1) made in 1924 with a similar map made in 1930 showed that the approximate area available for grazing had decreased about 14 acres on the unburned pasture, and about 26 acres, nearly twice as much, on the burned pasture as a result of the development of advance pine reproduction and second-growth stands (pl. 3). On the other hand, the lack of fire on the unburned pasture has encouraged a growth of scrubby oaks of no commercial value and hardwood shrubs, particularly gallberry (*Ilex glabra*), that have eliminated forage growth (pl. 4). On the burned pasture this hardwood growth has been held well in check by annual burning. It should be pointed out, however, that a certain amount of this hardwood growth may be desirable because it furnishes both cover and food for game.

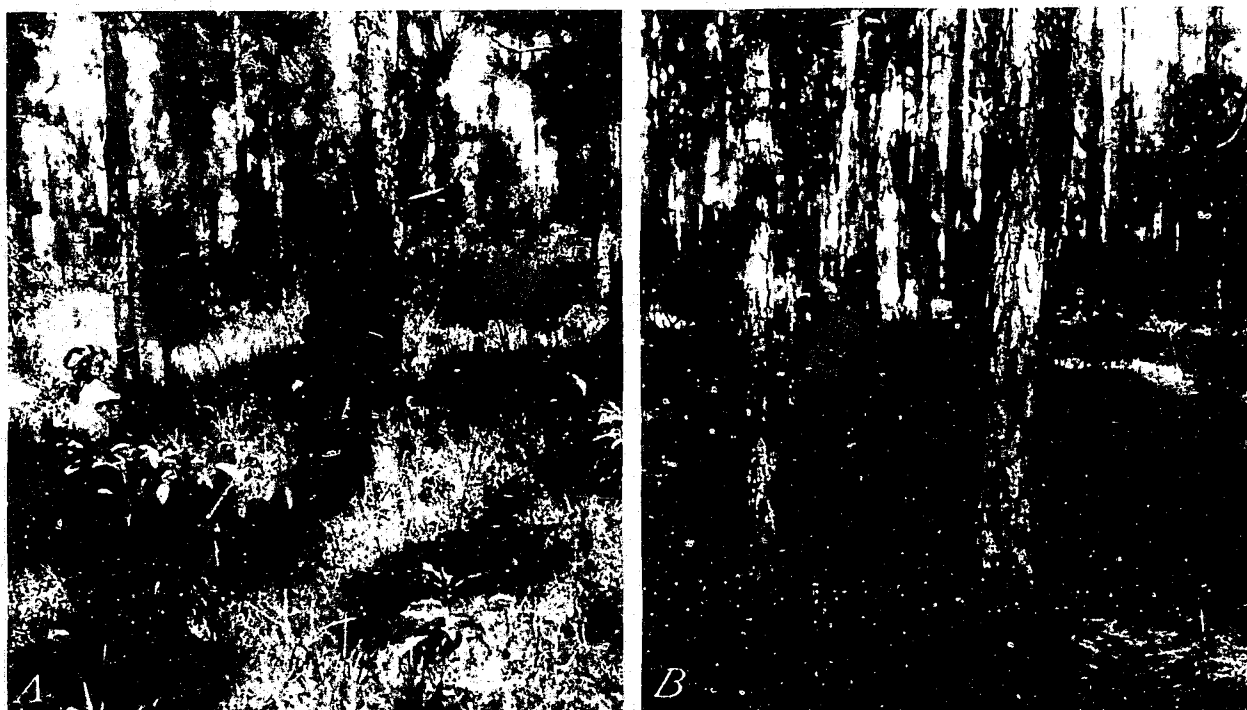
At the beginning of the experiment the 2 beardgrasses made up 64 percent of all the herbage, the 2 grasses being about equally abundant. Carpet grass made up but 3.7 percent of the herbage with about 50 other minor grasses making up the total. In early spring, cattle graze the 3 principal grasses readily, the preference according to observation being for slender beardgrass. After midseason the preference for carpet grass led to very close grazing of this species. Grazing of the beardgrasses during late summer and fall was confined largely to areas where the grass had been kept short and maturity retarded. In the period of flush grass growth early in the spring, the cattle grazed to some extent on the young grass underneath stands of pines, but later in the season the shade-grown grass was avoided. This seasonal preference in grazing had an important bearing on the changes in plant population and density, since close grazing and trampling tended to kill out the beardgrasses and encourage the spread of carpet grass.

The importance of the native legumes as forage plants and as soil builders is not definitely known, but indirectly they may influence the character of other plants growing in association with them. The seeds of most of the legume species identified on this experimental area have been classed as important quail food by Stoddard (*60*).

The data on the minor grasses show as a whole no injury due to burning. However, two of these grasses deserve some mention—broomsedge and the local wire-grass (*Muhlenbergia expansa*). Both of these are inferior grazing grasses, particularly the wire-grass, which is grazed by cattle only in its earliest stage of growth. The broomsedge does not stand competition from the other native grasses and rarely occurs on soils where the stands of other grasses have not been disturbed in some way and partly destroyed. This grass decreased under burning and grazing and increased under grazing without fire, but did not become a factor in the carrying capacity of the pasture. The wire-grass remained about stationary on the two pastures and on the ungrazed and unburned plot, but almost completely disappeared on the burned and ungrazed plot.

UNDER PROTECTION FROM GRAZING

Of the four experimental conditions, protection from both fire and grazing, proved to be the most active factor in producing a change in ground cover. The smothering effect of accumulated dead vegetation and fallen pine straw had full sway on this 10-acre plot where nothing was removed either by grazing or by fire. The change in plant composition was gradual, as shown in figures 8 and 9, but was



A and *B*, Two views of the unburned pasture covering a 7-year interval. *A*, On June 26, 1925; in the previous year this pasture had a 90-percent stand of grasses. *B*, The same plot on September 1, 1932, after 10 years of fire protection; the year following, the stand of grasses had become reduced by the straw fall to less than 1 percent.

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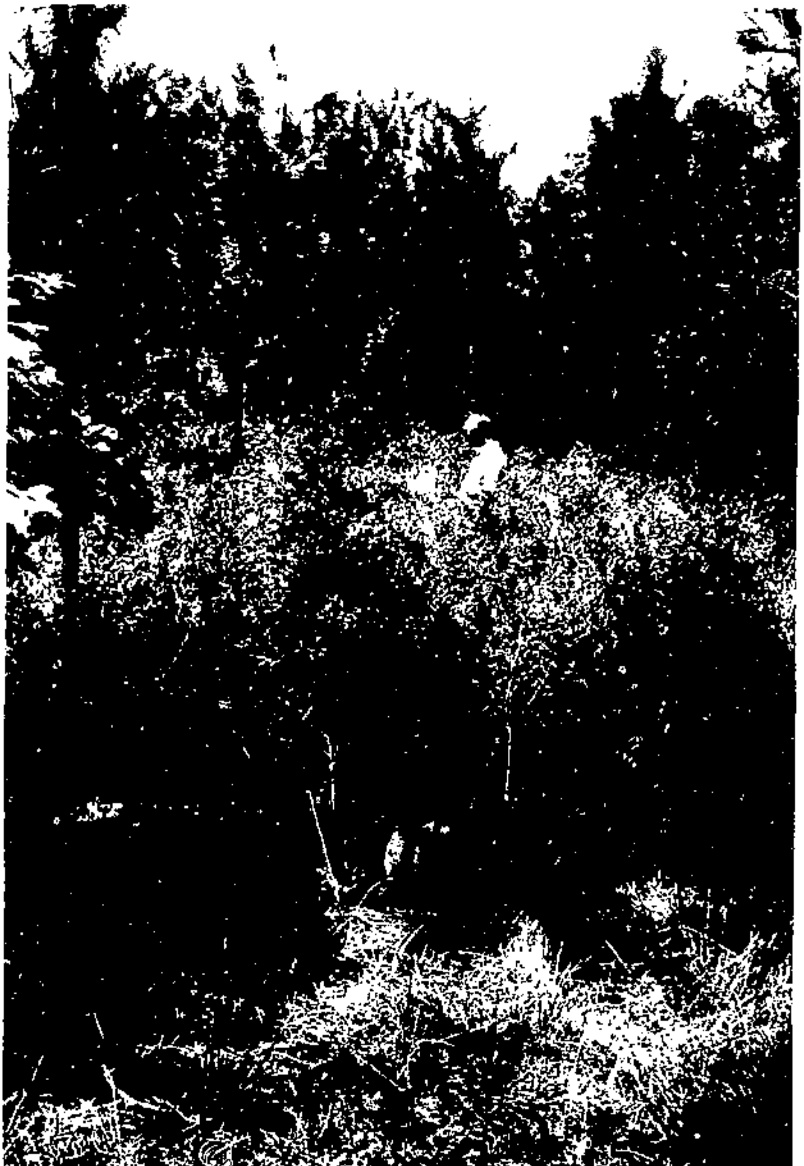
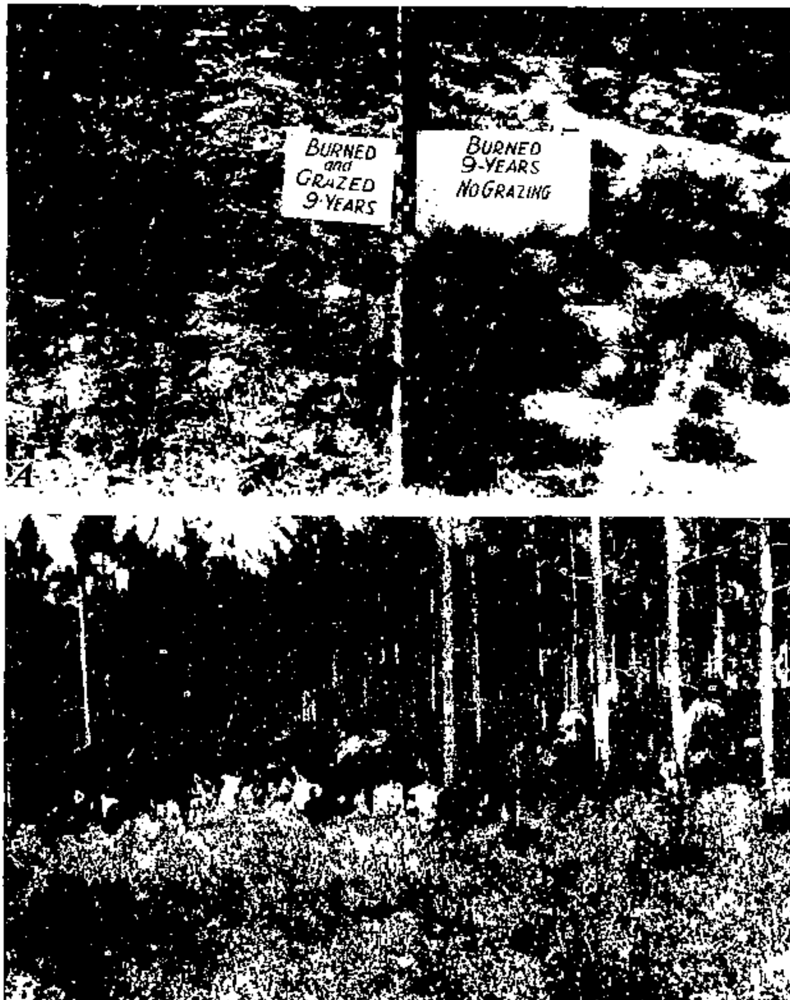
Two views of the burned check plot covering an interval of 7½ years. A, March 1926, after 4 fires. B, View from the same point on November 1933 after 11 fires. These winter fires were not always of the creeping type, since grass fuel was plentiful and the 10-acre plot was large enough for fires to gain momentum. Comparative growth is shown by the 21-foot sapling at the left, which, in the earlier picture, was only a seedling. Many of the saplings were seedlings no higher than tufts of grass when the earlier picture was taken.



Grazing on this hillside in the unburned pasture has been eliminated by a growth of gallberries. This shrubby plant is, however, readily killed out by fires, and on pastures burned annually is found only on wet areas.



A, The carpet grass on the left of the wire fence has stopped at the boundary line where grazing stopped, and its place on the check plot is taken by clump grasses. The same contrast occurred at the boundary line of the unburned pasture and check plot, showing that grazing and not fire is the controlling factor in the spread of carpet grass. (BPI42464B.) *B*, Steers grazing in a typical young longleaf pine stand on the experimental area, McNeill, Miss.

very distinct at the end of the experiment. Carpet grass was completely smothered out under the shade of the taller grasses. Slender beardgrass was also very susceptible to smothering and decreased from 39 percent of the herbage in 1924 to 12 percent in 1933. Prairie beardgrass, the most resistant to smothering of any of the grasses, increased in relative abundance in the same time from 25 to 46 percent. This relative increase, however, did not represent any spread, since all of the grasses were gradually reduced on this plot, as shown by the data for density of stands. On the division or fire line between the unburned and burned plots from which grazing was excluded there was a sharp contrast in 1933. Prairie beardgrass on the unburned side reached the fire line in almost a pure stand, while slender beardgrass, more resistant to fire than to smothering, formed almost a pure stand on the burned side with only a fire furrow between them. The grasses were reduced in the absence of fire and grazing, and it was evident that all forage growth would eventually be blanketed out by pine straw on the areas well stocked with longleaf pines.

On the 10-acre ungrazed plot that was burned over, no inflammable material had been removed by grazing, and the fires, set at midday, were as intense as could be produced from 1 year's plant growth. This plot showed the least change of any of the four experimental areas. Slender beardgrass was not so susceptible to fire as to smothering, and prairie beardgrass proved more susceptible to fire than to smothering, but their relative positions in percentage of herbage remained fairly constant throughout the period of the experiment. There was considerably less reduction in the density of all herbage on this plot as compared with the unburned plot, and the burned plot at the end of the experiment was producing nearly twice as much forage growth as the corresponding unburned plot (table 6).

Carpet grass was eliminated from this plot, as from the adjacent unburned plot, indicating that it cannot stand competition with the taller native grasses, whether burned or not burned. Carpet grass on the grazed areas, regardless of burning, stopped abruptly where it met the ungrazed native grasses at the pasture fence (pl. 5, A). Annual lespedeza (*Lespedeza striata*) was able to stand winter burning and gradually came in along the boundary from the burned pasture. The native perennial lespedezas were apparently favored by burning and were abundant on this plot at the end of 11 years of annual fires, the actual count showing approximately one legume plant for each square foot of the area.

Annual burning with no grazing reduced slightly the density of the stands of grasses but produced no noticeable change in the relative frequency of occurrence of the different species making up the stand. The plant population of this plot is evidently the climax association following frequent burning over a long period of years. Without grazing, the carpet grass was eliminated and the area brought back to approximately the average condition of unfenced range land of the region.

UNDER GRAZING

The second most radical change in plant population occurred on the 150-acre unburned pasture. The accumulation of dead vegetation was greatly reduced here through close grazing, but pine straw remained and smothered out plant growth, at the same time permitting the increase of hardwood shrubs during the experimental period.

Under pasturage both beardgrasses decreased in percentage of herbage as weeds and carpet grass came in to take their place. Slender beardgrass, however, being more resistant to grazing than to smothering, decreased less markedly on the pasture than on the ungrazed area. The plant associations have become spotty in this pasture owing to much closer grazing in some places than in others.

Carpet grass increased from 1.1 percent to 10.4 percent of the total herbage from 1924 to 1933, apparently its maximum spread, from which the accumulating litter of pine straw will force a decrease. On one of the intensive study plots located in advance pine reproduction a 90-percent stand of grasses in 1924 had been almost entirely wiped out by 1933 (Pl. 3). In dense stands of pine reproduction it is evident that the pine straw will, if left unburned, eventually eliminate all grass and legume growth.

On the 150-acre pasture where annual burning and close grazing were combined, the plant population changed somewhat but not as much as under fire protection. Slender beardgrass showed some relative increase as compared with prairie beardgrass but, as on the unburned pasture, the proportions of these two were reduced by the slow increase of weeds and carpet grass. Carpet grass increased from 4 percent in 1924 to 10 percent in 1933 on the burned pasture, and from 1 to 10 percent on the unburned pasture. It appears from observation, however, that carpet grass will furnish grazing under pine sapling growth longer where the straw is burned annually than where it is allowed to accumulate.

Legumes did not withstand burning and grazing so well as they did burning alone, but they stood it much better than they did either grazing without fire or protection from both fire and grazing. Sixteen species of legumes were represented in the counts on the burned areas and only 11 species on the unburned. This difference is sufficient evidence that unburned debris has a distinct smothering effect on the legumes as well as on the grasses. The vining types of legumes persist longer under fire exclusion than the erect types.

WHERE ACCUMULATED DEBRIS WAS BURNED

Since the intensive study plots presented only the effects of annual winter burning or continuous fire protection on the association of plants, a plot within the 10-acre area protected from fire and grazing was burned in October of the eighth year. The changes in plant growth caused by the burning of this heavy accumulated rough were much more radical than those under any of the other conditions studied. The beardgrasses, together with other associated grasses, were almost completely killed out and during the following few years were replaced by a sparse growth of annual weeds in which a species of goldenrod (*Solidago odora*) predominated. The perennial beardgrasses regenerated very slowly on this plot. A similar plot burned in January did not suffer the ill effects of the fall burning, although the hot fire killed out the grasses to some extent.

DENSITY OF FORAGE

On the unburned pasture a litter of dead grass, pine straw, and hardwood leaves accumulated so rapidly that very early in the experiment cattle began to select and to concentrate on the more open areas and to graze these closely. The accumulated litter also had a smothering or mulching effect on the grasses, forcing new shoots to put on a spindly early growth to reach the light. It was not until these grasses reached a height somewhat above the litter that cattle could graze the new growth, whereas on the burned pasture the new grass was available and palatable soon after growth started. Absence of this accumulated debris thus accounted in part for earlier and more uniform grazing on the burned pasture. (See also effect of soil temperature, p. 35.)

The study of changes in composition of the forage cover, already discussed, shows that there was a progressive smothering out of both beardgrasses on the unburned pasture and that the total number of plants per acre and the total yield of green weight of herbage were reduced because other forage plants did not fill in the vacant spaces. Of the two, slender beardgrass is the more susceptible to smothering. Clippings of mature growth from adjacent ungrazed plots on the burned and unburned areas in 1930 and again in 1933 showed that the green weight from the burned area was more than twice that from the unburned area (table 6).

TABLE 6.—*Forage yields of beardgrasses on burned and unburned ungrazed plots*[1] *in green weight per acre*

Grass	Burned plot	Unburned plot	Difference	Grass	Burned plot	Unburned plot	Difference
	Pounds	*Pounds*	*Pounds*		*Pounds*	*Pounds*	*Pounds*
Prairie beardgrass	4,566	3,092	1,474	Mixed stand	4,566	2,246	2,320
Slender beardgrass	5,435	1,304	4,131	Average	4,855	2,214	2,641

[1] Average of data collected Oct. 8, 1930, and Sept. 29, 1933, from 3 square yard plots at short distances on each side of the dividing fire line.

Carpet grass increased on both the burned and unburned pastures about equally. Close grazing is the factor favoring the spread of this creeping grass, which was smothered out on both the burned and unburned plots where grazing was excluded. Fire tended to kill it as the straw litter increased, but the pine straw also smothered it out graduaLy in the absence of fire (fig. 8).

FOOD VALUE OF FORAGE

The differences in crude protein and in crude fiber, as shown by the analyses already described, are of particular significance as indicators of the quality of the forage. As shown in table 7, the crude protein was higher and the crude fiber lower for both species of grass on the burned areas, and the lime and phosphorous contents were higher for the burned area. These differences possibly account for the preference of cattle for the forage on burned pastures, and for some of the gains in cattle weight discussed in the following section.

Cattle grazing on unburned pasture must unavoidably consume some of the dead plant material along with the green grass. The low forage value of this dead grass is indicated by a protein content less than half that of the fresh material on the unburned areas, a slightly higher crude-fiber content, and the extensive leaching of the

TABLE 7.—*Chemical analyses of dry material of grasses from burned and unburned areas* [1]

Grass species and management	Ash	Crude protein	Crude fat	Crude fiber	Nitrogen-free extract	Calcium oxide (CaO)	Phosphorus pentoxide (P_2O_5)
Prairie beardgrass	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
Burned	5.27	9.27	3.01	30.87	51.58	0.50	0.29
Unburned	4.56	8.05	2.50	32.35	52.54	.51	.27
Difference	.71	1.22	.51	−1.48	−.96	−.01	.02
Slender beardgrass:							
Burned	8.22	10.06	2.66	30.06	48.87	.54	.33
Unburned	7.45	7.53	2.07	32.73	50.22	.42	.25
Difference	.77	2.53	.59	−2.67	−1.35	.12	.08
Average:							
Burned	6.74	9.66	2.84	30.47	50.22	.52	.31
Unburned	6.00	7.79	2.28	32.54	51.38	.46	.26
Difference	.74	1.87	.56	−2.08	−1.16	.06	.05
Mixed dead grass	7.38	3.38	2.30	34.96	51.98	.35	.06

[1] The samples of prairie beardgrass were collected for analysis May 3, 1929. The data on slender beardgrass are averages for samples collected May 3, 1929, and Apr. 28, 1931. The analyses were made by W. F. Hand, State chemist of Mississippi.

lime and phosphorus. The inevitable mixing of this dead materia with fresh grass lowers the unit grazing value of the unburned area still further.

The effect of fire exclusion on the native legume population has been to reduce the legumes greatly on the unburned areas, whereas they remained about constant on the burned plot and pasture, as shown in the following tabulation of legume plants per acre taken on the 0.01-acre plots:

	Number of plants
9 annual fires, no grazing	41,500
No fire and no grazing	17,600
Decrease under fire protection	23,900
9 annual fires on pasture	35,700
No fire on pasture	27,600
Decrease under fire protection	8,100

The extent to which these legumes are consumed by cattle is not definitely known, although they were kept down on the pastures as compared with the ungrazed plots, either incidentally to grazing or by preference in grazing. Some of the perennial legumes, particularly the beggarweeds, are grazed readily by cattle about the time they begin to mature seed.

It has already been shown that the quantity of forage was greater on the burned than on the unburned areas, and this fact coupled with a lower unit value of the material on the protected pasture, accounts for differences in gains made by cattle as indicated in the following section. Also, the fact that the total amount of herbage produced was greater on the burned areas may be significant from another standpoint. Heyward and Barnett (*32*) attributed an increase in total nitrogen of the soil which they found to follow burning "mainly to the addition of organic materials to the soil through decay of roots of the grass vegetation characterizing burned areas." They pointed out that the superiority of grass over forest vegetation in increasing soil fertility had long been recognized by soil scientists.

WEIGHTS AND GAINS OF STEERS

In considering the gains made by the cattle in this experiment, it must be taken into account that they were grazed in a young forest rather than in an open pasture and that the forage was an additional product of land devoted chiefly to the production of trees (pl. 5, *B*).

The breeding cows unavoidably used in 1923 and 1924 lost weight in the first season and made a very low gain per head in the second. In 1923 seven calves were dropped in each pasture, and in 1924 four calves in the unburned and three in the burned pasture, although as many dry cows as possible were selected. For these 2 years, average gain for calves on the burned pasture was 129 pounds per head and on the unburned 101 pounds. These gains were not credited in the average weights or season gains for either 1923 or 1924 (table 8).

For the first 5 years (1923–27), with a grazing rate of one head to 10 acres, the gains were decidedly in favor of the burned pasture each season. The cattle were not consuming all the forage produced, and in 1928 the number of cattle was doubled on the pasture. The gains

TABLE 8.—*Average gains or losses of steers in pounds per head, by 28-day periods, and season gains, on burned and unburned native grass pastures, 1923–33* [1]

Month	1923 [2]	1924 [2]	1925	1926	1927	1928	1929	1930	1931	1932	1933	All years
ON BURNED PASTURE												
	Lb.	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*
March										15.0		15.0
April	37.6		41.0	69.0	52.7	52.6				31.0	40.4	46.4
May	47.0	52.9	18.7	58.3	29.0	32.6	31.7	42.0	89.0	17.0	45.8	42.2
June	−37.0	−13.7	26.3	23.3	26.0	27.6	5.7	1.0	17.3	27.0	31.2	12.2
July	20.0	45.4	44.3	9.3	34.3	4.5	14.7	24.7	16.6	−6.2	10.4	19.8
August	.3	−11.6	25.0	−12.6	−5.3	−20.1	21.0	−9.3	6.0	−1.2	−6.6	−1.3
September	−3.3	−9.2	−5.0	32.6	6.0	50.8	21.2	38.3	27.3	26.6	11.2	17.9
October	−19.0	−17.0	3.6	(3)	−4.3	−6.0	−5.7	20.5	5.3	1.2	10.4	−1.1
November	−56.6	−9.0	−6.0	−12.0	−19.0	−10.3	−33.2	1.5	−14.6	−18.0	−36.7	−19.4
Initial weight	544	520	592	599	562	556	603	531	466	580	610	560
Final weight	533	558	740	767	681	688	658	649	613	673	716	661
Season gain or loss	−11	38	148	168	119	132	55	118	147	93	106	101
ON UNBURNED PASTURE												
March										−37.8		−37.8
April	24.6		40.6	56.3	23.3	27.0				13.9	8.9	27.8
May	21.0	4.2	17.6	40.3	16.7	29.6	43.3	35.7	93.3	14.2	35.0	31.9
June	−25.6	.4	6.6	17.6	32.3	29.0	9.0	.3	20.6	32.8	26.8	13.6
July	22.0	43.4	35.3	5.3	25.7	.2	10.7	13.2	33.6	12.5	−1.0	18.3
August	−17.0	−4.2	38.0	−9.3	−2.7	−22.3	14.2	−4.3	−1.3	−13.2	−1.8	−2.2
September	−5.4	−6.5	−14.3	41.3	14.7	55.0	12.2	34.8	29.0	25.0	8.6	17.7
October	−17.0	−3.4	−4.7	(3)	−12.3	−11.7	15.7	8.8	−1.0	−10.0	8.5	−2.7
November	−42.0	−30.0	−9.0	−44.3	−12.3	−17.0	−44.0	−5.8	−4.6	−11.4	−27.3	−22.5
Initial weight	569	534	591	600	562	551	603	538	477	580	575	562
Final weight	530	538	701	708	648	641	665	621	647	606	633	631
Season gain or loss	−39	4	110	108	86	90	62	83	170	26	58	69

[1] Average grazing period, 217 days (Apr. 5 to Nov. 8). Average rate of grazing, 1 head to 8.9 acres. Area of each pasture, 150 acres.

[2] The average gains of calves are not included for 1923 or 1924. 7 calves averaged 150 pounds gain per head in 1923 on the burned pasture and the same number on the unburned pasture averaged 106 pounds. In 1924, 3 calves averaged 80 pounds gain per head on the burned pasture and 4 calves averaged 91 pounds gain per head on the unburned pasture. The season gain of calves is influenced by the date of birth.

[3] 42-day weight period.

per head were again in favor of the burned pasture and were about equal to those of previous years. However, the forage became very short towards the close of the season, and it appeared that yearling pine seedlings were being destroyed, particularly in the open areas. It also became apparent that the older pine saplings were filling in open spaces and producing more competition with forage plants throughout the pastures, so that grazing could not be continued at that intensity.

When the rate was reduced in 1929 to one head to 7½ acres, the steers did not make satisfactory gains on either pasture, and it was necessary to feed a pound of cottonseed meal per head daily for the last 56 days to prevent heavy losses in weight. However, the poor gains of this season were attributed to the unusual handling and dipping necessary each 14 days to comply with Federal tick eradication, and therefore the grazing rate of one head to 7½ acres was continued for 1930 and 1931.

In 1931 the unburned pasture had a season advantage of 23 pounds per head over the burned pasture. This is the only significant deviation in the trend of gains for the 11 years of grazing, and no reason for this reversal was apparent from a study either of the gains of individual animals or of the pasture conditions during the season. The condition of the water supply during dry periods was in favor of the unburned pasture for this year, owing to the digging out of spring heads, but the advantage in gains on the unburned pasture was constant throughout the season and did not accumulate during any dry period.

In 1932 the grazing rate was again reduced to one head for each 10 acres to allow for the reduction in forage which had been brought about by increased pine growth and straw fall. During the first 8 years the openings, which afforded most of the grazing, filled in with longleaf pines on the burned pasture twice as fast as on the unburned area, although this was balanced by an increased hardwood shrub growth on the unburned pasture. The cattle were turned on pasture on March 2 in 1932, and for the first period those on the unburned pasture sustained a heavy loss in weight while those on the burned pasture made a satisfactory gain. In 1933 the cattle were not turned on pasture till March 15, but in that year also there was a decided advantage to the cattle on the burned pasture for the initial period.

The difference in average gains made on the two pastures for 11 years and the seasonal character of gains is shown in the last column of table 8. The greater gains in April may indicate the superior quality of the forage during the first 60 days of the grazing season. Of the 32 pounds per head in average advantage gained by the cattle on the burned pasture for 11 years, most of the gain was made before June. This early advantage was maintained throughout the season, the grazing on the two pastures tending to equalize as the native pasture plants reached maturity.

With the exception of the years 1929 and 1931, the additional gains made by the steers on the burned area were reflected sharply in their appearance when they came off pasture at the end of the grazing season. The steers from the burned pasture could be easily picked out of a group by their sleeker coats and heavier fleshing, which naturally presented a better appearance to buyers of feeder steers. However, the pastures were not sufficiently good to produce fat grass cattle at the end of any season. By way of contrasting these results with those for improved pasture it is interesting to note that in 1933 the steers grazed on improved pastures of carpet grass and lespedeza at McNeill, on a much smaller area per head, gained 247 pounds per head, or more than twice as much as those on the burned experimental pasture.

After 12 years of fire protection an accidental fire burned over half of the previously unburned pasture. The burned portion was then fenced as a separate pasture and was burned over in 1935 and 1936. Like the older experimental areas, the new pasture was grazed at the rate of one head to each 10 acres. With the removal by burning of the accumulated dead grass, pine straw, briers, and gallberry bushes the steers gained 62 pounds per head the first year as compared with only 33 pounds for the older and still unburned portion of this pasture, and 64 pounds for the annually burned pasture. During the second season, with grazing starting very late, the steers on the newly burned pasture gained 99 pounds per head as compared with gains of 57 pounds on the unburned portion and 75 pounds on the pasture burned regularly every year.

For the period of 11 years the burned pasture produced 20,575 pounds of beef and the unburned 14,978 pounds. This difference, amounting to 509 pounds per season for a 150-acre pasture, although not great in pounds per acre, was 37 percent of the gains on the unburned pasture. On land of low producing capacity, serving the dual purpose of timber production and pasturage, this is a very material difference. It is an especially important consideration where pasturage during the period of immature timber growth represents the only possible annual cash return with which to meet annual taxes and other fixed charges.

EFFECTS ON THE SOIL

Erosion and soil deterioration have been ruinous in some regions where forest exploitation has been followed by fire. Certainly no manner of temporary gains could justify the continued use of fire, if such burning were destroying the basic soil resource in the longleaf pine region. In the absence of any conspicuous evidence at McNeill of surface run-off or erosion, these particular factors were not investigated directly. The main attempt was to ascertain whether the treatments, particularly burning, were causing soil degradation from a fertility standpoint. Although it was impossible to study all phases of possible changes in the soil due to burning, grazing, and protection, consideration was given to some of the chemical and physical properties of the soils. Types of soil on this area are shown on a map (fig. 10) prepared in 1924 by A. C. Anderson of the then Bureau of Soils.

PHYSICAL SOIL PROPERTIES

Soil temperatures in the zone of grass roots were measured daily in the spring of 1926 at a depth of 3 inches. The average of readings made at 4 p. m. showed the soil at this depth on the burned, grazed area to be 5.5° F. warmer than on the unburned, grazed area. As compared with the unburned areas, the daily maxima on burned areas averaged 1.5° higher on the grazed portion and 5.5° higher on the ungrazed portion. The higher temperatures on the burned land were probably due to its charcoal-blackened surface and the removal of the insulating effect of dead vegetation. The greater warmth brought an earlier spring growth of native pasture grasses. Hensel (*30*) found very similar differences in temperature and growth of grass as a result of burning on the prairies of Kansas.

Soil-moisture data consisting of 188 composite samples were gathered in the summer of 1931. The moisture-content figures indicate a slightly more moist soil under seed trees than under advanced reproduction or in openings (table 9). With respect to fire the averages show slightly more soil moisture on the unburned portion of grazed areas and on the burned portion of the ungrazed areas. All differences observed, however, were small and statistically insignificant.

TABLE 9.—*Soil moisture as affected by different conditions of overwood, grazing, and burning, 1926* [1]

Surface treatment	Composite samples	Average soil moisture in—				Samples favoring treatment	Average difference	Standard error of difference
		Open	Advance reproduction	Seed trees	Average			
	Number	*Percent*	*Percent*	*Percent*	*Percent*	*Number*	*Percent*	*Percent*
Ungrazed:								
Unburned	46	9.4	9.1	10.2	9.6	21	1.9	1.1
Burned	46	9.4	8.9	14.5	10.9	25	2.4	2.4
Difference		0	.2	−4.3	−1.3			
Grazed:								
Unburned	48	10.1	9.0	11.5	10.2	33	2.5	1.6
Burned	48	7.6	8.7	11.1	9.1	15	1.4	1.1
Difference		2.5	.3	.4	1.1			

[1] Moisture content is expressed in percent of dry weight of soil. The figures represent the surface foot of soil and are based on samples collected on 7 different dates between July 28 and Oct. 9, 1931, by L. J. Pessin of the Southern Forest Experiment Station. A total of 188 samples was divided by overwood conditions as follows: Open 82, advance reproduction 82, seed trees 24. The composite samples each consisted of soil from 10 spots within a radius of 10 feet, in each of a dozen different places representing various conditions. Such samples were taken at 3 depths down to 12 inches, but never sooner than 2 days after a rain. As the moisture samples showed only small and inconsistent variation with depth, the results at all 3 depths were averaged together.

A relatively loose and friable soil has been almost invariably associated not only with the ease with which germinating seeds can take root, but also with thrifty growth of plants in general. Such soils, as well as being more permeable to moisture, offer better growing conditions because of improved aeration and less resistance to root extension. Thus mechanical penetrability of soil, apart from its association with permeability to moisture, may be used as an indication of a generally favorable growing condition. If the trampling of animals and the baking action of the sun on exposed places serve to compact soil, the effect should be greatest and most immediately evident at the surface. To measure the degree of superficial hardness or resistance to penetration, an instrument originally designed for testing road-surfacing materials was used. This penetrometer measures, in tenths of millimeters, the extent to which a needle is driven into the soil by the pressure of a 100-g. weight.

In 13,122 measurements, the unburned areas showed universally higher average mechanical penetrability than the burned areas, the surface of the burned-over soil varying from slightly harder to five times as hard as unburned soil. In respect to grazing, a regrouping of the same data showed the soil varying from slightly harder to six times as hard on grazed as on ungrazed areas. These results refer to areas covered by seed trees or advance reproduction as well as to open areas. In respect to effect of cover on softening of surface soil, the

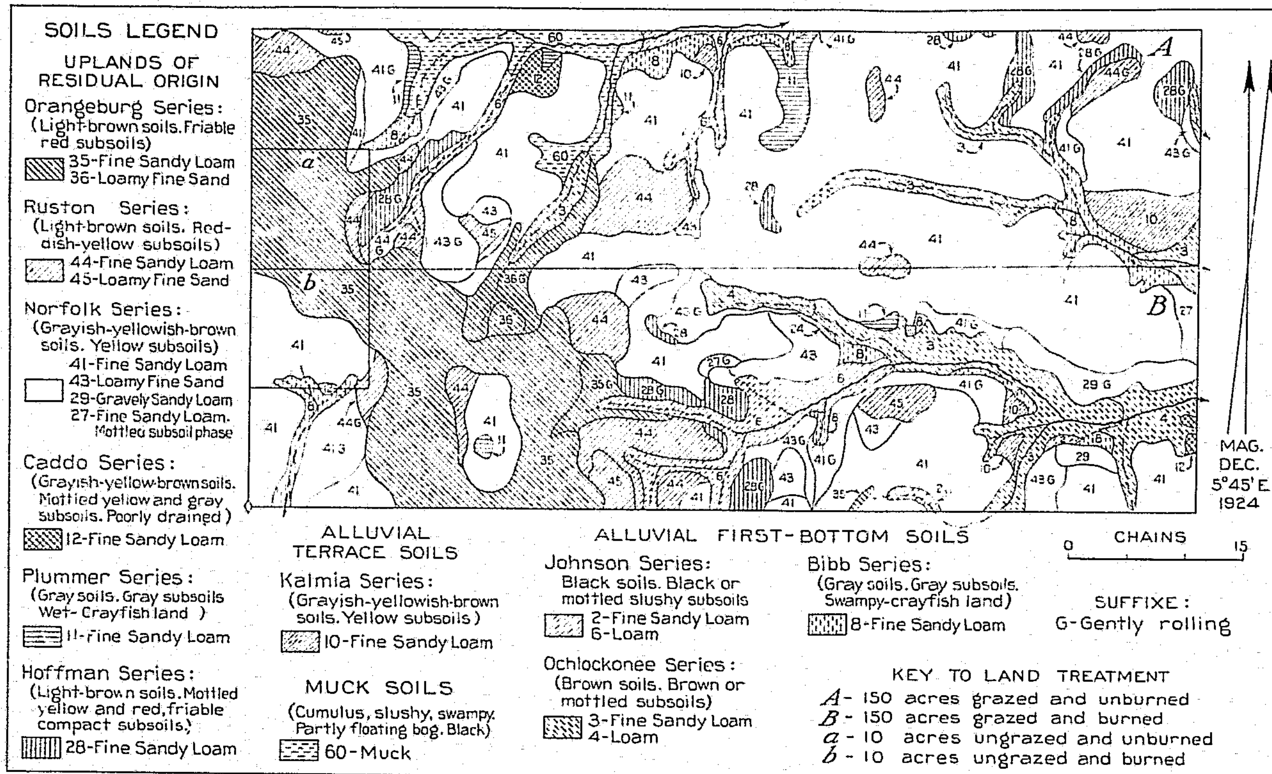


FIGURE 10.—Soil map of Experimental area, McNeill, Miss.

favorable effect was most evident on unburned land where litter remained as a mulch. On burned land the situation was reversed, the softer soil being found in open areas rather than under trees, though in this case the contrast was not as great. In general the favorable effect of forest cover was not so marked as were the adverse effects of burning and grazing.

Because it was thought that drier soil tends to be harder, regardless of other factors, none of the tests for hardness was made less than 2 days after a rain, and additional moisture samples from surface soil were gathered from the spots examined for penetrability. The data on penetrability with accompanying data on soil moisture are summarized in table 10. Obviously the average differences in moisture content were entirely too small to explain the associated very marked differences in superficial hardness. Tree cover had a tendency to prevent a hard surface where fire was excluded, and protection from either fire or grazing tended to keep the surface soil soft, regardless of tree cover.

TABLE 10.—*Hardness or mechanical penetrability of surface soil with accompanying moisture content* [1]

Overwood and treatment	Relative penetrability [2]	Soil moisture [3]	Readings	Overwood and treatment	Relative penetrability [2]	Soil moisture [3]	Readings
Seed trees:				Advance reproduction—Continued.			
Ungrazed:	*Percent*	*Percent*	*Number*	Grazed:	*Percent*	*Percent*	*Number*
Unburned	231	10.3	100	Unburned	87	10.1	1,000
Burned	110	15.0	100	Burned	48	9.7	1,500
Grazed:				Open—no overwood:			
Unburned	226	12.3	100	Ungrazed:			
Burned	41	10.9	100	Unburned	100	8.9	1,912
Advance reproduction:				Burned	61	8.9	1,602
Ungrazed:				Grazed:			
Unburned	179	9.5	1,606	Unburned	64	9.9	1,402
Burned	53	8.9	1,600	Burned	14	7.0	1,500

[1] No tests were made on carpet grass areas.
[2] Penetrability figures are the average of observations on 5 different dates in 1930-31, and are based on surface penetration with that on ungrazed, unburned, open areas taken as 100 percent.
[3] Soil-moisture figures are in percentage of oven-dry weight. Each is the average result obtained from composites of 10 samples taken in the 0- to 2-inch layer, within a radius of 10 feet, on each of these dates: Apr. 21, May 18, June 8, July 28, Aug. 9 and 13, Sept. 17, 22, and 29, and Oct. 9, 1931.

If the unburned and ungrazed areas as a whole is taken as 100 percent, then the other land treatments ranked as follows in penetrability of surface soil: Unburned and grazed, 84; burned and ungrazed, 67; and burned and grazed, 56 percent.

A partial check of these results was afforded in another test in which closely adjacent spots on the burned and unburned pastures were compared as to pore space and moisture content. A special soil-sampling tube was improvised for the purpose of measuring soil in its undisturbed field state.[13] Sixteen samples, each of 100 cm^3 of soil, were taken in 1927 for each condition, burned and unburned. Random sampling was done on closely adjacent areas where vegetative and soil types were uniform. The usual procedure of oven drying was followed by measurements of volumes occupied by soil particles as determined by water displacement.

[13] This tool consisted of a piece of thin brass pipe about 8 inches long and 1.2 inches in diameter, sharpened only on the outside of the lower end to keep the inner bore constant, and provided with a plunger for removing soil samples. An outside scratch marked the point of 50 cm^3 inside measurement. Samples of 100 cm^3 of fresh gravel-free surface soil were readily obtained by two insertions of this instrument. A surface layer about 2¾ inches deep was sampled in this way.

The results shown in table 11 consistently indicate a slightly more moist and more porous (less dense) soil in the pasture protected from fire.

TABLE 11.—*Moisture content, specific gravity, and pore space or density of surface soil as affected by annual burning* [1]

Field condition and treatment	Moisture content	Specific gravity: Field or apparent	Specific gravity: Particle or real	Porosity or air space [2]
Fully stocked stands of saplings in pasture:	*Percent*			*Percent*
Protected from fire	10.1	1.28	2.22	42.3
Burned annually	8.3	1.38	2.32	40.5
Open pasture, native grass cover:				
Protected from fire	12.9	1.39	2.36	41.1
Burned annually	10.6	1.49	2.41	38.0

[1] Volume of each composite soil sample was 800 cm³. Native grass was the vegetative cover in each case. A similar comparison of the effect of fire on pasture soil with carpet grass cover was not possible because the grazed carpet grass did not burn over. The field work was done in December 1927.
[2] Porosity was considered equal to the real (or particle) specific gravity minus the apparent (or field) specific gravity, all over the real specific gravity.

A study made in October 1931 showed that the failure of soil to absorb water varied in much the same way as its resistance to mechanical penetration, already discussed. The rates at which water can be absorbed were determined by a method developed by Auten (*4*) and introduced at McNeill in 1931 by M. A. Huberman, who conducted the tests. Metal cylinders 1½ inches in diameter and 10 inches long were driven 1 inch into the soil. Starting with a measured quantity of water for each test, the cylinders were kept filled for a period of 10 minutes. Measurements were made on areas with as nearly as possible the same stocking of forest trees and the same soil series (as indicated by the soil map and checked with borings). Deducting the volume of left-over water permitted an expression of the quantity absorbed in terms of cubic centimeters per minute (table 12). As with the tests for mechanical penetration, only relative values are significant. The quantity of water absorbed cannot be regarded as the absolute capacity of the soil to absorb rain water, for at least two reasons: (1) Under natural conditions a column of water does not stand on the soil for 10 minutes; and (2) inserting the cylinder inevitably causes some disturbance of the soil. As the errors from such causes may be expected to remain reasonably constant, they should not affect results expressed in relative terms.

TABLE 12.—*Water-absorptive capacity of Orangeburg fine sandy loam under different field treatments* [1]

Overwood and treatment	Absorption per minute	Standard deviation	Relative absorption
Open, ungrazed:	*Cm³*	*Cm³*	*Percent*
Unburned	25.9	±12.3	78
Burned	21.3	±3.4	64
Advance reproduction, ungrazed:			
Unburned	33.1	±13.9	100
Burned	7.1	±2.1	21
Advance reproduction, grazed:			
Unburned	11.6	±3.1	35
Burned	[illegible]	±3.3	17

[1] Basis: 10 determinations under each condition, utilizing the method employed by J. T. Auten. No tests were made on carpet grass areas.

Protection from fire increased absorption slightly but not with statistical significance on open ungrazed areas. In the advance reproduction or sapling stands it clearly doubled absorption on grazed areas and on the ungrazed areas the absorption was about five times as great. The increase in absorption as a result of protection from grazing was slight and statistically not significant on burned land, but on unburned land the absorption was threefold and the increase clearly significant.

The causes of these effects were not investigated. Presumably grazing tends to reduce absorption by compacting the soil and reducing porosity at the surface. Under protection from fire the main effect seems to be that of increased porosity due to the activity of soil fauna (*33*) and possibly also to the action of undisturbed litter in preventing the fine particles from sealing the soil pores at the surface. The action of litter in increasing absorption by retarding run-off was not studied.

Heyward and Tissot (*33*) believe that the permeable and well-aerated character of soils protected from fire as contrasted with the less porous compact soils of burned areas, may be explained on the basis of activity of the microfauna. They found the same forms of life in frequently burned-over longleaf pine soils as in comparable unburned areas. The layer of organic debris on unburned plots, however, contained about 5 times as many of these organisms as the ground cover on burned plots and the top 2 inches of mineral soil on unburned areas contained 11 times as many as the corresponding depth of soil on burned areas.

The studies of the physical properties of soil consistently showed that porosity, mechanical penetrability, and ability to absorb water were several times greater on areas protected from grazing and fire. This agrees with more extensive research by Auten (*4*), who found forest soils much more absorbent than field soils but greatly reduced in porosity as a result of overgrazing. He found grazed soil harder, drier, more poorly aerated, and inferior in tilth to ungrazed soil.

CHEMICAL SOIL PROPERTIES

The frequent burning of dead grass and surface litter induces chemical as well as physical changes.

The first measurements of acidity in the McNeill study were made in the fall of 1927, when 10 or more tests of soil reaction were made on the surface soil of each of the 4 differently treated areas, or a total of 55 tests on the quadrats distributed over the area. On ungrazed areas the pH values[14] were higher by 0.1 on burned land, and on grazed areas the readings on the burned exceeded those on the unburned by 0.4. The pH values of surface soil ranged from 4.7 to 6.5, with only slight variations, the most common being 5.0, indicating a strongly acid condition.

Laboratory determinations of soil reaction were also made on samples collected in April 1929. The pH values in 12 tests ranged from 4.5 to 5.5, most of them being 5.0. In these tests no difference

[14] The symbol pH is used in connection with numerical values for the concentration of hydrogen ions. On the pH scale, ranging from 0 to 14, the midpoint, pH 7, represents neutrality, or the reaction of pure water. Lower values indicate degrees of acidity and higher values degrees of alkalinity. In each case the number is the logarithm of the reciprocal of the hydrogen ion concentration. The pH values at McNeill were determined in the field by colorimetric reagents and in the laboratory by more precise methods. The tests of 1927 were made by the senior author; those of 1929-30 by W. F. Hand, Mississippi Agricultural Experiment Station, and those of 1933 by R. M. Barnette, Florida Agricultural Experiment Station.

connected with burning was detected. Again in January 1930 laboratory tests of 17 samples were made. These ranged from pH 5.3 to 6.2, most of them being close to 5.6 from both burned and unburned land. Again no effect from fire was manifest.

Sixteen samples, each a composite of 10 individual samples from burned and unburned land, were collected from the ungrazed check plots on June 3, 1933. Reaction tests from the 16 paired samples showed only 1 in which acidity was greater on the burn. As a whole, the pH value of the burned plot exceeded that of the protected one by only 0.18 of a unit, a statistically significant but very slight difference. This agrees in general with more intensive studies over the longleaf pine belt (*32*).

Because the changes in reaction of surface soil to be expected as a result of burning are so small, they can be regarded as negligible in growing acid-tolerant pines like longleaf.

Agriculturists have found that large numbers of bacteria are frequently, though not always, correlated with high fertility and productivity of soil. In general the numbers of bacteria, as determined by the plate method, range from 5 to 14 millions per gram in normal soils (*65*), the number varying with soil factors such as oxygen supply, organic matter, moisture content, acidity, temperature, and depth, and with season of the year.

From the soil samples collected at McNeill in January 1930, bacterial counts were made [15] with the following results in average numbers of bacteria per gram of soil:

	Number
Burned and grazed area, 7 samples	9,560,000
Burned and ungrazed area, 4 samples	1,110,000
Unburned and grazed area, 4 samples	3,180,000
Unburned and ungrazed area, 2 samples	1,960,000

Apparently both grazing and burning were associated with an increased number of soil bacteria. At present no practical significance is attached to these results. Similar determinations should be made at other seasons of the year, particularly in the summer. Batham and Nigam (*6*) have indicated a periodicity of the nitrate content of soils resulting from seasonal fluctuations of nitrifying bacteria. At the Rothamsted Station in England, Cutler et al. (*15*) found bacteria and protozoa most numerous at the end of November and least abundant during February, though the changes were not directly influenced by temperature or rainfall. He found that the numbers of these organisms rarely remained the same from one day to the next, and that the fluctuations were very great. Obviously no conclusions can be drawn from the single determination made at McNeill.

In another test the existing differences in soil structure or other physical properties were destroyed by cultivation before attempting to use the growth of an agricultural plant as an index of possible differences in chemical factors of soil fertility. Tests of growing corn were made on the ungrazed area in Orangeburg fine sandy loam soil on both burned and unburned portions. In each, a 0.22-acre plot was selected and all vegetation removed from half of the area by hoeing. Each plot was plowed 6 inches deep in April 1931, and corn (Hastings Prolific) was planted in hills 3 feet apart and rows 2 feet apart. The

[15] By C. F. Briscoe, Mississippi Agricultural Experiment Station.

crop, though puny from a farmer's viewpoint, developed sufficiently to yield comparisons. By August 28 it was possible to harvest, count, measure, and weigh the plants. Air-dry weights were taken 4 months later. The results are shown in table 13.

TABLE 13. *Average development of corn plants as indicators of soil fertility in Orangeburg fine sandy loam* [1]

Condition of experiment	Density of plant growth: Plants	Density of plant growth: Leaves per plant	Density of plant growth: Ears per plant	Weight of plants: Green weight	Weight of plants: Dry weight	Development of plants: Height of plant	Development of plants: Length of leaves	Development of plants: Length of ears
Grass plowed under:	*Number*	*Number*	*Number*	*Pounds*	*Pounds*	*Inches*	*Inches*	*Inches*
Unburned plot	65	9.9	1.0	2.2	0.7	37.0	12.9	6.3
Burned plot	39	9.6	.9	1.5	.5	33.0	10.6	6.0
Difference	26	.3	.1	.7	.2	4.0	2.3	.3
Grass removed:								
Unburned plot	50	9.2	.8	1.0	.3	25.2	9.6	5.1
Burned plot	48	9.6	.8	1.1	.4	29.0	9.9	5.6
Difference	2	-.4	0	-.1	-.1	-3.8	-.3	-.5
Increase or decrease (-) from plowing under:								
Unburned plot	15	.7	.2	1.2	.4	11.8	3.3	1.2
Burned plot	-9	0	.1	.4	.1	4.0	.7	.4

[1] Basis, 4 0.22-acre plots in corn, summer 1931.

A direct comparison of the plots on burned and unburned areas showed that corn grew better on unburned land only when the grass was turned under, whereas it did better on burned land where the grass of both plots had been removed previous to plowing. The greater growth of corn plants on the burned-over soil in these tests, when unaided by any artificial incorporation of humus, may be regarded as a slight indication that the soil on the burned area possessed chemical properties a little more favorable to plant growth.

In a 21-year experiment to determine the effect on tree growth of the removal of litter, Delevoy (*16*) showed that the removal by hand of soil covering retarded growth, the loss being greatest where the litter was removed every year. But removal by burning differs from removal by hand in that all mineral constituents are left on the site and thus, unless washed away, they become for a short period more readily available to plants than before.

Originally drawn from the soil solution, the minerals contained in burned portions of plants are returned to the soil as ash deposits. As expressed by Harper (*26*), annual burning in thus returning the mineral plant foods to the soil allows plants to do a large business on a small capital, whereas if many years elapse between fires most of the mineral plant food normally available near the surface may be locked above ground in an accumulation of dead plant material and the growing plants threatened with starvation. The analyses of the dead grass from unburned areas in table 7 serve as a rough measure of the potentially available mineral nutrients held away from the soil in the unburned debris.

Determinations of total soil nitrogen and of organic matter as indicated by loss of weight "on ignition" (really combustible materials including particles of carbon within the soil) were made on the experimental area over a period of 5 years. Differences between burned and unburned soils were not sufficiently large or consistent to permit of definite conclusions on the basis of this work alone. Fortunately, however, the McNeill plots were included in a much more thorough and extensive study of the effect of fire on soils throughout the longleaf pine region. The results of this region-wide study have been published in detail by Heyward and Barnette (*32*). Samples were drawn from eight widely separated study areas where soil from plots unburned for several years could be directly contrasted with soil from adjacent frequently burned plots. These soils varied from deep sand of low fertility to fine sandy and silt loams of much higher fertility. As the character of soil before burning was not found to be correlated with fire effects, it was possible to average the results of numerous tests. For samples from all eight areas the mean values for the burned land exceeded those for the unburned land, in percentage of dry weight, as follows: Total nitrogen, 0.0028 ± 0.0011; loss on ignition, 0.180 ± 0.1056; and replaceable calcium, 0.0085 ± 0.0024. The probability is beyond question that these differences were due to burning rather than to chance. These investigators regard the roots of plants as the main source of appreciable amounts of organic matter in soils that are frequently burned over. Certainly the supplies of nutrients in rather than on the soil have most direct significance to plants, as explained by Greene (*22*).

Undoubtedly the effect of fire exclusion on the nonmineral and often more volatile elements of plant nutrients, such as nitrogen, has been frequently misjudged. When accumulated debris is burned, organic matter is consumed and its nitrogen returned to the atmosphere. The theory that this escape of nitrogen and destruction of organic matter is a serious or readily avoidable loss is not tenable, because, on land protected from fire, nitrogen also returns to the air by slow volatilization in the process of weathering and decay above the soil. Fire merely speeds up this decomposition of organic refuse. On rare occasions the maximum direct damage to soil may reach the total commercial value of the nitrogen liberated and organic matter consumed, but actual damages seldom approach this value. Investigations have indicated that if the forest floor were to be plowed under, as in agriculture, then the prior removal of all the litter might cause a loss amounting to 90 percent of the cost of an equivalent amount of commercial fertilizer (*3*). But where the leaf litter is not turned under, as in forests, its loss by artificial removal or burning cannot be expected to approach the market value of equivalent fertilizer. The work of Alway and Rost (*2*) in Minnesota bears on these relationships. Studying the response of agricultural crops on new land Alway (*1*) found no clear evidence that a previous forest fire had reduced the fertility of the soil. Nitrogen was observed to be only 0.02 percent lower on burned than on unburned sites.

Under exposure to the weather, the storage of any appreciable quantity of nitrogen, even that already incorporated in the soil, seems futile in warm climates. Jenny (*37*) states that in southern latitudes it will be difficult, if not impossible, to increase permanently and profitably the nitrogen content of cultivated soils by such practices as green manuring, because high temperatures, by favoring decomposition, militate against organic-nitrogen accumulation. He further states that, in the southern two-thirds of the United States at least, crop production will be maintained or increased by control of this nitrogen turn-over rather than by an attempt to maintain the total nitrogen content at a particularly high level.

In brief the studies of the chemical properties of soil at McNeill, including those of Heyward and Barnette, have shown that frequently burned-over soils were slightly less acid in reaction, and that both grazing and burning served to increase the bacterial population of the soil. Corn plants grew somewhat better on cultivated burned-over soil than on unburned soil in which no green cover crop had been incorporated. Organic matter (as indicated by loss on ignition), total nitrogen, and replaceable calcium were found in greater quantities in frequently burned-over soils.

DISCUSSION

It should be understood that where forestry and grazing enterprises are attempted on the same land in the southern pine region, perfect harmony can never be achieved. The interests of one use cannot be vigorously promoted without injury to the interests of the other. It is true that in colonial times most of the forest-land owners were glad to have their longleaf pine lands burned and grazed, but only because at that time no hopes were cherished for a second crop of timber. The unavoidable conflict between grazing and forestry becomes increasingly plain as land use is intensified with the growth of population, particularly near industrial centers. Ultimately, the problem can be satisfactorily solved in many places only by segregating these two uses on separate tracts, so that each can be intensively developed unhampered by the other. In several places this point has already been reached, but many owners in the pure longleaf type, although definitely past the period of unconcern whether more trees are grown or not, are not yet ready to begin intensive separate-use development of their lands.

It is in formulating suitable nonintensive management practices for longleaf pine forest land that the facts in the present report should be found most useful. It would be best, however, to proceed slowly with any literal or complete application of the results of the study. It must be kept in mind that even where nonintensive dual use of pine lands is apparently feasible, precaution should be taken to avoid certain misinterpretation. For example, the experiment at McNeill does not cover conditions of southern pine forests outside of the longleaf-slash pine belt nor does it apply to forest tree species other than longleaf pine. Little can be concluded from it regarding the effect of burning and grazing on watershed values; while no serious erosion was in evidence on the experimental area, the tendency for burning and grazing to compact the surface soil suggests the possibility of more rapid run-off on critical watersheds. Certainly, if anything, the results would seem to discourage such practices on watershed areas. Also, in the absence of further study, livestock other than cattle cannot be used with any confidence of the same results from grazing. Hogs, for example, are notorious despoilers of longleaf pine seedlings, and both sheep and goats may be quite destructive to saplings. Despite these limitations, there are numerous situations in which the findings might be utilized in formulating management practices applicable to the combination of cattle grazing and longleaf pine growing, even when all but the 8 million acres of pure longleaf pine type on flat land is ruled out.

Generally speaking, it would seem that burning is a desirable concomitant to cattle grazing on wild forest range in the longleaf pine region, in that it is an economical means of removing the dead mantle of grass, which measurably affects the quality and quantity of forage. But even with the mantle of dead grass removed, the grasses provide good grazing only in spring and early summer, so that it is necessary to remove cattle in the fall if heavy losses in weight are to be avoided. To supplement the inferior and seasonal native range there seems to be a definite need for many more improved fall pastures (*64*).

Grazing damage to longleaf pine cannot be regarded as a serious factor. It was largely the cumulative and indirect ill effects of trampling which noticeably reduced survival of the young trees during the long period of years when the seedlings remained stunted by defoliation, caused by annual fires and by the brown spot disease in the absence of fire. With reasonably prompt emergence from the grass stage much of this injury would be prevented.

Granting the need for the practice of burning in wild forest-range management, it is evident that the opportunity to combine cattle grazing with the growing of longleaf pine without undue conflict would depend largely upon the ability of the forest to withstand fire.

The loss of soil fertility feared by many as a result of burning and grazing does not loom up as an obstacle to dual use where watershed values are not involved. Although the study of soil characteristics was not exhaustive and did not fully measure the effects on plant growth, it did show that, as a result of burning and grazing, changes in physical properties studied were slightly adverse, whereas changes in the chemical properties were slightly favorable. The net effect of fire on soil fertility appears to be small and of little practical significance. This finding, even though as yet not well supported by quantitative measurements, is believed to have considerable significance. It at least indicates the possibility of using fire in longleaf pine management in the flat Coastal Plain without serious danger to the soil fertility.

Likewise, the retardation in the growth of saplings and pole-sized or larger longleaf pine trees does not appear to be a serious obstacle to the dual use of land for producing longleaf pine and forage for cattle. Experience on many other areas has indicated that loss of one-fifth or more of the growth, as recorded on the McNeill study area, can be largely avoided by reducing the intensity of fires.

The new longleaf pine seedlings suffered ill effects from the annual burning. In fact, the experiment definitely showed that none of the treatments tried permitted the seedlings of longleaf pine that came in during the course of the experiment to emerge from the grass stage and develop into trees. This was equally true of annual burning, grazing, or exclusion of fire, singly or in combinations.

The conspicuous failure in development of these longleaf pine seedlings under complete protection from grazing and fire is attributed to defoliation by the brown spot disease locally epidemic at McNeill; and in the case of annual burning, to the frequency of severe defoliation. Of the two stunting agencies, brown spot had a somewhat greater detrimental effect on growth, although more of the weakened seedlings survived after 12 years. The burned and the diseased seedlings seem equally incapable of emerging from the grass under continued mistreatment.

The inference is that some use should be made of fire as a cheap measure to control brown spot. In fact, Chapman (*12*) and Siggers (*53*, *54*) have already suggested, on the basis of extended observation, light periodic fires for controlling epidemics of brown spot. That such periodic-rotation burning might do only a small amount of fire damage to seedlings seems reasonable. It was because of the repeated burning of the same areas each year that the pine seedlings suffered such heavy damage in the experiment. The seedlings were defoliated too frequently to permit recovery between fires. Also, the heavy seedling loss from fire soon after seed germination could easily be avoided by an adjustable schedule of periodic fires.

The use of fire for this purpose as well as for other silvicultural purposes deserves further research; some such studies are in fact now under way. Should it develop that periodic light controlled fire is a necessary tool in longleaf pine management, the practice might well fit into the management of wild forest land for grazing. Such a schedule of burning need by no means imply that cattle must attempt to subsist on inferior rough range, say 2 years out of every 3. On the contrary, the periodic burns can easily be planned in rotation so that a fresh burn would be available each spring in a new location.

In the consideration of any use of fire in the longleaf pine type at present, however, it must not be overlooked that large areas of second-growth and seedling stands which originated during the period of widespread and indiscriminate burning are gaining in thrift and are accelerating their growth in response to the relief from too frequent fires afforded by organized protection. The rapid early development of longleaf pine sapling stands should not be seriously retarded on these areas by resuming any kind of burning practice too soon.

Finally, it can be stated that the use of fire to improve grazing conditions on the longleaf pine range in conjunction with the growing of timber is possible only because of the outstanding ability of longleaf pine to withstand burning. A marvelous fire resistance is typical of the species. Because of this it would seem that periodic light burning of longleaf pine range land in winter on an adjustable and overlapping 2- or 3-year cycle might be in order for many areas where present dual-management procedures are not satisfactory and where conflicts are not excessive. The increased economic rewards of nonintensive dual use are for those landowners who can integrate conflicting interests most skillfully and conservatively.

SUMMARY

The effects of four types of land treatment on the use of longleaf pine land for cattle grazing as well as for timber were studied at McNeill, Miss., at a branch of the Mississippi Agricultural Experiment Station, from 1923 to 1933. The experimental area covered 320 acres, divided into 2 pastures of 150 acres each and 2 ungrazed plots of 10 acres each. One of the pastures and one of the plots were burned over each winter, so that four conditions were represented—burned pasture, unburned pasture, burned ungrazed, and unburned ungrazed.

The results of these treatments on the survival and growth of longleaf pine, production of forage, weights of cattle, and soil conditions were briefly as follows:

Annual winter burning of uncontrolled intensity retarded the growth of longleaf pine sapling trees by about one-fifth in diameter and one-fourth in height during a 5-year period. The growth of the larger trees was apparently little affected. Likewise cone yields were little, if any, affected by burning.

In order of survival of seedlings that came in during the course of the experiment, the land treatments ranked as follows (highest survival first): (1) Unburned and ungrazed, (2) unburned and grazed, (3) burned and ungrazed, and (4) burned and grazed. Survival of the seedlings of the 1924 heavy seed crop, after 10 years of excluding both grazing and fire, was 43 percent as against not over 5 percent from any one of the other three land treatments.

None of the treatments tried was successful in bringing new longleaf pine seedlings out of the grass stage. After 12 years the seedlings still remained in a stunted condition. Annual defoliation by fire on the one hand and by the brown spot needle disease, which was locally epidemic at McNeill, on the other hand, were considered primarily responsible for the stunting.

Annual winter burning maintained more favorable composition, quality, and quantity of forage than did exclusion of fire. The smothering due to pine litter and accumulated dead grass retarded the growth of native grasses and legumes and reduced the number of plants per acre.

The improvement in forage conditions through burning was reflected in the greater seasonal gains in weight of cattle on the burned area, which averaged 37 percent more than the gains made on the unburned pastures. The cattle secured their advantage in gains during the early part of the grazing season and held this advantage until removed from the area in the fall. The experimental pastures were grazed equally for about 7 months each year over a period of 11 years.

Burning and grazing did not result in serious soil degradation. Burned-over soils exhibited slightly favorable chemical characteristics and unfavorable physical characteristics in comparison with unburned soils. The net effect on plant growth of favorable and unfavorable soil changes was not measured.

While annual burning improved the forage conditions for cattle, the results indicate that successful regeneration of longleaf pine, especially where the brown spot disease is epidemic, may depend upon some system of periodic controlled burning rather than the extremes of annual fires or fire exclusion, both found unsatisfactory in this study.

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APPENDIX

WEATHER RECORDS AT McNEILL, MISS.

Month	Precipitation [1]	Average high and low temperatures [2]		Month	Precipitation [1]	Average high and low temperatures [2]	
		Maximum [3]	Minimum [4]			Maximum [3]	Minimum [4]
	Inches	*°F.*	*°F.*		*Inches*	*°F.*	*°F.*
January	5.15	77	23	September	5.00	96	56
February	5.46	78	25	October	3.35	91	39
March	5.75	85	33	November	3.26	83	30
April	5.12	88	41	December	5.12	77	27
May	5.77	94	50				
June	6.20	97	62	Total	63.11		
July	7.34	97	65	Average per month	5.26	88	43
August	5.47	97	66				

[1] Basis: 23 years, 1905–29, exclusive of 1919–20.
[2] Absolute extremes of temperature were recorded as follows: Maximum, 103° F. in 1909, 1924, 1925, and 1927; minimum, 12° in 1924.
[3] Basis: 14 years, 1907–16, 1922–23, 1927–28.
[4] Basis: 16 years, 1905–16, 1922–23, 1927–28.

PARTIAL LIST OF PLANTS FOUND ON THE EXPERIMENTAL TRACT AT McNEILL

GRASSES

Agrostis hiemalis (Walt.) B. S. P.
A. perennans Walt.
Andropogon elliottii Chapm.
A. furcatus Muhl.
A. longiberbis Hack.
A. mohrii Hack.
A. scoparius Michx.
A. tener (Nees) Kunth
A. ternarius Michx.
A. virginicus L.
Anthaenantia villosa Michx.
Aristida affinis (Schult.) Kunth (= *A. palustris* (Chapm.) Vasey)
A. lanosa Muhl.
A. longespica Poir.
A. purpurascens Poir.
A. virgata Trin.
Axonopus compressus (Swartz) Beauv.
Ctenium aromaticum (Walt.) Wood (= *Campulosus aromaticus* (Walt.) Scribn.)
Cynodon dactylon (L.) Pers.
Digitaria filiformis (L.) Koel.
Eragrostis refracta (Muhl.) Scribn.
Gymnopogon ambiguus (Michx.) B. S. P.
G. brevifolius Trin.
Muhlenbergia expansa (Poir.) Trin.
Panicum aciculare Desv.
P. agrostoides Spreng.
P. albomarginatum Nash
P. anceps Michx.
P. angustifolium Ell.
P. ciliatum Ell.
P. flavovirens Nash
P. leucothrix Nash
P. longifolium Torr.
P. longiligulatum Nash
P. lucidum Ashe.
P. rhizomatum Hitchc. and Chase
P. sphaerocarpon Ell.
P. strigosum Muhl.
P. trifolium Nash
P. verrucosum Muhl.
P. villosissimum Nash
P. virgatum L.
Paspalum bifidum (Bertol.) Nash
P. debile Michx.
P. dilatatum Poir.
P. floridanum Michx.
P. setaceum Michx.
Sorghastrum nutans (L.) Nash
Sphenopholis nitida (Spreng.) Scribn.
Sporobolus asper (Michx.) Kunth (= *Sporobolus drummondii* (Trin.) Vasey)
S. gracilis (Trin.) Merr.
S. macrus (Trin.) Hitchc.
Triodia flava (L.) Smyth
T. langloisii (Nash) Bush (= *Triodia ambigua* (Chapm.) Benth., and *Triodia elliottii* (Ell.) Bush)

LEGUMES

Bradburya virginiana (L.) Kuntze
Chamaecrista nictitans (L.) Moench
Cracca ambigua (M. A. Curtis) Kuntze
C. chrysophylla (Pursh) Kuntze
C. latidens Small
Crotalaria rotundifolia (Walt.) Poir.
C. sagittalis L.
Dolicholus erectus (Walt.) Vail (=*Rhyncosia erecta* (Walt.) DC.)
D. intermedius (T. & G.) Vail (=*Rhyncosia intermedia* (T. & G.) Small)
D. simplicifolius (Walt.) Vail (=*Rhyncosia simplicifolia* (Walt.) Wood)
Galactia volubilis (L.) Britton
G. erecta (Walt.) Vail
Lespedeza angustifolia (Pursh) Ell.
L. hirta (L.) Ell.
L. repens (L.) Bart
L. striata (Thunb.) H. and A.
L. stuvei Nutt.
L. virginica (L.) Britton
Meibomia arenicola Vail
M. marilandica (L.) Kuntze
M. paniculata (L.) Kuntze
Morongia microphylla (Dryand) Britton
Strophostyles pauciflora (Benth.) S. Wats.
S. umbellata (Muhl.) Britton
Stylosanthes biflora (L.) B. S. P.

HERBS

Agalinis setacea (Walt.) Raf. (=*Gerardia setacea* Walt.)
Aster dumosus L.
Chaptalia tomentosa Vent.
Chrysopsis aspera Shuttlw. (=*Pityopsis aspera* (Shuttlw.) Small)
Elephantopus tomentosus L.
Eupatorium capillifolium (Lam.) Small
E. verbenaefolium Michx.
Gaillardia lanceolata Michx.[15]
Helianthus radula (Pursh) T. and G.
Lacinaria spicata (L.) Kuntze
Linum striatum Walt. (=*Cathartolinum striatum* (Walt.) Small)
Monarda punctata L.
Pedicularis canadensis L.
Pentstemon laevigatus Soland. (=*P. pentstemon* (L.) Britt.)
Pinguicula lutea Walt.

[15] This is often confused with the more western *G. lutea* Greene.

HERBS—continued

Polygala nana (Michx.) DC. (=*Pilostaxis nana* (Michx.) Raf.)
Ruellia ciliosa Pursh
Solidago odora Ait.
Tithymalopsis corollata (L.) Kl. and Garcke
Viola primulifolia L.

SHRUBS

Ascyrum stans Michx.
Callicarpa americana L.
Hamamelis vernalis Sarg.
H. virginiana L.
Ilex decidua Walt.
I. glabra (L.) A. Gray
I. vomitoria Ait.
Leiophyllum buxifolium (Berg.) Ell. (=*Dendrium buxifolium* (Berg.) Desv.)
Leucothoë axillaris (Lam.) D. Don (=*Leucothoe platyphylla* Small)
Myrica cerifera L. (=*Cerothamnus ceriferus* (L.) Small)
Neopieris nitida (Bartr.) Britt. (=*Pieris nitida* (Bartr.) Benth. and Hook.)
Rhus copallina L.
Symplocos tinctoria (L.) L'Her.
Toxicodendron radicans (L.) Kuntze (=*Rhus toxicodendron* L.)
T. vernix (L.) Kuntze (=*Rhus vernix* L.)
Vaccinium elliottii Chapm. (=*Cyanococcus elliottii* (Chapm.) Small)
V. tenellum Ait. (=*Cyanococcus tenellus* (Ait.) Small)
Viburnum rufidulum Raf.

TREES

Acer rubrum L.
Cornus florida L.
Cliftonia monophylla (Lam.) Sarg.
Cyrilla racemiflora L.
Diospyros virginiana L.
Hicoria spp.
Ilex opaca Ait.
Liquidambar styraciflua L.
Magnolia virginiana L.
Nyssa sylvatica Marsh.
Pinus caribaea Morelet.
P. echinata Mill.
P. palustris Mill.
P. taeda L.
Quercus cinerea Michx.
Q. marilandica Muench.
Q. rubra L.

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