SOME ASPECTS OF WATER BALANCE IN THE GULF COASTAL FLATWOODS

by

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INTRODUCTION

In 1860, Hilgard (4)* described the area we now know as the Pamlico Terrace of the Coastal Flatwoods as, " ... a level meadowland, in which there is scarcely any distinction into upland and lowland. Almost the only living being, ... which inhabits this region at present, is the prairie-lark; settlements are few and far between, and no attempt is made to cultivate the soil, the raising of stock being the only occupation of the inhabitants." Further, "The timber is formed altogether by diminutive Long Leaf Pines (sic), averaging about 25 feet in height by 2½ to 4 inches in thickness, which stand at considerable distances (40 or 50 feet) apart, ..." The passage of 106 years has altered this picture considerably - we see the Coast as a highly urbanized, industrralized area. The ecological community has also been altered, particularly the species forming the overstory of the area. Where Hilgard found only "diminutive" longleaf pine (Pinus palustris), the species now found is slash pine (Pinus elliottii). Hilgard was, however, a most astute observer and a fair prognosticator - he was correct in his assumption that agronomic crops would never be important in the area, but incorrect when he stated that the pine meadows would produce only timber "fit for little else than (charcoal) burning... ." In 1965, the three coastal counties of Mississippi produced 25,304,000 board feet of sawlogs, poles, piling and crossties, and 100,232 cords of pulpwood (8): approximately 25% of the area of these counties could be classified as "pine meadows".

Although the area is unique among ecological communities, the same condition is also found along the Atlantic Coastal Plain; its uniqueness is derived from an abundance of rainfall combined with a particular physical soil condition and topographic situation.

This paper presents some preliminary results of an investigation concerned with the water balance relationships of the extensive, poorly drained areas of the Coastal Flatwoods. The study is sponsored by the Mississippi Water Resources Research Institute and supported by funds provided by the United States Department of Interior as authorized under the Water Resources Research Act of 1964, Public Law 88-379.

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* refers to literature cited

STUDY AREA DESCRIPTION

Location. The study area is located in Hancock County, Mississippi, approximately eight miles west of Bay St. Louis and one mile south of Highway 90. The land is owned by the St. Regis Paper Company.

Climate. The climate of this area is characterized by warm, humid summers, and cool, humid winters. Although freezing temperatures occur, they are not frequent, and the average frost-free season is nine months; the average date of the last Spring frost is March 1, and the average date of the first Fall frost is December 3 (7). Precipitation is relatively uniform and the average annual precipitation is about 60 inches; the greatest annual precipitation recorded was 96 inches with a least annual precipitation of 38 inches.

Geology and Hydrology. The Pamlico Plain is of Pleistocene age; it is bounded on the south by Recent beach deposits and salt marshes of the Mississippi Embayment, and on the north by Low Terrace deposits, also of Pleistocene age. The elevation of the Plain varies from 5 to 30 feet above sea level. The Pamlico sands which form the Plain are described as "gray and tan sands; (which) contain fresh water under water-table conditions in beach areas, and in contact with salt water" (1). The specific area under investigation is probably a lagoonal deposit as evidenced by the high silt content, and the stratification of the deeper sediments. Although there have been wells dug in the Pamlico sediments, for the most part water from these wells is not suitable for human consumption due to contamination from sewage. The porous and unconsolidated sands furnish a reservoir in and near thickly populated areas; also, the water would probably become salty if wells were located near tidal bays (1).

Topography. The topography of the "pine meadows" is characterized by broad, flat ridges separated by shallow, meandering drainage channels. The difference in elevation between the highest point on the study area and the adjacent stream channel is approximately six feet; the majority of the elevation change occurs in the gentle slope between the ridge flat and the drainage channel, a horizontal distance of approximately six chains (396 ft.).

Vegetation. In 1860, Hilgard reported that the area supported a dense ground cover of sedge-grass (Cyperaceae), cord rushes (Eriocaulon), Xyris, Sarracenia, and Dichromena; a dense undergrowth of gallberry, and the sparse longleaf overstory. Heavy cutting plus the advent of some form of fire protection has permitted slash pine to reseed much of the area formerly occupied by longleaf pine. Apparently the understory and ground cover has been little altered in the 100 year period since Hilgard described the plant community.

PROCEDURE

Several extensive areas in the Pamlico Plain were investigated and discarded on the basis of nonuniformity in physical soil conditions.

The site finally selected was approximately 60 acres in area. The uniformity of physical soil condition was determined by a series of deep borings with a bucket auger. The site was then surveyed with transit and leveling rod, and a topographic map with 0.5 foot contour intervals was prepared for later use.

One component of water balance, weather, was recorded at a standard station located approximately two miles from the study area; unfortunately, damage to some of the instruments during a hurricane necessitated the use of Bay St. Louis weather records during a portion of the year.

Soil moisture measurements were obtained by means of a neutron probe. Twelve-foot aluminum tubes with an inside diameter of two inches were installed at 20 locations selected with the aid of the topographic map. Four lines of tubes were arranged so that they crossed contour lines at approximately right angles. Two of the lines were treated by removing all woody vegetation around each tube for a distance of 33 feet; the remaining lines were not treated. A combination auger-post hole inspection was made in the immediate vicinity of each tube and brief profile descriptions were compiled.* From these descriptions, a depth listing was made at each point for each horizon, and probe readings were taken at the center of each of the A horizons, the upper B horizon, the lower B horizon, and at two points in the parent material. Depending upon weather conditions and degree of soil saturation, probe measurements were taken weekly, biweekly, or monthly.

In addition to the small holes utilized for profile description, large pits were excavated at three points in the sample area. These pits were placed in areas where it was felt that a deviation from the medial physical soil condition occurred. Both undisturbed soil cores and bulk samples were collected from each major horizon or horizon group in each pit. The undisturbed core samples were used in moisture retention and percolation rate studies and bulk density determinations. The bulk samples were used for particle size determinations and chemical analyses. Particle size determinations were made by the hydrometer method (2), and the chemical analyses by methods employed by the Soil Testing Laboratory at Mississippi State University (3, 5, 6).

RESULTS AND DISCUSSION

Although measurements will not be terminated until June, 1966, certain information has been summarized and trends established which are sufficiently strong to warrant presentation.

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*These descriptions were made by Soil Scientist Wm. I. Smith through the courtesy of the Soil Conservation Service.

Physical and Chemical Soil Properties. The soils of the study area are mapped in three soil series; Rains, Weston, and Dunbar. The Dunbar series is found only on the comparatively steep slopes between the flat ridges and the adjacent drainages. A comparison of physical and chemical properties of the Rains and Weston profiles indicated that differences within a series were of the same magnitude as differences between series and, consequently, properties were averaged for the sample area soil description (Tables 1, 2, 3). Although percentages of sand, silt and clay did not differ appreciably between samples, bulk density, available phosphorus and exchangeable potassium differences were sometimes in the vicinity of 10% of the mean values for comparable horizons.

Table 1. Mean physical soil properties of sample area.

Horizon	Hor. No.	Depth	Textural Class	% sand	% silt	% clay	Bulk Density
A_1	1	0-4"	sil	39.0	56.9	4.1	1.10
A_2g	2	4-13"	sil	38.5	55.1	6.4	1.39
$B_{21}g$	3	13-23"	sil	33.9	56.8	9.3	1.50
$B_{22}tg$(pl)	4	23-35"	sil	29.4	55.5	15.1	1.54
B_3tg(pl)	5	35-58"	sil	23.8	51.2	25.0	1.49

Table 2. Mean chemical properties of sample area.

Horizon No.	pH	Percent Organic Matter	Pounds per acre-inch Avail. P.	Exch. K.
1	4.7	2.41	0.78	4.80
2	4.8	0.42	0.44	3.64
3	4.9	0.42	0.30	5.11
4	5.0	0.39	1.21	5.63
5	4.9	0.30	4.62	19.63

Table 3. Mean soil moisture properties of sample area soils.

Hor. No.	Percent moisture retained, by volume, at tensions of 0.06 bar	0.1 bar	0.3 bar	0.6 bar	1.0 bar	4.0 bars	15.0 bars
1	44.5	38.8	33.6	29.5	26.8	20.3	14.4
2	39.6	36.4	28.6	23.7	20.2	14.8	11.4
3	37.6	34.7	29.8	25.4	21.5	15.1	12.3
4	37.0	34.9	31.3	28.0	25.4	19.6	17.7
5	45.8	39.6	36.1	33.4	31.7	28.8	26.4

The values obtained in Table 3 were plotted and desorption curves typical of silt loam soils were obtained (Figure 1). As expected, the subsoil horizons have different release and retention patterns than the surface horizons, due primarily to an increase in clay with depth. Assuming 0.3 and 15 bars as the upper and lower limits of soil moisture available for plant growth, the A_1, A_2g, and B_{21}g horizons will, on the average, yield 0.192, 0.172, and 0.175 acre-inches of water per inch of horizon, respectively.

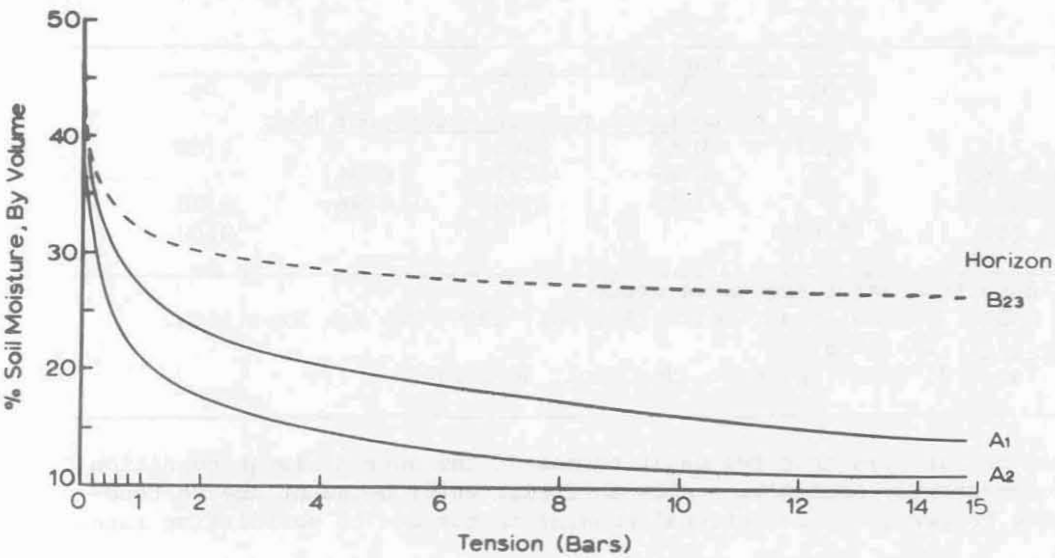

Figure 1. Desorption Curves for Medial Profile

In the approximate 24 inch depth represented by these horizons, the soil will then be capable of retaining 4.2 acre-inches of available moisture; it will, however, retain approximately 9.5 acre-inches in the same depth at a moisture content approaching saturation. Also noted in Figure 1 is the rather unique release characteristic of silt loam soils; there is a gradual release of soil moisture with increasing tensions, as opposed to a rapid initial loss for sands and a relatively slow release pattern for clays.

The mere fact that extensive areas of the ridge-flat topography should be so poorly drained was of interest, and consequently an attempt to explain the phenomenon was made. A comparison of percolation rates of the sample area soils with silty upland soils was made (Table 4), and it was found that rates for the Rains soil were considerably slower than the other soils. In fact, the percolation rate of the B_{21}g horizon is quite comparable to the rates observed in fragipans of upland soils. Another facet of this analysis was the differential rates found between horizontal and vertical water movement. The A_2g horizon of the Rains soil has the capacity to move water, under saturated conditions, at a rate of 0.62 inches per hour in a vertical direction, but only 0.20 inches per hour in a horizontal direction. This horizon occurs immediately above the $B_{21}g$ horizon which exhibits extremely slow movement in both vertical and horizontal directions, 0.05 and 0.07 inches per hour, respectively.

Table 4. Comparative percolation rates for soils of similar texture.

	Horizons				
	A_1	A_2	B_{21}	B_{22}	B_3
	percolation rate in inches per hour				
Rains (1)	0.17	0.62	0.05		0.08
Grenada (2)		0.89	1.87	0.84	
Grenada (3)		1.87	1.58	0.96	0.28
Henry (4)	2.67				0.30

(1) data from Water Resources study
(2) Table 39. So. Coop. Series Bul. 61, 1959, Va. Ag. Expt. Sta.
(3) Ibid. Table 38
(4) Table 3, Tenn. Ag. Expt. Sta. Bul. 367, 1963

It can be inferred that two major causes of the poor drainage condition are concurrently operative - slow surficial water movement due to topographic factors, and an internal ponding factor due to percolation rate.

One additional factor of water movement, a factor that tends to mitigate the slow percolation rates, was observed during the excavation of the various pits on the sample area. Crayfish (Cambarus diogenes, subspecies) burrows passing through the various horizons, sometimes to a depth of three feet, present a path of rapid water movement, primarily in the vertical dimension.

Seasonal Soil Moisture Levels. Examination of the weather records for the coastal area indicates that only two periods of relatively low precipitation can be expected; the initial period in May and June; and the second period in October and November. This study was not initiated in time to obtain measurements during the initial period, and, consequently, data are available only for the October-November desorption period.

As might be expected, for this combination of topography and soil the relationship of soil moisture levels to precipitation is particularily strong (Figure 2). It is anticipated that a desorption period similar to the one illustrated for the Fall of 1965 will occur during the May-June period of 1966; field observation during 1965 supports this statement. It is noted that soil moisture levels are well above the assumed lower limit of readily available water for all but 2½ weeks of the measurement period. The $B_{22}tg(pl)$, the $B_{23}tg(pl)$, and the C horizons did not deviate sufficiently from a saturated, or near saturated, condition for graphical presentation.

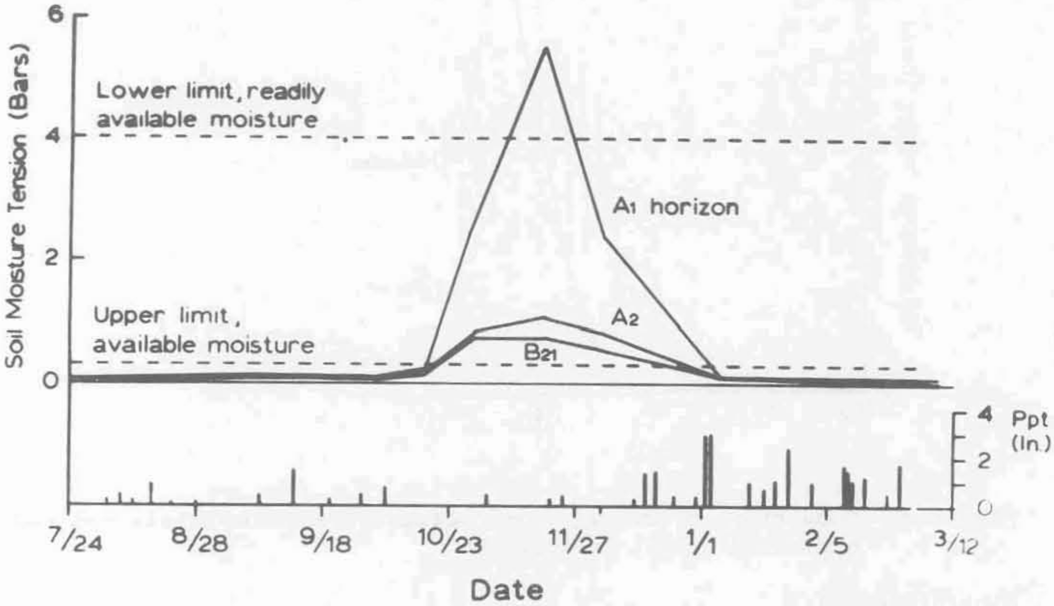

Figure 2. Study area soil moisture tension levels related to time and precipitation

A comparison of the soil moisture tensions at cleared and uncleared stations is also revealing (Figure 3). In the A_1 horizons, stations supporting a stand of five year old slash pine developed only 4½ bars of tension versus 3 bars for the uncleared stations. These tension differences become less prominent with depth in the profile until at approximately 36 inches (the base of the $B_{22}tg(pl)$) there is no significant difference between soil moisture levels of cleared and uncleared stations.

These data indicate that optimum soil moisture levels for rapid growth are rarely achieved for extensive periods during the growing season. Further, the transpirational area accumulated by planted slash pine in four field growing seasons is insufficient to appreciably reduce water table levels. This phenomenon has been observed by the writer along the Atlantic Coastal Plain in similar physical and topographic situations: following the cutting of a mature stand of pine, water table levels rise to the surface, and until encroaching hydrophitic hardwood species develop a transpirational area large enough to reduce high water tables, pine will not normally become re-established through natural regeneration.

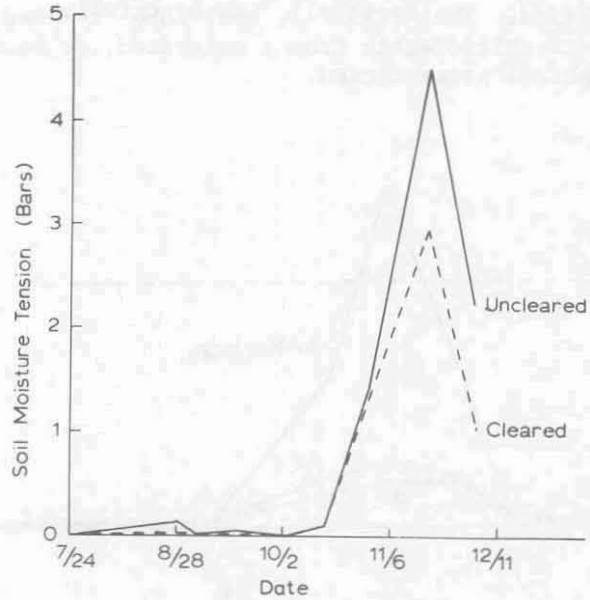

Figure 3. Comparison of average soil moisture tensions on cleared and uncleared areas. A horizons.

<u>Biotic Factors</u>

In the process of mapping the area, it was noted that there were apparent growth differences within the area. Examination of the topographic map revealed that although there was only a two foot elevational difference on the ridge (Figure 4), an area of increased slash pine growth rate occurred on this area. The computed average slope of the ridge-flat was only 0.2%, a minor topographic difference which, however, did result in a major change in plant response.

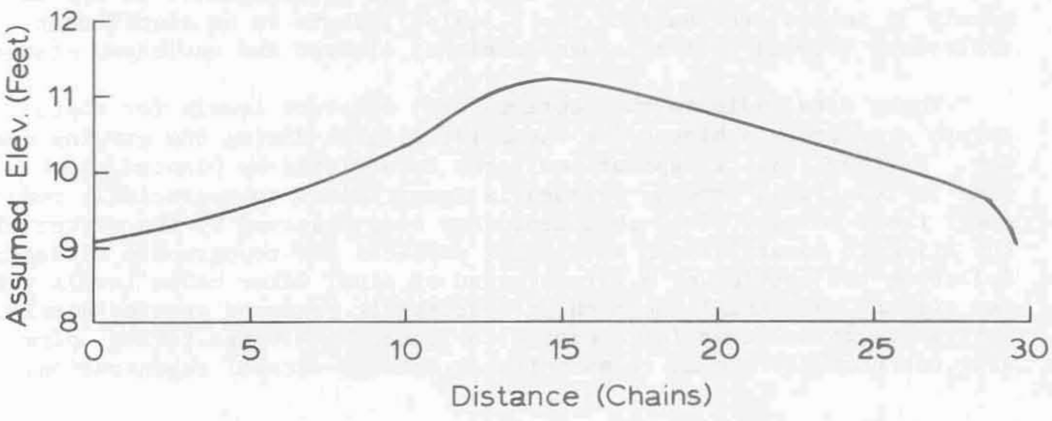

Figure 4. Profile on N-S line through ridge flat. 33:1 vertical exaggeration

Five year old slash pine seedlings growing on the "peak" of the ridge were found to be slightly more than twice as tall as seedlings growing on the remainder of the area (Figure 5, 6).

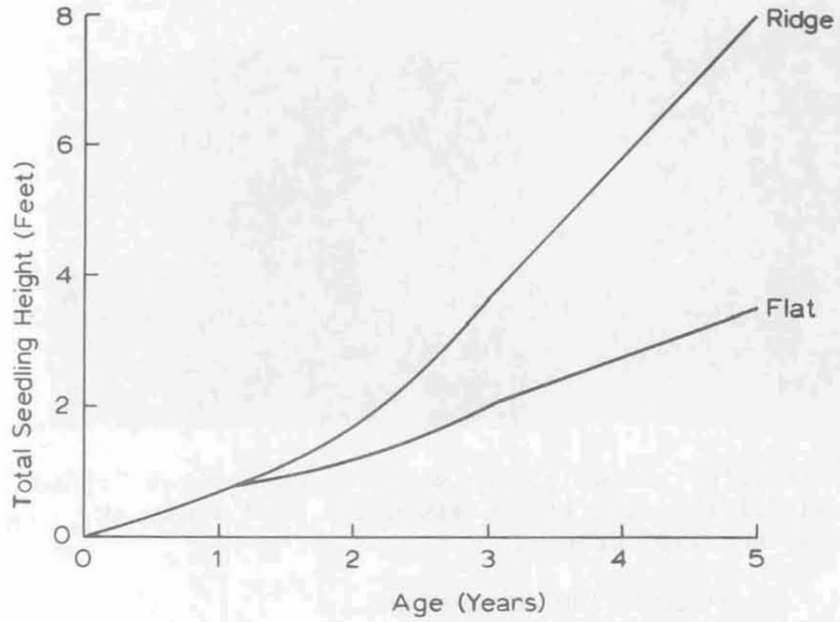

Figure 5. Comparison of height growth on two topographic extremes.

The average diameter, outside bark, one foot above the ground level was also approximately twice as great on the high point as on the flat - 2.04" versus 1.06". Physical and chemical soil differences between the high and low points are not of a magnitude that would account for the biotic difference; there is, however, a difference in the amount and duration of surface water ponding that occurs on the two areas. Following rains of 0.5 inches or greater, it was observed that the water was ponded in greater quantities and for longer periods of time on the flats; also, neutron probe stations located on the high points were generally at higher soil moisture tensions than those stations on the low areas.

On the basis of this information, it is estimated that the average height-growth rate of planted slash pine on these poorly drained situations can be increased from the current one foot per year to approximately three feet per year if water table regulation was practiced. One of the major problems of such water regulation would be the slow permeability rates of the soils - it is possible that in order to provide adequate water removal, costs would not justify increased returns.

Figure 6. Photographs illustrating growth differences between "ridge" (left) and "flat" (right); the student's hand rests at the base of the 1965 growth.

SUMMARY AND CONCLUSIONS

The soils of the sample area were mapped in three series, predominantly Rains and Weston, with Dunbar found on slopes: the soils were characterized by means of both physical and chemical properties, and it was found that a medial profile could be constructed because differences in properties were as great within series as between series. Retention and release patterns of soil moisture available for plant growth and percolation rates were also determined. The cause of poor drainage on the extensive, flat ridges was attributed to a combination of slow surficial water movement and slow percolation rates in both the vertical and horizontal direction.

Soil moisture fluctuations were of consequence only during a period of low precipitation in October and November; even at this point fluctuations occured primarily in the upper two feet of the profile. Differences in withdrawal patterns between neutron probe stations cleared of woody vegetation, and stations about which the vegetation was undisturbed were found to be significant primarily in the upper portion of the profiles, and at depths of 36 inches no differences were observed. On the basis of these measurements, it is concluded that rapid growth of woody vegetation will occur only during those periods of the growing season when evapotranspiration exceeds precipitation by an amount that will permit lowering of the water table.

Stem analysis of five year old slash pine taken from both high and low points of elevation on the ridge reveals a two-fold growth increase in both diameter and height on the high point of elevation.

This difference is attributed to slight water table differences caused by the almost negligible slope on the study area. It is felt that, through water table regulation, a height growth rate of three feet per year can be obtained; a three fold increase over the current rate of one foot per year.

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