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Abstract. Changes in microtopography, nutrient levels, and vegetation were followed for 4 years on treated plots in a north Florida flatwoods site. Plots were disk-harrowed, bedded to heights of either 15 or 30 cm above the normal ground line, and planted to *Pinus elliottii*. Site preparation changed the microtopography from flat to undulating, concentrated organic matter and nutrients in the beds, and nearly eliminated the typical flatwoods understory of *Serenoa repens*, *Ilex glabra*, and *Aristida stricta*. Four years later, *Ilex glabra* was the only major species showing signs of returning to its original frequency; meanwhile *Panicum*, *Paspalum*, *Andropogon*, *Rubus*, and *Vaccinium* predominated. Both high and low bedding increased the frequency of plants important for wildlife food and cover. Site preparation greatly altered the composition of vegetation and most species tended to be stratified by micro-relief. High bedding effected the greatest changes in microtopography, soil nutrient levels, and vegetation. *Forest Sci.* 20: 230-237.

Additional key words. Microtopography, nutrients, succession, *Pinus elliottii*, wildlife habitat.

PRESENT FOREST MANAGEMENT along the Atlantic and Gulf Coastal Plains relies heavily on intensive site preparation, such as chopping, disking, and bedding, as well as artificial regeneration for successful establishment and rapid growth of planted pines (Worst 1964, Wilhite and Harrington 1965, McMinn 1969). These treatments alter the ecosystem by changing the flora, microtopography, soil properties, and drainage patterns (Haines and Pritchett 1965, Langdon 1962, Lewis 1970), but little is known about the persistence of these changes over time.

Our study documents changes in vegetation and soil over a 4-year period on a north Florida flatwoods site that was intensively prepared and planted to slash pine (*Pinus elliottii* Engelm. var. *elliottii*).

Methods

The study was conducted on a 15-acre flatwoods site in Baker County, Florida. The soil was an imperfectly drained Leon fine sand (Aeric Haplaquod) with a well-defined spodic horizon normally found at depths of 30 to 50 cm.

Prior to treatment, the vegetation consisted of a sparse stand of longleaf pine (*Pinus palustris* Mill.) with an understory dominated by saw-palmetto (*Serenoa repens* (Bartr.) Small), gallberry (*Ilex glabra* (L.) Gray), and pineland threeawn (*Aristida stricta* Michx.). This pine flatwoods complex represents the most common vegetation type in Florida. It is a fire subclimax and predominates on relatively flat areas (Monk 1968). The area was logged in 1965 and disk-harrowed twice during the summer of 1966. Twenty plots, each 30 × 37 m with 12 m buffer strips between plots, were installed on the area.

Two site preparation treatments were created: low and high beds. Low beds (15 cm above normal ground line) were con-

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structed on 3.7-m centers with a bedder-packer on 10 randomly selected plots. They were 0.5 m wide across the top and 1.3 m wide at the base. On each side of a bed there was a furrow 0.6 m wide and 5 to 10 cm deep. The entire area below the normal ground line was designated as a furrow. A flat harrowed strip 1.3 m wide separated the shallow furrows.

On the other 10 plots, furrows were made on 3.7-m centers with a fire plow, and a bedder-packer pulled the soil between furrows into high beds (30 cm above normal ground line). High beds were 0.9 m wide across the top and 2.6 m wide at the base. Furrows between the high beds were 1.1 m wide and ranged in depth from 15 to 20 cm below the normal ground line. One-year-old slash pine seedlings were hand planted at 3-m intervals on the tops of the beds in all plots in January 1967.

Ten random lines stretching between the tops of two adjacent beds were installed in both high and low bedded plots shortly after site preparation and were remeasured 4 yr after treatment. Wire pins driven into the tops and sides of beds as well as furrow bottoms served to follow changes resulting from siltation or soil settling.

We took soil samples from each of the 20 plots in January 1967 and in February 1970, combining twenty random subsamples into each sample. Subsamples were taken with a King tube from the 0–15 cm and 15–30 cm layer on the top of beds and from the 0–15 cm layer midway between beds. Thus, we sampled a harrowed A horizon between low beds and an undisturbed B horizon in the furrow bottom between high beds. We compared these unlike soil layers simply because they both represented the surface layer of the areas midway between beds. No samples were taken from the shallow furrows on each side of the low beds.

Composite samples were air-dried, sifted through a 20-mesh sieve, thoroughly mixed, subsampled, and stored in airtight bottles for analyses. Identical chemical procedures were used to analyze the 1967 and 1970 samples. The pH was determined from a slurry of 1 part soil and 1.5 parts

water. Organic matter content was obtained by dry ashing duplicate 20-g samples at 700°C for 1 hr. The loss in weight on ignition was computed as a percentage of oven-dry sample weight. Total nitrogen (N) was determined by Kjeldahl analysis of 20-g samples. Exchangeable potassium (K), calcium (Ca), and magnesium (Mg) were extracted with neutral N ammonium acetate and analyzed by atomic absorption. Available phosphorus (P) was determined by the Bray No. 2 extraction (Bray and Kurtz 1945).

We made frequency counts of shrubs and herbs in April 1968 and October 1970 (approximately 2 and 4 yr after site preparation). Although season affects the prominence of some species, we believe that season of sampling did not bias our study. The counts were made along two permanently located, 30-m line transects in each plot, by the line intercept method. The transects were installed perpendicular to the beds. All beds were oriented in an east-west direction. One transect of each plot was randomly assigned to a line 0.3 m from a column of trees; the other was randomly assigned to a line midway between two columns of trees (trees were spaced to form both rows and columns). Wire pins divided transects into three microsites for low beds—bed, furrow, flat—and three microsites for high beds—top of bed, side of bed, furrow. Because of bed construction each of the 6 microsites was different. Our main interest was to compare vegetation on the different microsites. Transects were further subdivided into two hundred 15-cm segments, each consisting of an imaginary vertical plane. Each of 30 understory species groups was recorded by the number of segments in which it occurred and by microsite. Any leaf or shoot contact with a living plant in each segment was the recording criterion. Because of similar growth habit and response to treatment, species groups were combined into 19 classes for analyses and presentation.

Vegetation was not sampled on the study area prior to treatment. To compare vegetation frequency before and after treatment, we established 48 line transects during Oc-

TABLE 1. Relationship of soil nutrients to microsite following site preparation in north Florida flatwoods.

Sample position	Soil depth	OM (Loss on ignition)	N	P	K	Ca	Mg
	cm	percent	parts per million				
Low-bedded plots 6 mo after site preparation							
Bed	0-15	2.3	426	3.7	15.3	69.9	24.6
Bed	15-30	1.5	290	2.8	11.1	47.7	18.0
Flat	0-15	1.8	344	3.4	13.1	61.4	22.4
High-bedded plots 6 mo after site preparation							
Bed	0-15	1.7	345	3.1	13.2	67.8	21.7
Bed	15-30	2.0	371	2.9	15.6	72.6	23.2
Furrow	0-15	0.8	170	5.8	6.8	25.2	9.9
LSD(0.01) ¹		0.5	71	2.7	4.1	15.0	5.9
Low-bedded plots 4 yr after site preparation							
Bed	0-15	2.8	492	1.1	13.8	76.0	25.0
Bed	15-30	1.4	266	1.7	7.9	44.0	17.1
Flat	0-15	2.1	389	1.0	13.7	63.9	22.3
High-bedded plots 4 yr after site preparation							
Bed	0-15	2.2	403	1.1	13.4	78.3	24.0
Bed	15-30	2.0	378	2.1	12.2	73.5	23.9
Furrow	0-15	0.8	159	2.4	6.7	24.6	9.1
LSD(0.01) ¹		0.5	78	1.4	3.0	14.5	5.9

¹ Duncan's new multiple range test compares all microsites within each sampling period.

tober 1970 in an area approximately 2 miles from the study having the same soil type, vegetation type, and fire history. This comparison is tenuous but we believe the areas are similar enough to indicate trends in vegetational changes.

Analyses of variance were used to analyze changes in soil characteristics related to time and site preparation. Histograms were used to compare vegetative changes on permanent plots.

Results

Changes in Microtopography. Site preparation greatly altered the microtopography of the area. Low beds left 35 percent of the soil surface flat (unaffected by bedding), 36 percent in beds, and 29 percent in shallow furrows. High beds changed the soil surface either into tops of beds (23 percent), sides of beds (46 percent) or deep furrows (31 percent).

Shallow furrows alongside low beds did not penetrate the B horizon and rarely supported surface water. In contrast, furrows between high beds were deep ditches which sometimes penetrated the slowly permeable B_{2H} horizon (spodic layer) and had standing water for several days after heavy rains.

For the remainder of this paper the deep furrows between high beds will be compared to the flat areas between low beds. They occupy the same relative position and area but differ greatly in suitability for rooting as well as establishment and development of vegetation.

Soil settling reduced bed heights an average of 2 to 6 cm from 1966 through 1970. The greatest changes resulted from small amounts of soil sluffing from the sides of high beds and settling 2 to 3 cm deep in the furrows. These changes did not significantly alter the surface profile.

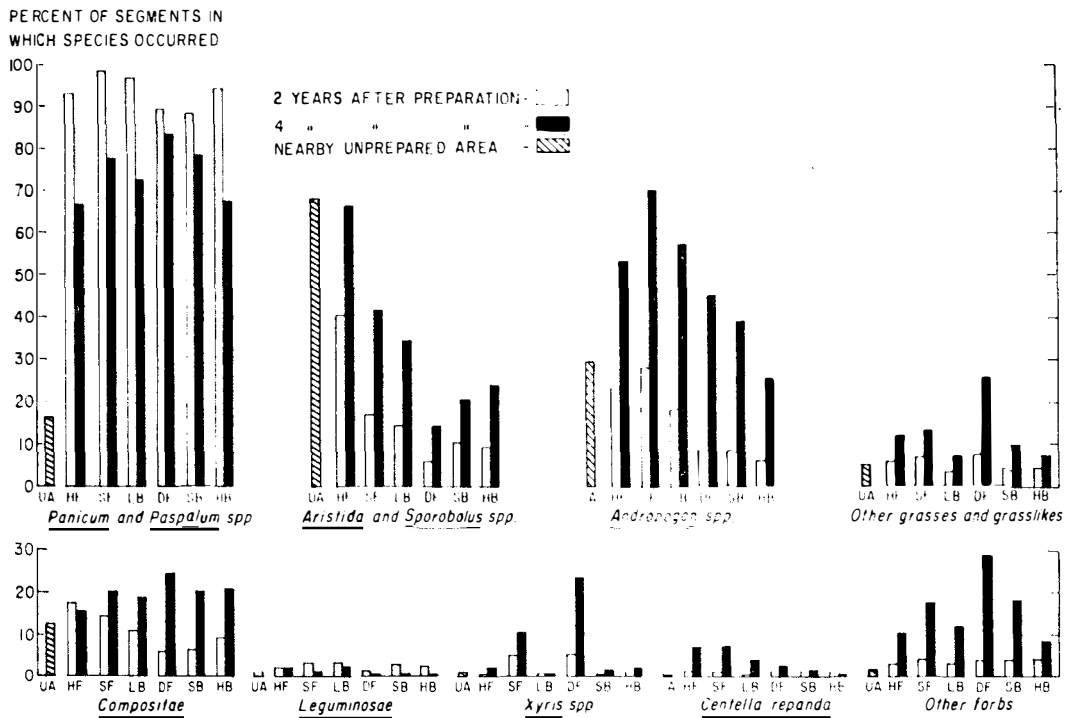


FIGURE 1. Frequencies of herbs on an unprepared area (UA); on the harrowed flats (HF), shallow furrows (SF), and beds (LB) of low-bedded plots; on the deep furrows (DF), sides of beds (SB), and tops of beds (HB) of high-bedded plots.

Changes in Soil Characteristics. Distribution of organic matter (OM) was significantly altered by the method of bedding (Table 1). Six mo after preparation, flat-harrowed strips between low beds had more than twice as much OM in the surface 15 cm as furrows between high beds. At the same time the surface 15 cm of the low beds averaged one-third more OM than the surface 15 cm of the high beds. The reverse was true at depths of 15 to 30 cm. These same conditions were apparent 4 yr after preparation and showed that site preparation concentrated OM in the beds.

Site preparation also significantly altered the levels of N, K, Ca, and Mg at various soil depths, both 6 mo and 4 yr after treatment (Table 1). At depths of 0–15 cm nutrient levels were higher in the low beds than in the high beds; however, the opposite was true at depths of 15 to 30 cm. Levels of all nutrients except P were higher between low beds than between high ones

because none of the surface soil was left between the high beds.

Site treatment affected levels of soil P quite differently from levels of other elements. Six mo after treatment the amount of P in the furrows between high beds was significantly higher than in the beds or flat-harrowed areas. In addition, there were large decreases (28 to 71 percent) in the amount of available P from 1967 to 1970 on all microsites (Table 1).

Six mo after treatment, soil acidity (pH) was 4.3 for all microsites except the furrows between high beds which averaged 4.7. This difference was significant at the 0.01 level of probability. The pH decreased 0.3 unit during the 4 yr after site preparation, but the relationship among microsites remained stable.

Changes in Vegetation. Site preparation initially appeared to have killed nearly all vegetation. Two yr later, 97 percent of the 15-cm transect segments on the low-bedded

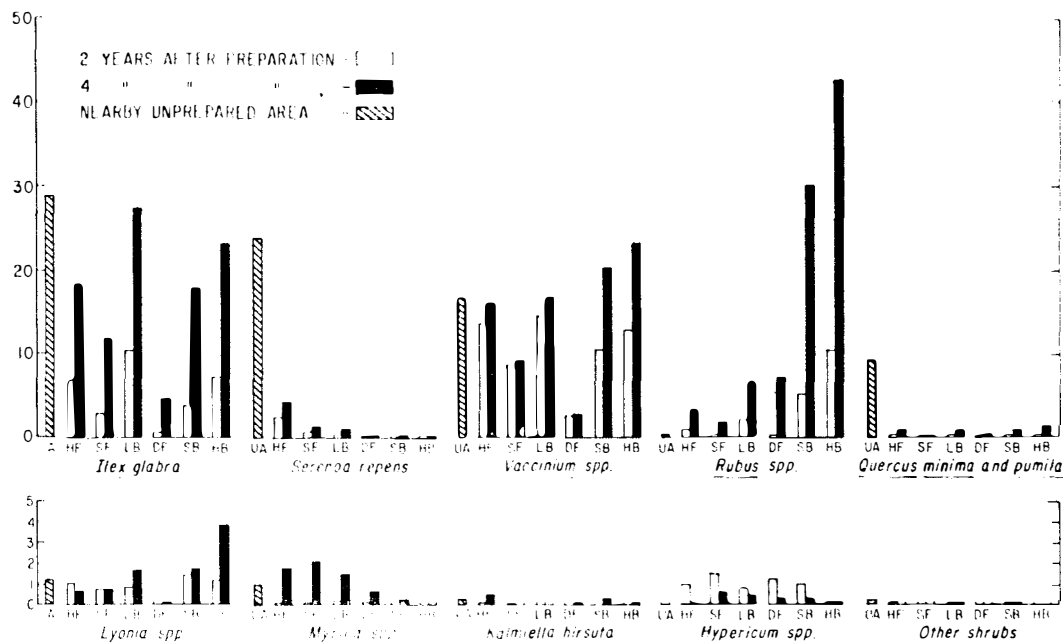


FIGURE 2. Frequencies of shrubs on an unprepared area (UA); on the harrowed flats (HF), shallow furrows (SF), and beds (LB) of low-bedded plots; on the deep furrows (DF), sides of beds (SB), and tops of beds (HB) of high-bedded plots.

plots intersected at least one living leaf or stem. Vegetation was present on 99 percent of the furrowed, 97 percent of the flat, and 95 percent of the low-bedded areas. With high beds, vegetation was present on 82 percent of the segments on the tops, 86 percent of the sides, and 80 percent of the area in deep furrows. By the fourth yr after site preparation, vegetation was recorded on nearly 100 percent of the segments on both high- and low-bedded plots.

Frequency measurements for each species group were similar for transects located 0.3 m from planted trees and those located midway (1.5 m) between columns of trees. Because the trees had little effect on understory vegetation during the first 4 yr of development, the two transects taken on each plot were combined for presentation.

Species and species groups varied in frequency by microsites (Figs. 1 and 2). The disk-harrowed strips between low beds had the least effect on the original vegetation, probably because this treatment was the

least intensive. In contrast, deep furrowing and high bedding disturbed the area and altered the vegetation to the greatest extent. **Grasses.** *Panicums* and *Paspalums* were the first species to revegetate the prepared areas. Visual observations one yr after preparation indicated that new seedlings of these grasses were the only common vegetation on all microsites on both high- and low-bedded plots. They remained important over the first 4 yr, but their frequency was reduced as other larger vegetation developed (Figs. 1 and 2).

Aristida and *Sporobolus* increased on all microsites from the second through the fourth yr after preparation. They were more frequent on low-bedded than high-bedded plots and most frequent on the least disturbed microsite—the flat—where their frequency after the fourth yr was nearly the same as would be expected on an unprepared area. Although these two genera were not distinguished by species, visual observation indicated that *Aristida stricta*,

a very common flatwoods grass, was reduced by intense preparation whereas *A. spiciformis* (Ell.) and *Sporobolus curtissii* (Vasey) Small ex Scribn., were greatly increased.

Bluestems (mainly *Andropogon virginicus* L.) gradually increased in frequency following site preparation and were more frequent on low- than on high-bedded plots. *Andropogon stolonifer* (Nash) Hitchc., a rhizomatous species, greatly increased in patches on disked strips and low beds.

Forbs. Compositae increased on all microsites except the flats from the second through fourth yr. Leguminosae occupied less than 4 percent of the segments on any microsite after 2 yr, had even lower frequencies after 4 yr, and were not encountered on the unprepared area. *Centella repanda* (Pers.) Small and *Xyris* spp. increased on all microsites from the second through fourth yr and had higher frequencies in the furrows.

Shrubs. Gallberry increased on all prepared microsites from the second through fourth yr. Frequency was highest on the low beds and almost equaled that on the unprepared area (Fig. 2). Double disk-harrowing, the only treatment on the flats, killed much of the saw palmetto. Double harrowing plus furrowing or bedding almost eliminated it.

Blueberry (*Vaccinium* spp.) frequencies were relatively low in the furrows, but after the fourth yr on the flats and beds they equaled or surpassed the frequency of blueberries on the unprepared site.

Four yr after site preparation, blackberry (*Rubus* spp.) was more than four times as frequent on the tops and sides of high beds as on any other microsite. On all microsites, however, blackberry frequencies more than tripled from the second through fourth yr. This high frequency should eventually decline because of competition from the pines and no disturbance.

Myrica spp., *Lyonia* spp., *Kalmiella hirsuta* (Walt.) Small, and the dwarf oaks (*Quercus minima* (Sarg.) Small, and *Q. pumila* Walt.) had low frequencies, but they all increased from the second through fourth yr. *Hypericum* spp. also had low

frequencies and were the only shrubs that declined from the second through fourth yr.

Discussion

The changes in microtopography caused by bedding will probably persist for several decades. The firm packing of soil by the water-filled rolling drum molded the soil into a form which was substantially unchanged by rain and weathering even before vegetation covered the soil surface. Complete vegetative cover of the soil 4 yr after treatment greatly limits future changes in microtopography.

The high level of soil P found in deep furrows (the original B horizon) 6 mo after site preparation indicates that this element was leached over time from the surface of the undisturbed soil. Leaching probably occurred because the surface horizons of Leon fine sand has a negligible P sorption capacity (Humphreys and Pritchett 1971). The rapid decrease in soil P on all microsites from 6 mo to 4 yr after treatment further reflects a leaching of this element plus some uptake by developing vegetation.

The negative relationship found between site preparation intensity and amount of natural vegetation substantiates results reported by Sutton (1964) and Haines and Pritchett (1965). The deep furrows developed to form high beds exposed a relatively infertile soil layer which was often inundated for several days at a time following heavy rains. In contrast, the tops of high beds, composed of much of the soil removed from deep furrows, dried out quickly after rains. Visual observations during the first yr following treatment indicated that vegetation developed slowest on these two microsites, probably because of the extreme microenvironmental conditions plus the lack of viable seed exposed in the subsurface soil. Two yr measurement data showed that these microsites still had the least amount of vegetation—80 to 82 percent coverage. By 4 yr even these adverse sites were completely covered with vegetation. Composition of the three primary species of flatwoods vege-

tation was altered by site treatment. The most striking change in vegetation was the virtual elimination of saw-palmetto on all but the disk-harrowed plots between strips. The slight increase in frequency from 2 to 4 yr after treatment on some microsites is probably due to growth and sprouting of existing plants. This species seeds in and grows slowly and will not return to its pretreatment frequency if soil scarification continues as a site treatment.

The great increase in gallberry from 2 to 4 yr after treatment on all microsites shows the capacity of this species to sprout from root and from stems broken and buried by site preparation. Furrowing appeared to concentrate this species on the beds, probably because most roots were removed from the furrows and buried on the beds.

Although we have no data to substantiate our observations that *Aristida stricta* was reduced by intensive preparation, other studies¹ (Hughes *et al.* 1965, Univ. of Fla. 1972) indicate that this common flatwoods grass is reduced by intensive site preparation.

The increase in bluestem grasses, *Andropogon* spp., following disturbance has continued through age 4 on all microsites. Hebb (1971) noted that bluestems increase in prominence at least up to 7 yr after site preparation on Florida sandhills. Bluestems are desirable cattle forage and small game cover but dry out quickly and can present an extreme fire hazard in ungrazed stands of young pine.

Generally the flatwoods are not noted for high game productivity; but when they are well interspersed with other communities such as ponds, pond margins, upland ridges, they may be quite productive (Ripley *et al.* 1965).

Our results indicate that for 4 yr after treatment disk-harrowing followed by bedding more than doubled the number of plants important for wildlife food and cover. The high occurrence of *Panicums*,

Paspalums, *Andropogons*, and fruit-producing shrubs (*Vaccinium* and *Rubus*) form suitable habitat for bobwhite quail, wild turkey, and songbirds (Moore 1961, Ripley and Halls 1966, Harshbarger and Buckner 1971, Hebb 1971). Bedding may also offer a greater number of dove, quail, and songbird nesting sites than would normal flatwoods because it provides numerous high and dry areas which would not be flooded out during heavy summer storms.

The high bedding treatment was the most severe in terms of changes in microtopography, soil nutrient levels, and vegetation. Justification for this treatment, rather than low bedding on flatwood sites, will depend on future differences in tree growth.

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