HISTORICAL RECORDS OF AGRICULTURAL PRACTICES PROVIDE INSIGHT ON HYDROLOGY AND SOILS AT WETLAND RESTORATION SITES

Abstract: Wetlands drained prior to the "Swampbusters" Act in 1980 are being restored in increasing numbers throughout the United States. Restoration efforts are often costly and any information that can lead to increased likelihood of success is important. Historical records are seldom used in restoration efforts, but may provide valuable information of hydrology prior to drainage, and soil variability due to human activity. A 254 ha drained Carolina bay wetland in Robeson County, North Carolina, called Juniper Bay, is being restored. Historical records from the county court house, aerial photos from the USDA-FSA, personal interviews with prior landowners, and contact with the National Railroad Historical Society provided information that proved useful in restoration efforts. The Charleston & Raleigh Railroad ran through Juniper Bay in the 1920's and included a raised bed and adjacent ditch. A 1922 county map showed a stream that exited the bay at the SE corner and photos and interviews indicated a small lake in the center of the bay. This indicates that restoring hydrology to Juniper bay may result in a watertable above the soil surface. Personal interviews provided information on the methods of clearing and draining Juniper Bay. The NW third was drained in 1971, the center third in 1981, and the SE third in 1986. There were two different ditching systems in the NW third. Evidence of ditch fill from the first drainage system and the railroad ditch was found in the field and altered soil profiles to one meter. Information on agricultural practices was also obtained and allowed us to examine the extent of nutrient movement and the effects on re-vegetation. Fire, land shaping, and the addition of material from ditch maintenance have altered the surface soil. The

historical information that has been gathered has allowed us to focus studies in areas of concern and account for variability in other studies.

INTRODUCTION

Wetland restoration is being conducted on an increasing scale throughout the U.S. In the southeastern U.S., wetlands that were cleared and drained for agriculture in the 1930's or later, are now having their ditches plugged to restore the original hydrology and wetland trees are also being planted to restore the original vegetation. Such restoration is expensive and any information that increases the likelihood of success is of value. We are involved in a current restoration of a Carolina Bay wetland in North Carolina. As part of this effort we assembled a record of historical data on land use that provided additional insight into practices that have affected both the soils and hydrology.

In our experience historical data on landuse is frequently not used in planning restoration activities. Water sources such as surface inflows and outflows can affect restoration and should be known before hydrologic alterations are designed. Existence of perennial natural lakes suggests groundwater inflow is an important contribution to a wetland's hydrology. However, small lakes or ponds may not appear on all soil maps, especially if the area has been drained for agriculture. Many construction or demolition projects, land clearing, mining and farming can leave the surface of the landscape looking unaltered, but examinations below the surface can show dramatic soil variability due to human activities. For example, soils developed from mine spoils have been shown to be more variable between 1 to 10 m depths than natural soil (Shafer, 1979). In soil research studies it is important to have a grasp on the variability of the soil so that the correct number of samples can be taken. In areas known to be altered by human activity, it can be beneficial to collect historical land use data to document where and when alterations occurred that could explain variation.

The Carolina bay being restored is called Juniper Bay. The North Carolina Department of Transportation (NCDOT) bought 256 ha of drained agricultural land in 1999, near Lumberton, North Carolina. This land was purchased with the intent of returning it to its natural state so that the NCDOT would gain wetland mitigation credits. The NCDOT awarded a seven-year grant to the Soil Science Department of North Carolina State University, in 2000, to evaluate and help develop methods of restoration that will insure success. Since one of the intended outcomes of this project is the restoration of soils typically found in Carolina bays, we had to describe the soils as they were after drainage and agriculture production and to examine soils of undrained Carolina bay soils. This Carolina bay wetland was altered thought ditching that allowed agriculture production to occur. However former landowners also reported other activities that had occurred that may have altered soil properties.

The purpose of this study was to assemble an historical record of land use spanning the last 80 years to find potential sites of human induced variability and discuss implications on wetland restoration.

METHODS

Site Description

Carolina bays are elliptical depressions in the landscape that are orientated along the long axis SE to NW (Prouty, 1952). They range in size from 10 m to 4 km along the long axis. The bays are usually surrounded by a sandy rim and have a high amount of organic matter within the depression (Johnson, 1942). The extent of these bays range from Northern Florida to Delaware with the highest concentration in North and South Carolina. Estimates on the number of these bays are as high as 500,000 (Johnson, 1942), but the actual number maybe less than 100,000 (Nifong, 1998). Many theories for bay formation have been proposed. The most popular but scientifically discredited is a meteor impact (Johnson, 1936). Others theories include artesian springs (Prouty, 1952; LeGrand, 1953), whale wallows (Grant 1945), and ice push (Bliley and Burney, 1988). Currently the most plausible explanation is that originally there was a slight depression in the landscape with a shallow aquitard that allowed the water table to be held above the surface. Prevailing winds then shaped the depression into the now familiar orientated shape (Thom, 1970; Odum, 1952). During the past century agricultural and community development have led to the drainage and use of these bays. It is estimated that 50% of all Carolina bays were drained and developed in some manner in Bladen County, NC by 1982 (Weakley and Scott, 1982). This figure would be higher if other management practices such as logging were included. As these bays are used for agriculture and other activities, their defining characteristics of sand rims and organic surfaces, become blurred into the surrounding landscape.

The Carolina bay in question is called Juniper Bay and is located approximately 10 km south of Lumberton, North Carolina. The soil survey of Robeson County (Fig. 2.1) shows Juniper Bay with areas of Ponzer (Loamy, mixed, dysic, thermic Terric Haplosaprists), Leon (Sandy siliceous, thermic Aeric Alaquods), Pantego (Fine-loamy, siliceous, semiactive, thermic Umbric Paleaquults), and Rutlege soils (Sandy, siliceous, thermic, Typic Humaquepts) (McCachren, 1978). An earlier soil survey (Hearn, 1909) identified the soils in Juniper Bay as Portsmouth fine sandy loam.

Sources of Information

There were several sources of information that we used to conduct the historical land use search. They included aerial photos from the United States Aerial Photography Service

Office, the former landowner, Mr. Robert Freeman Jr., courthouse documents and the National Railway Historical Society (NRHS). Aerial photos were available from 1938, 1955, 1961, 1966, 1972, 1981, 1993, and 1997, and were obtained from the USDA-FSA Aerial Photography Field Office, 2222 W 2300 S, Salt Lake City, UT 84119-7619. Mr. Freeman provided a wealth of information about Juniper Bay before it was drained. He was also the person who drained and placed Juniper Bay into agricultural production. Documents found from the Robeson County courthouse provided a history of ownership and use. The NRHS provided information concerning a railroad that ran through Juniper bay and how the tracks were constructed.

RESULTS

1911-1938: Railroad Years

A Robeson County road map found at the county court house, dated 1922, showed a creek flowing out of Juniper Bay that was initially unnoticed in the aerial photos. This creek flowed out of the NE corner and was originally the head water of Little Indian swamp which flowed south into Big Indian Swamp which fed into Ashpole river and finally into the Lumber River which is an important river in the area. A faint outline of this creek was discovered in a few of the older aerial photos upon close examination. The aerial photo (Fig. 2.2) shows that Juniper Bay was heavily forested. The vegetation supported abundant wildlife. Mr. Freeman (2001) told of seeing deer, black bear, beavers, bobcats, snakes, foxes, otters, and hundreds of geese and ducks when he hunted there before draining Juniper Bay. The densely forested bay contained large Atlantic White Cedars (*Chamaecyparis thyoides*), Bald Cyprus (*Taxodim* ssp.), Tupelos (*Nyssa biflora*), and various Bay (*Persea borbonia*) trees.

While virtually undeveloped, the site did have a railroad line running through it in a north-south direction. Mr. Freeman remembered stories about how his father would hop the train in Fairmont and ride it 16 km into Lumberton to conduct business. A map of the Seaboard Airline Railway (SAL RY) in 1911 (Prince, 1966) showed a route running from Lumberton through Ashpole (Fairmount) and to Pee Dee (just NE of Marion S.C.). This route ran through Juniper Bay and is identified (Fig. 2.3) in the 1909 soil survey of Robeson County (Hearn, 1909). The company that built and owned the railroad that ran between Lumberton and Marion, South Carolina, was The Raleigh-Charleston Railroad Company. The Raleigh & Charleston Railroad (R&C) was formed in December of 1905 (Carriker, 1985a). SAL RY bought controlling stock of the R&C in November 1911 (Carriker, 1985b), and in 1933, 23 miles of its line between Lumberton, N. C. and Lakeview, S.C. in 1933, and the remainder into Marion in 1946 (Prince, 1966).

The railroad bed was around 1.5 m above the surrounding terrain. Mr. Freeman recalled that there was one ditch that ran along the track, and that it appeared the railroad bed was mostly fill material from the ditch. With the assistance from the NRHS, literature was found that supported the Mr. Freeman's description of the construction of the railroad bed in Juniper Bay. During the time of R & C, the common construction practice was to dig a ditch and use the spoil for the railroad bed (Kirkman, 1904). The ditch supplied fill for the bed, and was not dug for drainage or long-term bed stability. Clay was brought to the site to stabilize sections of the bed at a later date. We estimate that the railroad bed in Juniper bay was elevated to match the surrounding areas, resulting in a bed elevation of ~1-1.5 m above the surface inside the bay. This bed was also estimated to have been approximately ~3m wide with an adjacent ditch on one or both sides of the bed. Ditch depth probably ranged from 2 to 3 m, but an exact depth could not be determined. It is still possible to see the location of the old railroad bed in current aerial photos. In addition, a slight crest across the bay where the bed used to be can still be seen when in the field. We have also found several rusted railroad spikes along the old railroad transect during our field studies.

While the railroad's tracks are visible in the 1938 photograph, it was apparently abandoned by that time. It is uncertain if the tracks were removed by 1938. During our soil sampling, pits placed where the old railroad bed was did have evidence of disturbance by excavation and filling to a depth of one meter (Fig. 2.4). This disturbance could be traced along the railroad line, and was considered to be of small extent.

1938-1966: Forest Harvest

Aerial photos from 1955 showed little change in Juniper Bay since 1938, but by 1966 some major changes had occurred. M. Carr Gibson of Canal Industries bought the land from Lawrence Ballard in the mid 1960's to harvest trees. The 1966 aerial photo (Fig 2.5) shows an outline through the vegetation where drainage ditches will be located, and also shows that some of the vegetation has been thinned. One ditch runs parallel, and possibly adjacent to, the old railroad bed. Another ditch will run SW to NE and with a perpendicular ditch running SE to NW. Canal Industries harvested timber from the entire the bay except for the area around the center of the bay that contained a shallow lake and parts of this lake can be seen in the 1966 photo.

By the time Canal Industries sold Juniper Bay to Mr. Freeman's father in the mid 1970s, a drainage system on the NW side of Juniper Bay had been constructed (Fig. 2.1). This drainage system included a perimeter drainage ditch surrounding the NW end of the bay, five lateral drainage ditches running parallel to the railroad bed on the north side of the

NW/SE ditch, and one ditch that ran the width of the bay. It is uncertain if the railroad bed had been leveled at this time but the drainage ditch along the old railroad bed probably still served as a collector to the main outlet. During the time Canal Industries owned Juniper Bay, the Robeson County Soil Survey was being conducted (1966-1971). Willie Spruill (2001), a NRCS soil surveyor who helped with the survey, has stated that often Carolina bays were so thick with vegetation that it was impossible to conduct a thorough survey through the bay itself. Often the Carolina bays were mapped extrapolating soil map units into the Carolina bays from adjacent lands. Vegetation patterns visible on aerial photos were used to estimate map unit boundaries within the bays (Soil Survey Division Staff, 1993; Buol et al., 1997). Mr. Spruill could not recall if this is how Juniper Bay was mapped and it is uncertain how accessible Juniper Bay was at the time of mapping, however, the 1966 and the 1971 aerial photographs show that the soil delineations follow vegetation patterns fairly well.

1975-1981: Clearing and Cultivation

Mr. Freeman's father purchased Juniper bay in October 1975 and drainage of the bay for agriculture began during a dry summer in 1979. This was no small operation, and over 15 individuals were employed to operate 10 bulldozers, 3 trackhoes, and a dragline. Over a period of 9 months in 1979, the railroad bed was leveled and the parallel ditches were filled. Mr. Freeman said that when he was ditching the bay, there were many creosote crossties that remained, but no rails. Lines where the lateral, main and perimeter ditches were to be located, evenly spaced, were cut with handheld equipment including chainsaws, machetes, and bush-axes because the soils were too wet to support heavy equipment. While cutting over 48 km of trails for the ditches, workers would climb up in the trees to escape the stifling heat and mosquitoes during lunch and work breaks.

Once trails for the ditches were cut, a trencher was used to excavate the ditches inside the bay. Workers had to lay logs and other debris ahead of the trencher so it had a "solid surface" to work on. A dragline was used to dig the perimeter ditch on the sandy rim of the bay. During the ditching and clearing operations, many preserved trees, logs and roots were pulled from the muck with tree rakes. For example, see Fig 2.6 photo taken in the Blacklands of North Carolina. For years after the clearing occurred, any time the fields were tilled, wagonloads of roots and debris had to be removed. During our sampling of soils in 2001 we did find buried roots of trees in many pits.

After enough drainage had occurred to allow the soils to support the weight of heavy equipment, debris was windrowed with bulldozers into piles 15-20 m wide that ran the length of the bay and is illustrated in Fig. 2.7. The debris was then burned, with some piles burning for 2 to 3 years. The debris fires ignited the peat that lined the bay floor, and in some areas burned the surface was lowered 50-90 cm to either a mineral layer or the water table. This created a depression that filled with water and was inaccessible with any equipment (Fig. 2.8). To drain the depressions, an additional ditch had to be dug or the depression had to be filled. Fill material would come from another ditch, located near the depression. According to Mr. Freeman, this is why the lateral ditches do not match up across the length of the bay, the cuts are of uneven size, and the distance between cuts decreased. After the ditches were in place and sufficient drainage had occurred, spoil from the ditches were used to shape all the fields such that the center of the field was approximately 45 cm higher than the edges to increase surface runoff. This practice is locally called "crowning" or "turtle backing."

1981-2000: Agricultural Production

The aerial photo from 1981 (Fig. 2.9) shows almost all of the bay completely drained and in agricultural use except for a small corner in the NE section. This was and is the wettest and lowest area in the bay. This was re-emphasized when a landowner adjacent to Juniper Bay on the NE cleared and ditched a small parcel of land and tied into Juniper Bay's drainage system. Unfortunately for this farmer, his land was lower than the main outlet of Juniper Bay, and thus his new field became a semi-permanent pond. That landowner eventually disconnected from Juniper Bay's drainage system. The NE corner of Juniper bay was cleared and drained in 1986, and put into production the following year.

Currently, 2003, Juniper Bay is drained though one outlet point (Fig. 2.10). There is a perimeter ditch around the whole bay, and two main ditches that run SW/NE and one that runs SE/NW, which are approximately 3 m deep and 6 m wide. Perpendicular to the SW/NE main ditches are lateral drainage ditches that are approximately 1 m deep and 1.5 m across. Mr. Freeman stated that ditches were maintained as needed yearly. Every 5 or 6 years all ditches were cleaned using a piece of equipment, called a Dondi ditcher (Fig. 2.11), that dredged out the ditch and slung the spoil out over the field, where it was disked in.

Mr. Freeman maintained excellent records and has soil test results dating back to 1976 giving us an idea of what the chemical variability was. The 1976 soil test analysis of the plow layer from various (unknown) locations across the bay, conducted by Brookside Farms Laboratory Association, Inc., showed that pH ranged between 3.6 and 4.8, cation exchange capacity 2.76-14.04 meq $100g^{-1}$, 2.7 to 11.5 % organic matter, 163-2520 kg ha^{-1} P, 314-775 kg ha^{-1} Ca, 29-408 kg ha^{-1} K, and 31-51 % base saturation. Soil test reports from

1978 and 1979, by A & L Eastern Agricultural Laboratories, Inc., of Richmond, Virginia, show approximately the same values. Mr. Freeman estimated that 15 to 20 cumulative tons per acre of lime have been applied over the years in addition to the yearly-recommended fertilizer rate. Crops grown in Juniper Bay included; soybeans, corn, tobacco, cotton, oats, millet, wheat, and vegetable crops like lettuce and okra. One year, a leasing farmer raised winter wheat and burned the stubble off leaving a blanket of ash that looked like snow. Of course this re-ignited some of the peat, burning some areas down to the water table, most notably in the NE corner.

USE OF HISTORICAL DATA

Historical information has provided insight into spatial heterogeneity of the soils and hydrology that we have at Juniper Bay. Successful restoration depends on a returning the site's hydrology to what it was prior to ditching. The historical record has given us a glimpse of the past hydrology. The 1922 Robeson, County map documented the creek on the NE side of the bay that was historically a source of surface water removal. The aerial photos and personal accounts indicated the existence of a natural lake in the center of the organic soils. This was unexpected because none of the neighboring bays (~5 km) have lakes or even organic soils even though some are lower in elevation. This suggests that Juniper Bay was might be receiving subsurface inputs of water that resulted in organic soils and standing water, unlike the neighboring bays, which may have been rain-fed. Our hydrologic measurements are confirming that groundwater upflow (discharge) does appear to be occurring on the north side of the organic soils.

The historical record has also shown that human activities have affected soil variability in Juniper Bay. We were able to document processes that affect organic soil subsidence, and estimate that 50-90 cm of subsidence has occurred. It is well known that organic soils subside following drainage (Everett, 1983). Processes responsible for this include a rapid settling of material as it loses the buoyant force provided by water after drainage (primary subsidence), oxidation of organic matter, and shrinkage of the organic material on drying (both termed secondary subsidence). The historical record shows that the primary subsidence can be increased by compaction from the heavy equipment used to clear the land. More importantly, fire increases oxidation rate of organic matter. The historical record has shown that fire events have occurred in Juniper Bay more than once and one fire burned for 2 years. We found evidence of fire, including charcoal and ash, in several soil profiles throughout Juniper Bay. We have dated charcoal and other buried vegetation to 8400 and 3100 years before present (Zanner et al., 2002). The burning also explains why some of the wettest areas in the bay were devoid of organic soils. Estimating the amount of subsidence that has occurred is useful to predict the elevation of the original water table, and the potential elevation after restoration.

Construction of the railroad and the current and previous ditching systems has altered the soils to depths of one meter and more. Historical aerial photos provided approximate dates showed where the ditching occurred. We were able show how the fill from the railroad bed changed soil profiles, which allowed us avoid similar areas during studies of the soils and hydrology since those areas were small relative to the whole bay and could of skewed the results. The present soil material at the surface is not necessarily a product of the original soils owing to the spreading of dredge material during canal construction. The surface of Juniper Bay has been shaped several times since drainage to promote surface drainage, and ditch maintenance brought subsurface material to the surface and broadcast it over the field.

Our historical records also included the dating of agricultural development including application of lime and fertilizer. Leaching of agricultural chemicals, notably phosphorus, to the groundwater is currently of great interest because it reduces quality of surface waters. The historical record provided specific dates for when chemical additions began. This information is being used to evaluate the rate and depth of chemical movement through the soil profile over 15, 20, and 30 years of agricultural additions across the bay.

By establishing the presence of spatial variability prior to drainage evaluation of restoration efforts should not expect uniform results over the entire area. Although many early soil surveys identified wetland areas only as swamps, marshes, etc., important soil properties were not identified or spatially mapped. Many of the soil properties appear related to underlying hydrology that will again influence restoration results.

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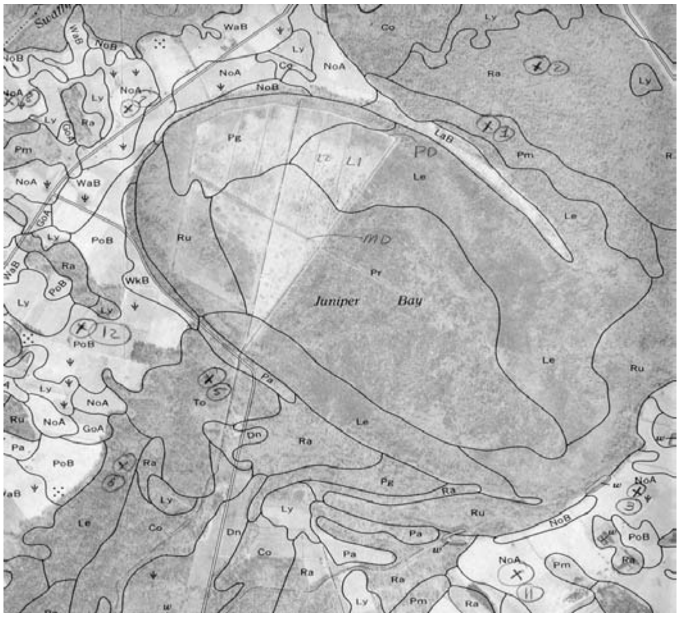
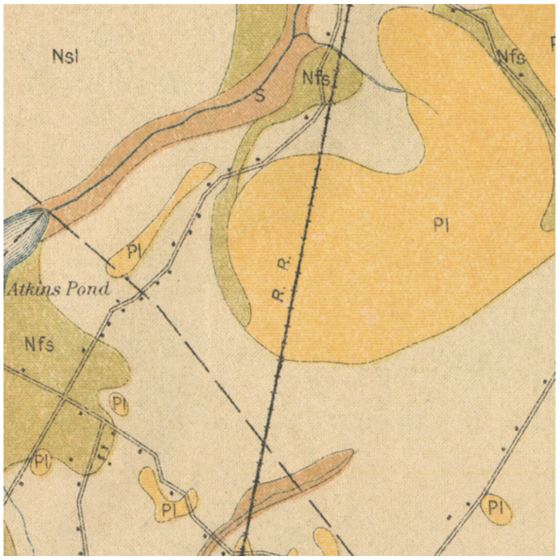


Legend
Co- Coxville loam
Dn- Dunbar sandy loam
LaB- Lakeland sand 0-6%
Le- Leon sand
Ly- Lynchburg sandy loam
GoA- Goldsboro loamy sand, 0-2%
NoA- Norfolk loamy sand, 0-2%
NoB- Norfolk loamy sand, 2-6%
Pg- Pantego fine sandy loam
Pm- Plummer and Osier
PoB- Pocalla loamy sand, 0-3%
Pr- Ponzer muck
Ra- Rains sandy loam
Ru- Rutledge loamy sand
To- Torhunta loam
WaB- Wagram loamy sand, 0-6%
WkB- Wakulla sand, 0-6%

Figure 2.1. Aerial photo 1972 and Soil Survey map of Juniper Bay, Sheet 61 (McCachren, 1978).

Figure 2.2. Aerial photo of Juniper Bay in 1938 (National Archives and Records Administration).



Legend

Nsl- Norfolk sandy loam
Nfs- Norfolk fine sandy loam
Pl-Portsmouth fine sandy loam
S- Swamp

Figure 2.3. The 1909 Soil Survey of Robeson County (Hearn, 1909) shows the Raliegh & Charleston Railroad going through Juniper Bay. The "R.R." on the map is located inside the boundaries of Juniper Bay.

Figure 2.4. Soil profile showing a prior ditch and subsequent fill material from the railroad transect. Arrow points to the interface between undisturbed soil and ditch fill. Scale is in cm.

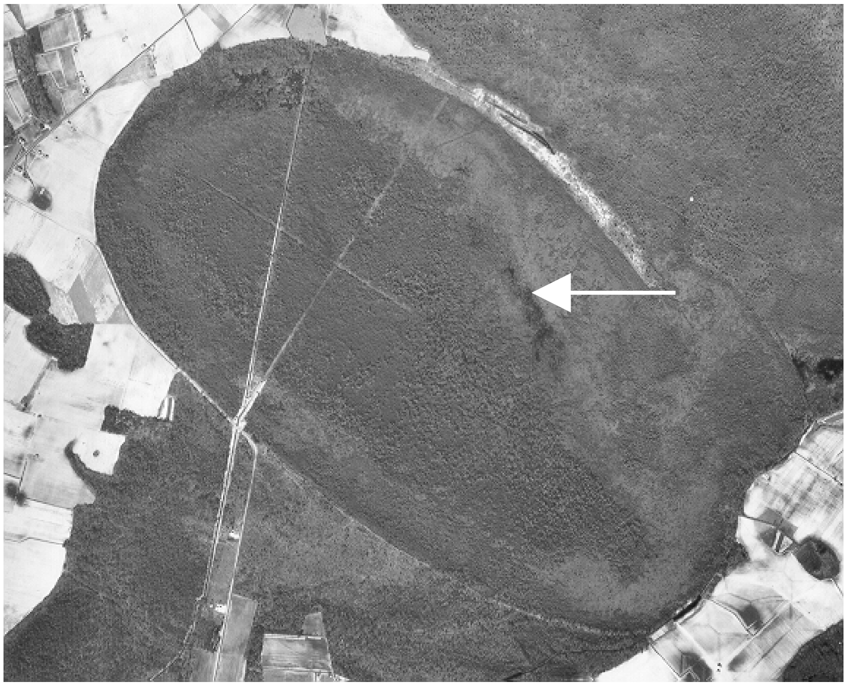


Figure 2.5. Aerial photo from 1966 (USDA-FSA). Arrow indicates potential location of 'lake' mentioned by Mr. Freeman.

Figure 2.6. Log-rake pulling log from the soil in the Blacklands of North Carolina (with permission S.W. Buol).

Figure 2.7. Debris from clearing piled into windrows in the Blacklands of North Carolina (with permission S.W. Buol).

 a.

 b

Figure 2.8. a). Windrows burning down to mineral. The white areas are ashes from the most intense fire and the black areas to the right are areas of largely unburned organic soil. b). Loss of approximately 30 miles (48km) organic soil after a wild fire in the Blacklands of North Carolina (with permission S.W. Buol).

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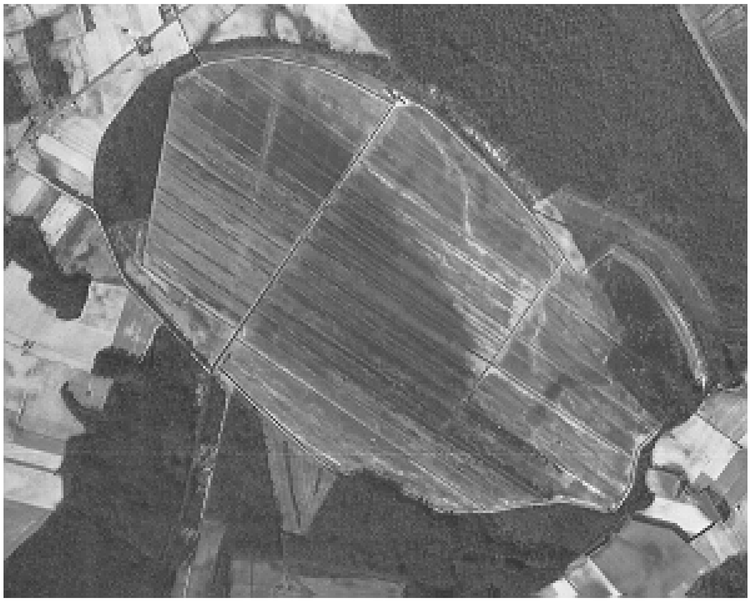

Figure 2.9. Aerial photo of Juniper Bay from 1981 (USDA-FSA).

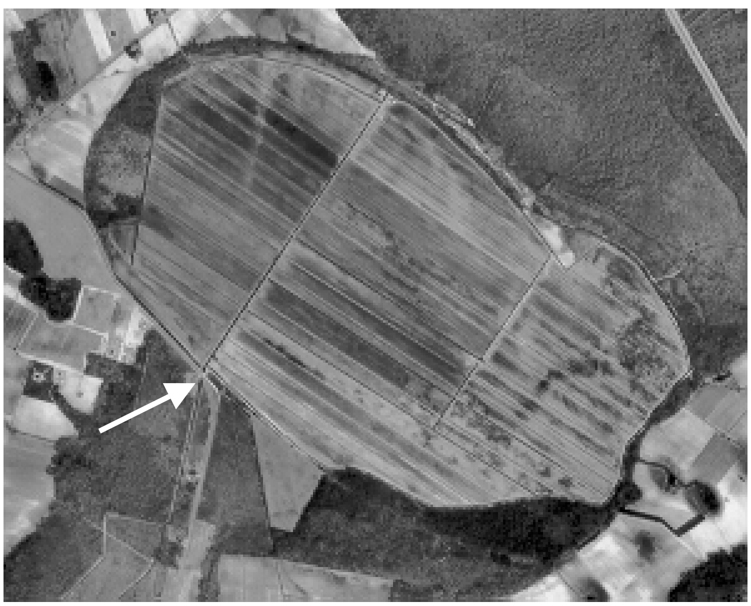

Figure 2.10. Aerial photo of Juniper Bay from 1993 (USDA-FSA) Arrow indicates drainage outlet of ditching system.

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Figure 2.11. Ditch maintenance with a Dondi ditcher.