SOIL, ENVIRONMENTAL, AND WATERSHED MEASUREMENTS IN SUPPORT OF CARBON CYCLING STUDIES IN NORTHWESTERN MISSISSIPPI.

U.S. GEOLOGICAL SURVEY

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By T. G. Huntington[1], J. W. Harden[2], S. M. Dabney[3], D. A. Marion[4], C. Alonso[3], J.M. Sharpe[2], T. L. Fries[2]

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Atlanta, Georgia

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Table of Contents

List of Tables

List of Figures

Conversion Factors

Multiply	by	to obtain
	Length	
Centimeter, cm	2.54	inch
Meter, m	3.281	foot
Kilometer, km	0.6214	mile
	Area	
Hectare, ha	2.471	Acre
Square meter, m^2	10.76	Square foot, ft^2
	Mass	
Milligram, mg	3.52×10^{-5}	Ounce (avdp), oz
Gram, g	3.52×10^{-2}	Ounce
kilogram	2.205	Pound
Megagram, Mg, metric ton	1.102	Ton (US, 2000 lb), ton
	Yield and Rate	
Milligrams per square meter	3.27×10^{-6}	ounces per square foot
Kilogram per hectare, kg ha^{-1}	0.893	Pound per acre, lb $acre^{-1}$
kilogram per hectare, kg ha^{-1}	1.86×10^{-2}	Bushel per acre, 48 lb, bu $acre^{-1}$
Megagrams per hectare, Mg ha^{-1}	2.24	Tons per acre, tons $acre^{-1}$
	Pressure	
Megapascal, Mpa (10^6 Pa)	9.9	atmosphere
Megapascal, Mpa (10^6 Pa)	10	Bar
Kilopascal, kPa	1×10^{-2}	Bar
Pascal, Pa	1.45×10^{-4}	Pound per square inch, lb in^{-2}
	Concentration	
Gram per kilogram, g kg^{-1}	0.1	Percent, %
	Water Measurement	
Liters per second, L s^{-1}	3.53×10^{-2}	Cubic feet per second, ft^{-3} s^{-1}
	Volume	
Liter, L	3.53×10^{-2}	Cubic foot, ft^{-3}
Milliliter, ml	3.3378×10^{-2}	Ounce (fluid), oz

Equivalent Units

Pressure

1	Atmosphere
1.013	Bar
1013	mb
101.3	cb
101.3	kilo Pascals
101325	Pascal
101325	Newton m^{-2}
101325	Joule m^{-3}
1013250	Dyne cm^{-2}
0.76	meter Hg
76	cm Hg
760	mm Hg
760	torr
29.92	inches Hg
14.7	lb in^{-2}
1033	cm water

CO_2 Efflux

100	mg C m^{-2} hr^{-1}
2.4	g C m^{-2} day^{-1}
8.77	Mg C ha^{-2} yr^{-1}

Temperature

Temperature in degrees Celsius (°C) can be converted to degrees Fahrenheit (°F) as follows:

$$°F = 1.8\,°C + 32$$

VERTICAL DATUM

Sea level--In this report, "sea level" refers to the National Geodetic Vertical Datum of 1929 -a geodetic datum derived from a general adjustment of the first-order level nets of both the United States and Canada, formerly called Sea Level Datum of 1929.

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Abstract

Measurements including soil respiration, soil moisture, soil temperature, and carbon export in suspended sediments from small watersheds were recorded at several field sites in northwestern Mississippi in support of hillslope process studies associated with the U.S. Geological Survey's Mississippi Basin Carbon Project (MBCP). These measurements were made to provide information about carbon cycling in agricultural and forest ecosystems to understand the potential role of erosion and deposition in the sequestration of soil organic carbon in upland soils. The question of whether soil erosion and burial constitutes an important net sink of atmospheric carbon dioxide is one hypothesis that the MBCP is evaluating to better understand carbon cycling and climate change. This report contains discussion of methods used and presents data for the period December 1996 through March 1998. Included in the report are ancillary data provided by the U.S. Department of Agriculture (USDA) ARS National Sedimentation Laboratory and U.S. Forest Service (USFS) Center for Bottomland Hardwoods Research on rainfall, runoff, sediment yield, forest biomass and grain yield. Together with the data collected by the USGS these data permit the construction of carbon budgets and the calibration of models of soil organic matter dynamics and sediment transport and deposition. The U S Geological Survey (USGS) has established cooperative agreements with the USDA and USFS to facilitate collaborative research at research sites in northwestern Mississippi.

Introduction

Data in this report were collected in support of site-specific hillslope process studies of the Mississippi Basin Carbon Project (MBCP). The MBCP is part of the USGS effort in global change research (Sundquist et al., 1998). The MBCP focuses on the Mississippi River basin, the third largest river system in the world, that drains an area of 3.3 x 10^6 km^2 (1.27 x 10^6 mi^2) (Figure 1). The Mississippi River basin includes more than 40 percent of the land surface of the conterminous United States. Because climate, vegetation, and land use vary greatly within the Mississippi River basin, the primary terrestrial sinks for carbon need to be identified and quantified for representative parts of the basin. The goal of the project is to increase understanding of the role of terrestrial carbon in the global carbon cycle, particularly in the temperate latitudes of North America. Terrestrial ecosystems in northern temperate latitudes are thought to be a substantial net sink for atmospheric CO_2 (Ciais et al., 1995; Detwiler and Hall, 1988, Tans et al., 1990). The identity of this sink is unknown, but probably includes aggrading temperate forests on abandoned agricultural lands (Dixon et al., 1994; Birdsey et al., 1993; Huntington, 1995) and may include agricultural lands under improved management and higher residue production (Paul et al., 1997) and deposition along hydrologic pathways along a continuum including toeslopes, flood plain alluvium, reservoirs and river deltas (Stallard, in press).

The primary objective of the MBCP is to quantify the interrelated effects of land-use, erosion, sedimentation, and soil development on carbon storage and nutrient cycles within the Mississippi River basin. The project includes spatial analysis of geographic data, estimation of whole-basin and sub-basin carbon and sediment budgets, development and implementation of terrestrial carbon-cycle models, and site-specific field studies of relevant processes. Site-specific studies are directed at estimating rates of carbon accumulation in soil organic matter, decomposition of soil organic matter, and the erosion, transport, and deposition of sediments containing organic carbon. One specific objective of the project is to assess the sensitivity of these rates to climatic, hydrologic, topographic, and land-use gradients.

Research sites in the Yazoo River Basin were chosen based on several criteria including; parent material, existing infrastructure, historical data, and representativeness. Sites on uniform parent material were chosen to eliminate one variable in the comparison of cultivated and forested sites. The field sites in the Yazoo River Basin were located primarily on Peorian Loess. Comparable field studies are underway in Iowa in agricultural and prairie sites on soils also derived from Peorian Loess. We wished to compare agricultural and forested watersheds representing extremes in management impacts on carbon cycling on a uniform parent material under relatively constant climate. Sites were chosen on small gauged watersheds maintained by USDA Agricultural Research Service or U.S. Forest Service in support of ongoing research projects where, rainfall, runoff, and sediment transport were monitored. We also needed data on grain yield or forest biomass and stand age to estimate carbon input. To understand the carbon budgets at these sites it was considered essential to have the data that could constrain rates of erosion and deposition within small watersheds because these variables are difficult to quantify yet crucial to our understanding and ability to model carbon cycling.

This report includes field site descriptions, documentation of methods used for field data collection, sample processing and analysis, and examples and description of the data collected. Field site descriptions are included for the following sites in the Yazoo River Basin; (1) the agricultural watershed at the Nelson Farm, near Senatobia, the mixed hardwood watershed at Goodwin Creek, near Batesville, the pine watershed near Coffeeville, and the pine-hardwood watershed near Abbeville. Methods are described for measurement of soil respiration, soil water potential, soil water content, soil temperature, sediment export, and sediment analysis. This report also includes examples of the data collected at each field site, summary data for selected data series, and information necessary for obtaining the data in digital format.

Site Descriptions

Soil respiration measurements and environmental data including runoff and sediment yield are reported for several forested and one agricultural site in the Yazoo River Basin (Figure 2). The Yazoo River Basin is in the northwestern portion of Mississippi and drains into the Mississippi River at Vicksburg. The Basin can be divided into two distinctly different regions. The delta includes all of the nearly level lands to the west of the Yazoo River and a narrow strip of land along the east of the Yazoo (Figure 3). To the east of the bluffline, occupying about one half of the Yazoo River Basin, is the Coastal Plain including the prominent loess hills region dominated by the drainages of the Coldwater, Tallahatchie, Yocona, and Yalobusha Rivers (Figure 2).

The delta region is dominated by cropland and the Coastal Plain region is dominated by forest or forest and cropland mixtures (Figure 4). The land cover map shown in figure 4 was derived from, 1990, advanced very high resolution radiometer reflectance data (AVHRR). Normalized difference vegetation index (NDVI) is computed as (IR-

Red)/(IR+Red) {green vegetation reflects IR and absorbs red}. Ten-day seasonal composite NDVI is processed with a clustering algorithm to classify area based on simiarlity in seasonal pattern. This map of 5 classes was derived by collapsing 159 national classes (Loveland et al., 1993). The resolution of the map is one square kilometer. The crop/wood classification may contain any area proportions of crop and woodland within each square kilometer pixel.

The research sites were located in small hydrologically monitored headwater catchments (Figure 2). In this region presettlement mixed southern hardwood forests were cut during the mid-1800's and the land was farmed under various cropping, and management practices until the early to mid-1900's when much of the agricultural land was abandoned and natural or managed afforestation began (Morris, 1981, Huddleston 1967, 1978). We selected two principal sites, the Nelson Farm (agricultural) and Goodwin Creek Watershed #10 (forested). At these principal sites we have the most complete information on soil characterization and soil respiration. We also established ancillary sites near Coffeeville, MS (Coffeeville- Pine, Reference Watershed #1) and near Abbeville, MS (Pine-Hardwood, Reference Watershed #2). We established ancillary sites to take advantage of ongoing US Forest Service hydrologic and sediment studies and to provide replication for the forested condition.

The Nelson Farm, Goodwin Creek and Coffeeville sites all contain soils derived from Peoria Loess parent material. In this region of Mississippi the thickness of the loess cap decreases from greater than 4.5 m along the bluff line in the east to less than 60 cm or absent at the eastern boundary of the Yazoo (Figure 5) (Wascher et al., 1948). During periods of intensive cultivation in late 1800's and early 1900's these regions experienced some of the most extensive erosion of any area in the United States (Blackmarr, 1995). The loess soils contain a fragipan and the depth of the fragipan is indicative of the severity of post-settlement erosion (Rhoton and Tyler, 1990).

Nelson Farm: The Nelson Farm is an agricultural research experiment station established in 1987 by the USDA-ARS, Mississippi Agriculture and Forestry Experiment Station (MAFES), and Mississippi personnel of the USDA-NRC as an interdisciplinary research project to develop economically profitable and environmentally sustainable conservation production systems for silty upland soil resource areas. The Nelson Farm is located in Tate County, between Senatobia, Mississippi and Como, Mississippi off HWY 51 (Dabney et al., 1997). The Nelson farm is found on the Senatobia, Mississippi 1:24000 topographic quadrangle, latitude 34°33'50" longitude 89°57'30", at an elevation of approximately 98 m. The farm is located in Range 7 W and Township 6 S. The Nelson farm is within the Coldwater River Drainage in the Yazoo River Basin.

Soils at the Nelson farm were described as eroded Memphis silt loam (Typic Hapludalf) on the broad ridges and severely eroded Grenada silt loam (Glossic Fragidualfs) on the hillslopes (map sheet 70, Huddleston, 1967). Based on the depth to the fragipan (Table 1) (Rhoton and Tyler, 1990) these soils are classified as moderately eroded. The parent material is Peoria Loess. The climate in summer is usually moist tropical but occasionally northerly winds cause hot dry weather which can be persistent causing drought to develop (Huddleston, 1967). Annual precipitation in Tate County is 134 cm and annual average daily maximum and minimum temperatures are 23.9 and 10.6 °C respectively (Huddleston, 1967). Rainfall is distributed fairly evenly throughout the year but 60% of the rainfall occurs during the period November through April (Figure 6).

In 1987 the USDA established Watershed No. 2 at the Nelson Farm with a drainage area of 2.09 ha (5.16 acres). The Land use history includes forest clearing around 1870 and primarily cotton production until about 1950. The land was terraced in 1934 using mule-drawn plows. In the 1960's the terraces were plowed down to permit mechanized agriculture. Between 1950 and 1985 various crops were grown including corn, sorghum, soybeans and wheat. Between 1985 and 1987 the land was in grass. From 1987 to 1997 soybeans have been grown under conventional-till management.

In the process of establishing Watershed No. 2, the USDA backfilled a large gully with soil taken from an adjacent area and constructed soil berms on the flanks of the watershed to direct runoff through a weir at the outlet (Figure 7). Two, 5.5 m-wide permanent grass buffer strips 46 m-apart were seeded in the watershed in October 1991 as a conservation practice. To deal with serious headcut erosion, a 1-m deep gully was filled during August 1994, and a 5.5 m-wide grassed waterway was established from the watershed outlet to the upper buffer strip. After excessive sedimentation in the waterway a 12 m-long switchgrass (*Panicum virgatum* L.) hedge was planted along the drainage through the lower grass buffer strip in 1995. Details of these conservation measures are described in Dabney et al. (1997).

The Nelson Farm Watershed No. 2 has been managed for conventional tillage soybean production since 1987. The management schedule for watershed No. 2 at the Nelson Farm including dates of tillage, planting, harvesting and agrichemical applications is described in Appendix 1. The USGS has established primary measurement sites on upper (eroding) and lower (depositional) sites within the watershed (Figure 7). An additional site on the ridge was added later. Fallow plots are on adjacent lands (not shown in figure 7). The "worm fallow" plots are located on an older USDA/ARS study comparing worm populations under different tillage practices and irrigation. The fallow treatments were begun in the Spring of 1996 on plots that had been under conventional and no-tillage soybeans for five years prior the establishment of the fallow condition. Both the fallow plots and Watershed No. 2 were in grasses for about three to five years preceding the establishment of the plots in 1987 to 1990. Treatment 1 is conventional tillage and Treatment 2 is no tillage. The old fallow plot was established in 1989 on land that was previously in grass.

Goodwin Creek Watershed No 10: The Goodwin Creek Watershed No. 10 is in Panola County about 13 km southeast of Batesville, Mississippi near the community of Eureka Springs, MS. The watershed has a drainage area of 6.03 ha (13 acres). The watershed is in the loess hills region of the Coastal Plain Physiographic Province. The parent material is Peoria Loess. Soils are Loring series (fine-silty, mixed, thermic Typic Fragiudalfs) moderately well drained on thick loess (Blackmarr, 1995). A fragipan is found at about 76 cm. Annual average temperature is 17.2 °C and the average annual precipitation is 140 cm (Blackmarr, 1995). Little is known about the historic land use of this watershed. Post Oak (*Quercus stellata*) cored at the sites where soils were sampled and respiration measured indicated average tree age of approximately 90 to 100 years. There was evidence of selective cutting within the watershed but also based on normal diameter by age relations for oak species some trees appeared to be older than 100 years. Aerial photographs from the 1950's indicate that the area was forested at that time except for a small homestead on the ridgetop. Cedar currently growing on the ridgetop is indicative of homesteads in this area.

Goodwin Creek Watershed No. 10 is located on the Sardis SE, Mississippi 1:24000 topographic quadrangle, latitude 34°15'45" longitude 89°50'27", at an elevation of about 110 m. The watershed is within Township 9 S and Range 6 W. Goodwin Cr. is a tributary of Long Cr. which flows into the Yocona River, one of the main tributaries of the Yazoo River Basin. The watershed was entirely forested with a mixed southern hardwood species assemblage. The dominant species on the plot areas where soil respiration measurement s were made was Post Oak (*Quercus stellata*).

The USDA maintained a gage and sediment sampling on this watershed from 1982 through 1996. In 1997 the land was sold and the new landowner requested that ARS remove the gauging station. Suspended sediment sampling for analysis of carbon concentration had been established for only a few months before the gage and automatic sampler were removed. Soil respiration plots were located on hillslope and toeslope positions similar to the landscape positions where measurements were made at the Nelson Farm.

Coffeeville-Pine Reference Watershed No 1: The Coffeeville watershed is in the loess hills region of the Coastal Plain Physiographic Province. The watershed is in the Holly Springs National Forest, in Yalobusha County, between Tillatoba, Mississippi and Coffeeville, Mississippi off HWY 330 (Schrieber and Duffy, 1982; Ursic and Duffy, 1972). This watershed is located on the Scobey, Mississippi 1:24000 topographic quadrangle, latitude 33°59'48" longitude 89°46'43", at an elevation of approximately 134 m. The watershed has a drainage area of 2.81 ha (6.95 acres). Soils include Memphis, Loring, Providence, and Lexington Series, all Fragiudalfs developed on Peorian Loess (unpublished soil map, USDA) (figure 7b). Respiration plots were located on soils mapped as Providence and Memphis silt loam on hillslope and toeslope positions. The soils were very generally mapped as Smithdale-Providence association, hilly, in the Yalobusha County Soil Survey (map sheet 23, Huddleston, 1978).

The watershed was planted in southern commercial pines in 1939 after agricultural abandonment. The watershed is now dominated by mature southern pines, including predominantly, slash (*Pinus elliotti* Engelm.) with smaller numbers of loblolly (*Pinus taeda* L.) and a few naturally seeded short leaf pines (*Pinus echinata* Mill.) . The climate in summer is usually moist tropical but occasionally northerly winds cause hot dry weather which can be persistent causing drought to develop (Huddleston, 1978). Annual precipitation in Tate County averages 136 cm and annual average daily maximum and minimum temperatures are 23.8 and 11.1 °C respectively (Huddleston, 1978). Rainfall is distributed fairly evenly throughout the year but 60% of the rainfall occurs during the period November through April (Figure 6).

Pine-Hardwood, Abbeville, MS, Reference Watershed No 2: The Pine-Hardwood watershed is in the loess hills region of the Coastal Plain Physiographic Province about 8.3 km east of Abbeville, MS. The watershed in the Holly Springs National Forest in Lafayette County. It is in the SW (1/4) of Section 3, Township 7 South, Range 2 West. This watershed is located on the Malone, Miss. 1:24000 topographic quadrangle, latitude 34°30'40" longitude 89°24'04", at an elevation of about 122 m. The watershed has a drainage area of 1.85 ha (4.56 acres). The watershed was first established and instrumented in 1958 and 1959 (Ursic, 1991). Vegetation was surveyed in 1959 for all trees 10 cm diameter at breast height (DBH) (Table 2). The vegetation is classified as mature upland southern pine and hardwood mixture. Southern pine beetle, *Dendroctonus* *frontalis* Zimm. (Colepotera:Scolytidae), infestations have killed some pine in the watershed recently. The land use history for this area has not been established but it was likely deforested in the mid 1800's and the more level portions may have been cultivated or pastured for several decades. The pine in this watershed is native short leaf pine, *Pinus echinata* Mill., which is substantially slower growing than the majority of planted southern commercial pine species at Coffeeville. Judging from the diameter of the short leaf pine on the watershed, agricultural abandonment and afforestation probably began in the late 1800's or early 1900's.

In contrast to the predominant loess-derived soils at the Nelson Farm, Goodwin Cr. and Coffeeville, the predominant soils at this site were derived from sedimentary materials deposited in marine environments during the late Mesozoic and early Cenozoic. The soils of this area were very generally mapped as Smithdale-Lucy association on the upper and mid slopes and Maben-Smithdale-Tippah association, hilly, on the lower slopes of the watershed in the Lafayette County Soil Survey (map sheet 10, Morris, 1981). More intensive soil descriptions indicate Ora sandy loam soils (fine, loamy, mixed, thermic, Typic Fragiudult) occur on the upper slopes and a narrow band of Providence-Dulac silt loams (fine-silty, mixed, thermic, Typic Fragiudalfs) occurs along the lower divide (written communication, 1998, Dan Marion) (figure 7c). The steep midslopes are occupied by deep well-drained, Lakeland /Ruston soils (fine-loamy, siliceous thermic Paleudults). Wilcox series soils (fine, montmorillonitic, thermic, Vertic Hapludalfs) occupy the lower portions of the catchment.

The climate is similar to that described for the Coffeeville site (Huddleston, 1978). Annual precipitation in Lafayette County averages 137 cm and annual average daily maximum and minimum temperatures are 22.5 and 9.72 °C respectively (Morris, 1981). Rainfall is distributed fairly evenly throughout the year but about 60% of the rainfall occurs during the period November through April (Figure 6).

Methods

Soil Respiration

Theoretical Considerations: Carbon dioxide (CO_2) flux from the soil to the atmosphere (soil respiration) was estimated using a non-steady state chamber technique (Hutchinson and Livingston, 1993; Livingston and Hutchinson, 1995; Hutchinson and Mosier, 1981; Loftfield and Brumme, 1992). In this method the increase in chamber headspace CO_2 concentration following chamber deployment is used to calculate CO_2 flux. There are a number of assumptions inherent in this method. It is assumed that diffusive flux is the only form of flux into the chamber. A uniform porous media is assumed so that all measured CO_2 is assumed to originate from respiration occurring beneath the surface area covered by the chamber and that there is no net lateral transport of CO_2 either into or out of the column of soil directly beneath the chamber. It is assumed that the "seal" to the soil surface does not permit convective flux of CO_2 into or out of the chamber. It is assumed that the placement of the chamber has no effect on soil temperature, soil moisture, headspace temperature, headspace relative humidity, atmospheric pressure or other variables potentially affecting respiration, diffusive flux or the infrared gas analysis technique. It is also assumed that changes in atmospheric pressure during the measurement period will not affect flux. Finally, it is assumed that the recirculation of chamber air is sufficient to thoroughly mix the air but not vigorous enough to displace CO_2-rich soil air. It is acknowledged that in practice most of these assumptions are violated but that the errors introduced are relatively small provided measurements are made carefully.

This technique is generally thought to result in an underestimate of the true flux because of distortions to the concentration gradient in near-surface soil and change in boundary condition at the soil-air interface (Healy et al., 1996). These distortions result in an effective decrease in the concentration gradient that drives diffusive flux. Measured flux will be lower than the true flux both because lateral diffusion will increase at the expense of vertical diffusion and because there will be an increase in soil CO_2 storage during the measurement period. This error is predicted by diffusion theory but it can be minimized (to less than about 10 to 15 percent) by performing measurements over short time periods (eg. 6 minutes or less), appropriate chamber geometry, adequate headspace mixing and appropriate "sealing" of the chamber to the soil surface (Healy et al., 1996).

Chamber geometry, headspace mixing and "sealing" to the soil surface are each important considerations in the design of field flux measurement protocols. The citations above provide useful insights into the choices and tradeoffs of various designs. From a physical standpoint chamber design should avoid small surface area to height ratios because it is difficult to insure proper mixing and because a minimum of surface area will be measured. On the other hand, practical considerations limit the surface area that can be easily measured with a portable system and the volume of the chamber must be small enough that the mixing can be assured with commonly used pumps. Mixing within the headspace can be accomplished with the flow of air recirculated between the CO_2 analyzer and the chamber in a closed system. Vigorous air movement within the chamber, such as that produced by fans within the chamber, that can generate convective displacement of soil air from the soil surface should be avoided so that CO_2-enriched soil air is not inadvertently pumped into the headspace and measured as diffusive flux.

Making field measurements involves a number of uncertainties that are not evaluated in a theoretical analysis such as that done by Healy et al. (1996). Healy and coworkers assumed that the porous media was uniform in terms of pore size, pore size distribution, and pore geometry. Furthermore, they had to assume a set of initial boundary conditions that defined the initial gradient in soil CO_2 concentration as being uniform emanating from an infinite source at the bottom of the modeled soil system. In the field none of these conditions are met which suggests the actual measurement error may be somewhat higher or lower than they show but the computational complexity of representing a non-uniform porous media and a spatially heterogeneous source make such an analysis impractical.

It is also important to minimize changes in air pressure at the instant of chamber deployment. It has been shown theoretically that even minor pressure changes can have major impacts on measured fluxes because of the potential for the displacement of CO_2 -enriched soil air into the chamber. A coil of tubing attached to the chamber headspace vented to the outside provides for the release of air from the chamber headspace as the chamber is placed on the soil surface and pushed down into the soil or loose sand collar. If the chamber is not vented in this way, placing the chamber would effectively compress the air within the chamber and create positive overpressure. The coil used to vent the headspace should have a small diameter (<0.5 mm) and be of sufficient length, about 20 cm, to insure that diffusion of CO_2 through the coil would be negligible.

For practical considerations field flux measurements with this technique which are not automated must be made periodically. To estimate total annual flux, fluxes between measurement periods must be modeled using relationships between measured flux and seasonal climatic variables that control flux. Therefore it is critical that field measurements reflect "average" flux for that period and not flux associated with transient conditions which might influence flux for very short periods only. Given the limitations on the frequency of potential flux measurements, it is best to avoid flux measurements immediately following significant rainfall or soil disturbance associated with agricultural practices. Water draining through the soil following heavy rainfall may result in piston-like displacement of CO_2-enriched soil air causing short term convective flux into the chamber. Following long antecedent dry periods rainfall may also produce a spike in the activity of litter organisms (Paul Hanson, Oak Ridge National Lab, personal communication, 1996). Infiltrating water may also cause transient anaerobic conditions that could inhibit heterotrophic respiration until the soil has partially drained. Tillage is known to result in short term increases in soil respiration (Reicosky and Lindstrom, 1993) and unless repeated measurements are made to quantify the short term release seasonal measurements should avoid periods immediately after tillage.

When making field measurements of soil respiration with this chamber technique a decision must be made regarding how to handle herbaceous vegetation that would be enclosed within the chamber. In our measurements it was decided that aboveground plant respiration would not be measured and that any existing herbaceous vegetation would be clipped at ground surface prior to chamber placement. When opaque chambers are used (as in our studies) the potential "greenhouse effect" of warming the soil surface is minimized and any herbaceous vegetation within the chamber would not have light for the assimilation of carbon dioxide. With opaque chambers, if vegetation were left in the chamber above ground respiration would contribute to the measured "soil respiration" therefore vegetation was clipped to remove this source. In practice it is impractical to remove more than 80 or 90 percent of aboveground green vegetation when there is substantial areal coverage of small broadleaf weeds with prostrate growth habit because of the time required and because of the tradeoff in soil disturbance.

Field measurements in both agricultural and forest ecosystems require decisions regarding the placement of chambers in relation to the location of crop plants and trees and shrubs. Field measurements have indicated that in agricultural ecosystems where crops are planted in rows soil respiration during the growing season is generally higher immediately adjacent to the row (undoubtedly because of higher root density) than midway between rows. Therefore, it is important to place the chambers such that all of the surface area is proportionately sampled. In forest systems, for practical considerations, it is not possible to place chambers over stumps, stems, or large coarse woody debris.

Infrared Gas Analysis (IRGA) determination of CO_2 concentration is sensitive to temperature, pressure (both ambient barometric and any differential imposed between the sample and reference cells), and the presence of water vapor in the air. When the IRGA is operated in absolute mode, as in this study, the reference cell is maintained free of water vapor but is subject to changes in ambient temperature and pressure. The IRGA measures temperature at the optical bench and this is logged continuously during flux measurements and corrections are routinely applied. If the IRGA is calibrated at the barometric pressure at which measurements will be made and the pressure is recorded then the appropriate correction can be applied when the signal voltage is processed. In general both ambient barometric pressure and vapor pressure corrections for the range of environmental conditions normally encountered in this project are relatively small resulting in corrections of less than 5% for absolute CO_2 concentration.

Barometric pressure and vapor pressure were not regularly measured in the field in this study. Corrections were evaluated using relative humidity and barometric pressure from nearby meteorological stations. Because of potential differences between the nearby field sites and meteorological stations and because vapor pressure changes in the chamber headspace during flux measurements, the effect of errors due to assumptions about these corrections was assessed. Equations 1, 2 and 3 (Figure 8) were provided by the IRGA manufacturer to calculate CO_2 concentration from measured signal voltage, temperature, barometric pressure and vapor pressure. The LI-COR manual for the LI-6252 CO_2 analyzer describes how water vapor affects the measurement of CO2 and how corrections can be performed. Using these equations a sensitivity analysis was performed to evaluate both the absolute error in determination of CO_2 concentration and the error in determining flux that would be introduced when barometric and vapor pressure corrections were incorrect. Table 3 presents a set of calculations illustrating the magnitude of error in absolute CO_2 concentration that resulted given a variety of possible combinations of ambient relative humidity (converted to vapor pressure in the calculation) and atmospheric pressure. The range of error from anticipated extremes in relative humidity and barometric pressure is also illustrated in a contour plot (Figure 9). The absolute CO_2 concentration is overestimated if the true RH is greater than the assumed RH and underestimated if the true pressure is greater than the assumed barometric pressure.

The flux calculation is based on the change or difference in concentration in the chamber rather than the absolute concentration. There is a non-linear effect of errors in concentration resulting from pressure and water vapor corrections at high and low CO_2 concentrations. Because of this nonlinearity, the flux estimation will also be in error and therefore an analysis was done to assess the potential error for a range of typical barometric and vapor pressure values. Errors in flux estimation because of inaccurate barometric pressure or vapor pressure, expressed as a percent of the true flux are relatively constant independent of the rate of flux (Figure 10). Error increases slightly with increasing ambient temperature because vapor pressure increases for a given relative humidity as temperature increases (data not shown). For combinations of barometric and vapor pressures normally encountered at these sites errors in flux estimation associated with errors resulting from lack of corrections even under extreme conditions would result in errors in flux estimation of less than 5%. Under the environmental conditions normally encountered in this study the errors generally indicate a small (<2 percent) negative bias.

Field Measurement Techniques: Soil respiration measurements were made with a LI-COR Inc. infrared gas analyzer (IRGA) Model LI-6252 equipped with a LI-COR model LI-670 Flow Control Unit and Campbell Scientific Inc. Model 21X data logger. The IRGA and flow control unit were connected to a chamber in a closed loop with flexible Bevline tubing. The chamber was constructed of opaque PVC Pipe and a "welded on" opaque PVC sheet for a lid. The chamber was 27.3 cm O.D. and 25.4 cm I.D. Two concentric rings of PVC pipe. were used to form a collar on the soil surface. The inner PVC ring was 23.8 cm O.D. and 22.9 cm I.D. The outer PVC ring was 32.4 cm O.D. and 29.9 cm I.D. These diameters of PVC pipe are not regularly available but may be obtained through S.E. Ind. Plastics, 2740 S. Cobb Industrial Blvd., Atlanta, GA. The rings were cut to approximately 5 cm length. When making a measurement the rings were placed on the soil surface rather than pushed down into the soil to minimize disturbance.

When making measurements in the forest the concentric PVC rings forming the collar were carefully worked into the forest floor by separating the loose litter (Oie and part of the Oe layer) and placing half of what fell under the ring itself inside the ring and half outside until the rings were resting on a fairly compact organic layer. Efforts were made to minimize disturbance to the underlying rots in the Oie, Oa, and mineral soil horizons. When making measurements in the agricultural fields the concentric PVC rings forming the collar were placed on the soil surface and loose litter, if present, was treated in the same way as in the forest.

The annulus between the concentric PVC rings was filled with fine silica sand to a depth of 3 to 4 cm. The chamber was placed on the sand in the annulus and gently pushed into the loose sand to a depth of approximately 1 cm. When the chamber was depressed into the sand collar to one cm depth the effective headspace volume including tubing was 10.2 L. The flow rate through the analyzer was maintained at a constant 2 L min^{-1} with the LI-670 Flow Control Unit. Prior to each measurement ambient CO2 concentration was recorded until it stabilized. The chamber was then placed in the sand collar and the raw signal voltage from the infrared detector and temperature sensor at the optical bench were recorded every 15 seconds for 5 minutes with the data logger.

In some of the fallow plots the soil surface was very smooth and compact and in these instances PVC rings were not used and instead sand was simply banked against the outside of the chamber wall. Field trials on fallow plots were conducted to compare flux measurements made with concentric PVC rings and sand collars versus with sand banked against the chamber walls and no significant differences were observed.

The CO_2 concentration time series was calculated using equation 1 (Figure 8). During flux measurements the pattern of increasing concentrations of CO_2 in the chamber head varied systematically. CO_2 concentration usually rose slowly for approximately 1 to 1.5 minutes following chamber deployment and then increased rapidly for two to three minutes, following this period concentrations increased progressively more slowly. This systematic decrease in the rate of increase in headspace CO_2 concentration has been termed a "rollover effect". Estimated instantaneous soil respiration decreased by about 3% per minute immediately following peak flux. Absolute magnitude of the observed decrease in flux was proportional to the maximum flux over the observed range in flux.

The best estimate of true soil respiration (CO_2 flux density) was assumed to be the maximum observed rate of increase in CO_2 concentration . This rate was obtained by taking the higher of: (1) the maximum rate of change in CO_2 concentration derived from the third-order polynomial fit to the concentration-by-time data series provided that the inflection point fell between minutes 0.5 and 5 following chamber placement or (2) a simple linear regression between minutes 2 and 5 following chamber placement. Figure 11 shows a summary of the third-order polynomial fit method of flux computation. During some measurements the initial lag period was very short or nonexistent so that this technique produced an unreasonable result. These cases were determined automatically because the calculated time of maximum flux did not fall between minutes 0.5 and 5. In these cases the slope, calculated from a simple linear regression between minutes 2 and 5, was used to estimate the maximum rate of increase.

Usually, nine separate chamber placements resulting in nine separate flux measurements were made at each site or plot during a seasonal measurement. The respiration data reported in tables and figures in this report represent the means of these replicate measurements. Chamber placements were made with a stratified-random approach within designated plots. For example, because of the relationship between the diameter of the chamber and the spacing between soybean rows, six chambers were randomly placed adjacent to a row and three were randomly placed between rows. This placement approach was used to insure proportional representation for surface area measured. Under conditions where spatial variation in measured flux was minimal, only six, seven, or eight chamber placements were made rather than nine. Soil respiration was measured approximately every 4 hours during diurnal cycles except during the 3/6/97 - 3/8/97 period when measurements were less frequent. During diurnal measurements the chambers remained in the same locations for all measurements. Following seasonal measurements and at the end of diurnal measurement periods the PVC collars were removed to allow normal runoff and erosion processes to occur and so as not to interfere with normal agricultural operations in the soybean fields.

Soil Moisture and Soil Temperature

Theoretical Considerations: Soil water potential (θ_ψ) was determined with Campbell Scientific Inc. (CSI) Model 229 heat dissipation probe using a thermocouple and line heat source embedded in a porous ceramic cylinder designed to approximate typical pore size distribution and geometry for a silt loam soil (Campbell and Gee, 1986; Reece, 1996). Heat dissipation (or thermal diffusivity) has been used since 1939 and although there have been many advancements in the technology it has not been widely adopted because of difficulty in the empirical calibration. CSI's 229 sensor is still experimental in that they have not been evaluated under a broad range of soils and soil conditions. Water potential is derived from the exponential relationship between measured heat dissipation (measured as a change in temperature, ΔT) and θ_ψ (Reece, 1996).

Each sensor must be calibrated separately. Calibration requires that heat dissipation be recorded for at least two known θ_ψ soil conditions. There are important advantages to these probes over tensiometry or psychrometry. These probes can be easily automated and they are capable of measurement over a very wide range in θ_ψ. Furthermore, ambient soil temperature is recorded with the embedded thermocouple prior to each measurement so that no additional soil temperature probe is required. The probes were recently evaluated in comparison to standard tensiometers and psychrometers and they were found to be an effective alternative for measurement across a broad range (0.1 to 10 bars suction) in soil water potential (Reece, 1996). Tensiometers are only effective at suction pressures below about 0.9 bar suction which corresponds to the air entry pressure of the ceramics at standard atmospheric pressure. The probes are used in the Oklahoma Mesonet Project and have been found to be reliable over a wide range in soil moisture conditions (Basara et al., 1998). In the Oklahoma Mesonet Project water potenial measurements recorded with the Model-229 probes were better correlated with metoeorolgical variables than were estimates of volumetric water content (Basara et al., 1998).

Calibration of Water Potential Probes: The Model-229 probes were calibrated using *in situ* measurements of soil volumetric water content and ΔT for each probe as well as soil moisture characteristic curves determined for the Grenada Silt Loam soil for a site about 50 km from the Nelson Farm (Römkens et al., 1986). The soil moisture characteristic curve provides the relationship between volumetric water content (θ_v) and water potential

(θ_ψ) (Figure 12). Based on documentation provided by CSI (Bilske, written communication 5/14/96) for each probe it is assumed that there is a linear relationship between ln θ_ψ and ΔT and that this relationship can be applied over a range of soil water potential from zero to about -1500 kPa (15 bars suction).

To calibrate each probe ΔT and θ_v pairs of data were obtained using *in situ* measurements taken from the probes and from measurements of volumetric water content under both very moist and relatively dry soil conditions. Measurements of volumetric water content were obtained from both CSI Model-615 TDR probes and from gravimetric water content and bulk density measurements. Water potential (θ_ψ) was estimated from θ_v using the appropriate soil moisture characteristic curve for the probe soil depth (Römkens et al., 1986). Simple linear regressions were obtained from this ΔT and ln θ_ψ data for each probe.

Six Model-229 probes were independently calibrated by David Radcliffe, University of Georgia, Athens, Georgia, using a sealed pressure plate apparatus (Klute, 1986) with electrical feeds for connection to a data logger. Sensors were embedded in intact soil cores by auguring a small hole into the center of the soil core and backfilling after burying the probe in the hole. The probes were placed on ceramic pressure plates in a standard chamber and overpressures of 0.3, 1.0, 2.0, and 2.9 bars were applied. Heat dissipation was monitored at each pressure until the system equilibrated at the new pressure (i.e. heat dissipation no longer changed). The data for each probe consisted of a continuous time series of heat dissipation (expressed as a change in temperature [ΔT] accompanying a heat pulse of fixed energy and duration). Calibration relationships were established from these curves between ΔT and pressure. This procedure took nearly 3 months and was considered too costly to apply to all probes.

Subsequent probe calibrations were performed at the USGS laboratory in Atlanta. The calibrated probes were used to calibrate additional probes by assuming that the mean value for water potential from two or more calibrated probes was the true water potential. To calibrate the new probes a box was constructed containing a 9-cm layer of soil over a 2-cm layer of sand over a 6 cm layer of pea gravel. A length of 5-cm diameter PVC well pipe screened within the gravel layer was placed in one corner of the box. All materials were in an air dry state when they were placed in the box. The soil was sieved to 2 mm diameter. The sand was a fine silica sand. Sixteen probes (calibrated and uncalibrated) were buried within the soil layer by placing them at approximately the same depth after half of the soil had been added and then covering them with the remaining soil.

To initialize the calibration distilled water was introduced through the PVC pipe so that the gravel would be saturated first and water would "wick up" through the sand and soil. Water was added until the soil surface became uniformly moist. Water was then pumped out of the gravel layer until the soil, sand and gravel had thoroughly drained. A heat lamp and fan were placed over the surface of the soil to increase the rate at which the soil would dry out. The soil was allowed to dry for approximately 8 weeks. ΔT was recorded hourly for each precalibrated and unknown probe. Calibration relationships were established from these time series between ΔT of the unknown probes and the θ_ψ as inferred from the precalibrated probes.

Theory and Calibration of Water Content Probes: Volumetric soil water content (θ_v) was measured with a Campbell Scientific Inc. (CSI) Model-615 water content reflectometer using the principle of time domain reflectometry. The probe provides an indirect measurement of soil water content. The measured properties of a standard electromagnetic wave propagated along a standard steel rod wave guide is proportional to the dielectric constant of soil which in turn is dependent upon the water content of the soil. The Model-615 probe integrates soil moisture content over a 30 cm-long rod pair. Each sensor was calibrated independently using water content data (gravimetric) for soil samples of known volume. The Model-615 probe calibration requires only an offset to the manufacturer supplied polynomial calibration equation.

Field Measurement Techniques: Combination soil θ_ψ and temperature Model-229 probes were installed at upper and lower soil respiration plot locations at the Nelson Farm Watershed #2 (Figure 7a) for continuous monitoring. At both upper and lower sites 3 probes were installed at 10 cm, three at 30 cm and one each at 60 and 90 cm soil depth. Wire leads were run back to a centrally located data logger in a trench at 30 cm soil depth. Prior to Spring tillage the 10 cm depth probes were excavated and buried at 30 cm depth so that tillage would not destroy them. After tillage these six probes were re-excavated and installed at 10 cm depths. Data from the probes were recorded hourly.

One volumetric water content Model-615 probe was installed at the upper site and one at the lower site. Probes were installed at an angle, rather than vertically, from the soil surface downwards so as to integrate the water content of the upper 20 cm of soil. The wire leads for these probes were not buried and were inadvertently cut with tillage operations on two occasions resulting in data gaps in the record.

Soil temperature was also recorded with a hand held electronic thermometer periodically during some CO_2 flux measurement periods. Air temperature and soil temperature under grass sod at about 7.5 cm soil depth were recorded at a USDA/ARS mini-met station located near WSH #2 on the ridge at the Nelson Farm.

Sediment Export

The methods used in measurements of runoff and sediment export vary among the research watersheds monitored by the USDA and the USFS. Weirs are placed in the stream channel, ideally in locations where there is a natural drop in elevation and focus or concentration of flow. The weirs are designed to be "self-cleaning", i.e. sediment does not accumulate immediately above or within the weirs but is passed though the weirs with the runoff water. The flow is focused through a relatively narrow control section to insure a more precise measurement of stage. Concentration of flow in the control section also insures that the runoff and entrained sediment are well mixed within the water column. In most cases "streamwater" stage is measured continuously with a stage recording device that senses the water level and records and stores the data on a fixed time interval. Stage is recorded in a control structure, usually a metal or concrete weir, calibrated to develop a stage-to-discharge relationship. Continuous discharge is then estimated from measured stage.

Suspended sediment samples are collected using one of two methods. Either a flow-proportional Coshocton wheel-type sampler is used or an automatic sampler is used to pump suspended sediment from the channel. If a Coshocton wheel sampler is used all of the flow is directed over the sampler intake manifold and the manifold is adjusted to capture a predefined fraction of total flow. If an automatic sampler is used, sampler inlet tubes for collection of suspended sediment samples are placed in the center of the control section. Automatic samplers can be programmed to collect samples on either a fixed-interval basis or on a flow-proportional basis. The assumption is made that all of the sediment entrained in the runoff water is well mixed in the water column at the weir and sampling point. Therefore, it is assumed that there is no separate sediment fraction moving as bedload. With the Coshocton wheel sampler this assumption is not as critical as it is with the automatic pump samplers because a fraction of all of the sample is collected. With automatic pump samplers, the assumption is likely an oversimplification, and to the extent that the sediment is not well mixed some fraction would be unquantified bedload because it would not be pumped into the sampler. Quantification of this error is beyond the scope of this study.

At the Nelson Farm site runoff samples were collected using stage-actuated automatic samplers equipped with peristaltic pumps (Dabney et al., 1997; Grissinger and Murphree, 1991). Discharge weighted samples were collected after every 0.51 cm of runoff. Runoff samples from the Nelson Farm and all other sites described in this report were processed for gravimetric analysis of sediment weight per sample. Sediment export was calculated by applying measured or calculated sediment concentration to continuous records of discharge. Methods used to measure sediment export at Goodwin Creek Watershed No. 10 are described in Kuhnle et al. (1996). At Goodwin Creek, runoff samples were collected at intervals during storms using a stage-actuated automatic sampler controlled by a data logger that continuously recorded stage. Methods used to measure sediment export at the Coffeeville Watershed No. 1 are described in Ursic and Duffy (1972). At Coffeeville runoff samples were collected using a Coshocton Wheel that collects a flow proportional sample and stage is continuously recorded with a data logger. At Pine-Hardwood Watershed No. 2 samples were also collected using a Coshocton Wheel. Methods used to measure sediment export at the Pine-Hardwood, Watershed No. 2, near Abbeville, MS are described in Ursic, 1991.

Sediment Sample Processing

Runoff samples containing suspended sediment were processed by various procedures to recover sediment for analysis. The procedure used depended upon the sample volume and the sediment concentration. Small sample volumes were freeze dried directly. Large sample volumes containing relatively small sediment concentrations were de-watered using a Westphalia flow-through centrifuge followed by freeze drying (lyophilization) of the sediment recovered by the centrifuge (Horrowitz et al., 1989). Samples containing large amounts of sediment that made churn splitting unreliable (> 1 g L^{-1}) had supernatant and sediment processed separately and all recovered sediment was later recombined. The procedures were as follows:

1. Suspended sediment samples were shipped from the field to the GA District where they were assigned a Laboratory ID code consisting of a two letter site designation (NF=Nelson Farm, CV=Coffeville, PH=Pine Hardwood) followed by SS (designation for suspended sediment) and a sequential number. For example the first sample from the Nelson Farm Watershed No. 2 was designated NFSS1. Sample login information included ID, collection date, and sample volume. The Georgia District Sedimentation Laboratory tracked the Sample ID in both paper and digital format.

2. Sample weight was recorded

3. For large sample volumes (larger than would fit into drying containers):

   I. Relatively Small Quantities of Sediment (< approx. 25 g)
   - Samples were de-watered using a Wesfalia flow-through centrifuge at 2 L/min flow rate.
   - The "de-watered" samples were quantitatively transferred to a stainless steel drying container and lyophilized (freeze-dried).
   - Freeze-dried samples were quantitatively transferred to a suitable sample container such as a 25 ml polyethylene scintillation vial.
   - Liquid effluent from centrifuge was recovered in the original sample container, and subsampled for potential measurement of total organic carbon (TOC).

   II. Moderlately Large Quantities of Sediment (approx. 25 to 40 g)
   - Samples were "churn split" to obtain a representative aliquot and the aliquot was quantitatively transferred to a stainless steel drying container and lyophilized.
   - Freeze-dried samples were quantitatively transferred to a suitable sample container such as a 25 ml polyethylene scintillation vial.
   - The remainder of the sample from churn splitter was recovered in original sample container and subsampled for potential measurement of total organic carbon (TOC).

   III. Large Quantities of Sediment (>approx. 40 g)
   - All supernatant (whether one carboy or multiple carboys) was pumped through the Wesfalia flow-through centrifuge at 2 L/min flow rate and the recovered sediment was freeze dried.
   - All remaining sediment in the bottoms of the carboys was transferred to freeze drying dishes (either by cutting apart the carboy and scraping or by washing). The resulting material was also freeze dried.
   - All freeze-dried material from the sample was recombined.

4. For low volume samples that would fit in drying containers:
- Samples were quantitatively transferred to a stainless steel drying container and lyophilized (freeze-dried).
- Freeze-dried samples were quantitatively transferred to a suitable sample container such as a polyethylene scintillation vial.

Carbon and Nitrogen Analysis: Freeze dried sediment was shipped to the USGS Laboratory in Menlo Park, CA. The sediment was thoroughly mixed to insure that representative subsamples of approximately 50 mg could be obtained for analysis. Selected sediment samples were analyzed for inorganic carbon using the procedures described by Fries and Markewich (1998). It was determined that these samples contained no measurable amounts of inorganic carbon so the remainder of the samples were not analyzed for inorganic carbon. Sediment was analyzed for total carbon and total nitrogen concentrations using a Fisons (Carlo Erba) Model NA1500 elemental analyzer employing the Dumas combustion method (Fries and Markewich, 1998).

Data

In this section of the report the field data including; soil respiration, soil temperature, soil moisture, sediment yield, sediment carbon and nitrogen concentration and C13 N15 isotopic analysis, grain yield, and forest biomass are described. Selected data is presented in tabular and graphic form so to acquaint the reader with the scope and form of the data, and, in the case of soil respiration data to present summaries of all of the data. Only selected examples of the physical data are presented because of the large quantity of this data. In each subsection filenames are provided to permit access to the complete data set using FTP. A list that includes all of the downloadable files and describes the protocols and path names required to access the data is provided in appendix 2.

Soil Respiration:

Soil respiration (carbon flux) measurements were made from December 1996 through January 1998 at agricultural and forested sites according to the schedule shown in table 4. The temporal pattern of soil respiration at mid slope (upper) and toe slope (lower) sites at the Nelson Farm Watershed No. 2 and forested sites near Goodwin Creek, Coffeeville, and at the Pine-Hardwood site, near Abbeville are shown in Table 5, Table 6, and Figure 13. The growing season covers the period from approximately May 1st through October 15. A t the Nelson Farm soil respiration measurements were made at several additional sites that are part of a fallow experiment. Figure 14 shows a comparison amongst all of the cropped and fallow plots at the Nelson Farm.

Diurnal measurements, or measurements made periodically over a 24-hr period, were made at upper and lower sites at both the Nelson Farm and at the forested site near Coffeeville. The diurnal pattern of soil respiration and soil and air temperature at Coffeeville for the period November 14 - 16, 1997 is shown in figure 15. The diurnal pattern of soil respiration and soil and air temperature in cropped (soybean) plots at the Nelson Farm for the period November 10 - 11, 1997 is shown in figure 16. The diurnal pattern of soil respiration and soil and air temperature at Coffeeville for the period January 28 - 29, 1998 is shown in figure 17. The diurnal pattern of soil respiration and soil and air temperature in cropped (soybean) plots at the Nelson Farm for the period January 27 - 28, 1998 is shown in figure 18.

Soil respiration was plotted versus the mean of three soil temperature measurements at 10 cm depth for plots at eroding and depositional sites at the Nelson Farm for the period December 1996 through January 1998 (Figure 19). The best fit second order regression equation and analysis of variance was determined using a statistical analysis package

Statview (Figure 19). The r-squared values for these regressions were >0.8 and the p-values for significance of the regressions were <0.0001.

Soil respiration (carbon flux) was plotted versus air temperature for plots at eroding and depositional sites at the Nelson Farm for the period December 1996 through January 1998 (Figure 20). The best-fit second order regression equation and analysis of variance was determined using Statview (Figure 20). The r-squared values for these regressions were >0.7 and the p-values for significance of the regressions were <0.0001.

Soil respiration (carbon flux) was plotted versus soil temperature at 10 cm depth for plots at eroding and depositional sites in the forested Goodwin Creek Watershed No. 10 for the period December 1996 through January 1998 (Figure 21). The best fit second order regression equation and analysis of variance was determined using Statview (Figure 21). The r-squared values for these regressions were >0.8 and the p-values for significance of the regressions were <0.18. The p-value was much higher at Goodwin Creek compared with the Nelson Farm because there were many fewer measurements.

Data files for soil respiration measurements are not included in this report but may be obtained from the USGS by ftp. The data files are organized by site(s) and date of measurements. For example, a typical file would contain all flux measurements made at the Nelson Farm upper (eroding) and lower (depositional) sites on a single date and time. These files contain the time series data of IRGA signal voltage for (1) detector temperature and (2) detector CO_2 concentration for each 15-second interval during each individual 5-minute measurement for each chamber placement. The files are Microsoft Excel spreadsheets in binary format. The files contain the equations used to calculate CO_2 concentration using the fifth order polynomial supplied by the manufacturer and signal voltage, temperature, and barometric pressure. The spreadsheets also contain algorithms used to calculate flux based on the CO_2 concentration time series in the chamber headspace based on either the best fit polynomial approach or the simple linear regression as described in the methods section of this report. These files may be obtained from the USGS from URL:
http://geochange.er.usgs.gov/pub/carbon/OFR_98-501/.

Physical Data Nelson Farm Watershed No. 2 :

Summary data on rainfall, runoff, sediment yield, and grain yield from Watershed No. 2 at the Nelson Farm, near Como, MS are shown in Table 7 (modified and updated from

Dabney et al. 1997). The carbon concentration for suspended sediment exported from this watershed collected for several storms are reported in Table 8.

Soil temperature was monitored continuously at the Nelson Farm Watershed No.2 at four soil depths at upper (eroding) and lower (depositional) sites. To illustrate the form of the data Figure 22 shows the time series for soil temperature at the 10 cm depth for the lower site (mean of three replicate sensors) for the period March 4, 1997 through March 7 1998. Soil temperature data from 10, 30, 60, and 90 cm soil depth at the upper and lower sites at the Nelson Farm Watershed No. 2 may be obtained from the USGS from URL: http://geochange.er.usgs.gov/pub/carbon/OFR_98-501/.

Soil water content was monitored continuously at the Nelson Farm Watershed No.2 for the upper 20 cm soil depth at upper (eroding) and lower (depositional) sites. To illustrate the form of the data Figure 23 shows the time series for soil water content at the lower site for the period March 4, 1997 through March 6, 1998. Soil water content data from the upper and lower sites at the Nelson Farm Watershed No. 2 may be obtained from the USGS from URL http://geochange.er.usgs.gov/pub/carbon/OFR_98-501/.

Soil water potential (θ_{ψ}) was monitored continuously at the Nelson Farm Watershed No.2 at four soil depths at upper (eroding) and lower (depositional) sites. To illustrate the form of the data Figure 24 shows the time series for soil water potential at the 10 cm depth for the lower site (mean of three replicate sensors) for the period March 4, 1997 through March 7 1998. Soil water potential data from 10, 30, 60, and 90 cm soil depth at the upper and lower sites at the Nelson Farm Watershed No. 2 may be obtained from the USGS from URL: http://geochange.er.usgs.gov/pub/carbon/OFR_98-501/.

Air temperature, solar radiation, rainfall, and wind speed are recorded hourly by the USDA/ARS GOSSYM weather station at the Nelson Farm. Data for the entire period of record 1988 - 1998 is available from the USDA/ARS. Data for the period March 1997 through March 1998 may be obtained from the USGS from URL http://geochange.er.usgs.gov/pub/carbon/OFR_98-501/..

Air temperature, solar radiation, rainfall, and other meteorological variables recorded at a SURFRAD station within Goodwin Creek within a few kilometers of Watershed 10. The SURFRAD Meteorological Station is part of a NOAA network focusing on radiation budgets. The data are available through the WWW at: ftp://titan.srrb.noaa.gov/pub/data/surfrad/Goodwin_Creek_MS/

Physical Data From Forested Watersheds

Rainfall, runoff, and sediment yield from Watershed 10 at Goodwin Creek are shown in Table 9 (modified and updated from Tuttle and Alonso, USDA-ARS National Sedimentation Laboratory, Oxford, MS, written communication, 1998). The carbon concentration for suspended sediment exported from this watershed collected for several storms are reported in Table 10.

In this project we are working on the reference Pine-Hardwood watershed No. 2, near Abbeville, MS. The USFS has long term data on runoff and sediment yield from several watersheds within a 1.4-km radius of Pine-Hardwood watershed No. 2, near Abbeville, MS. The other watersheds were cut in 1982 to evaluate the affects of different forest harvesting practices on runoff and sediment export (Ursic, 1991). There is substantial variation in runoff and sediment yield between years on these watersheds, for example Ursic (1991) reports sediment yields varied between 2 and 664 kg/ha during the calibration period (undisturbed) 1960 through 1982 for the yarded catchment, watershed No. 1 (Table 11). The long-term (1960-1982) mean annual sediment yields for the watersheds 1, 2, and 3 were 183±57, 261±88, and 142±37 kg/ha/yr respectively.

Rainfall, runoff, and sediment yield from the reference watershed, Coffeeville-Pine Watershed No. 1 near Coffeeville, MS are reported in Table 12. The data cover two brief periods in the record. The USFS is currently processing historical data to provide a more complete record.

Comparisons in Sediment and TOC Yields from Conventional and No-till Management

Plot and watershed studies at the Mississippi Agricultural and Forestry Experiment Station near Holly Springs, Mississippi on thin loess soils for the 1976 water year compared sediment TOC yields between conventional and no-till management (Schreiber and McGregor, 1979). Sediment TOC concentrations were higher under no-till than conventional till, but sediment TOC export was 6 to 13 times greater from conventional till because of much higher soil losses. Carbon export associated with sediment was 270 kg/ha/yr under conventional tillage grain production and 29 to 43 kg/ha under no tillage grain production.

Comparisons in Sediment Yields between Forested Basins with and without Channel Networks

Watershed studies in the upper Coastal Plain in undisturbed forested basins have shown that where well-defined channel networks are present sediment yields are ten times higher than where they are absent (Marion et al., 1997). Mean sediment production from forested basins lacking channel networks averaged 5.3 to 6.2 kg sediment per hectare per centimeter of runoff (kg/ha-cm) compared with 52 kg/ha-cm where channel networks were present. Assuming an average value of 26 cm of runoff per year (Ursic, 1991) the annual sediment yields would be about 150 kg/ha/yr for basins lacking a channel network and 1400 kg/ha/yr for basins having a well defined channel network. Comparisons between several other forested basins throughout the Upper Coastal Plain support these findings (Ursic, 1975; Marion and Ursic, 1993).

Comparisons Between Solution and Sediment Export of Carbon from a Small Forested Watershed

Schreiber and Duffy (1982) measured concentrations TOC in solution (<.45μm) and sediment from runoff samples collected in 1977 and 1978 from watershed 2 at Coffeeville, Miss. and they determined that solution TOC was 75% of the total (Solution + Sediment TOC). They reported runoff solution TOC yields of 8.6, 9.1, and 33.4 kg/ha for 1976, 1977, and 1978 respectively and sediment TOC yields of 5.8 and 8.5 kg/ha for 1977, and 1978 respectively. Sediment carbon concentration averaged 6.1% for watershed 2 but varied from 2.3% to 8.6% among watersheds 1 through 5 that are all within a 1.4 km radius. There was a direct positive relationship between carbon concentration in sediment and soil carbon concentration determined for the 0-15 cm soil depth. Sediment TOC concentrations decreased exponentially with an increase in sediment concentration (r=0.58 for all 5 watersheds combined).

Vegetation Data

Grain yields from Watershed No. 2 at the Nelson Farm are reported in Table 7. The USDA has also collected data on weed biomass at the Nelson Farm. This data complements the crop yield data for estimation of total residue inputs. Weed biomass is for weeds harvested immediately prior to Spring tillage. This weed biomass data is available from the USDA, ARS, National Sedimentation Laboratory. Tree DBH and height data at all forested sites (Goodwin Creek Watershed No. 10, Pine-Hardwood Watershed No. 2, and Coffeeville-Pine Watershed No. 2) were collected by U.S. Forest Service staff, Center for Bottomlands Hardwood Research, Oxford, MS. This data may be obtained from the USGS from URL:

http://geochange.er.usgs.gov/pub/carbon/OFR_98-501/.

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Table 1 Erosion Class for fragipan soils developed in Peoria Loess (adapted from Rhoton and Tyler, 1990).

Erosion Class	Depth to Fragipan (cm)
uneroded	> 90 cm
slightly eroded	60 - 90 cm
moderately eroded	30- 60 cm
severely eroded	< 30 cm

Table 2.- Summary vegetation measurements on Pine-Hardwood Watershed in 1959.

Size Class/Species (dbh>10 cm)	CU ft/ac	BD ft/ac	Basal Area sq ft/ac
Poles-Hardwood	276.3		
Poles-Softwood	65.2		
Saw Timber-Hardwood		443	
Saw Timber-Softwood		5237	
Pine			40.7
Hardwood			41.5

Table 3 Showing calculated CO_2 concentration s with corrections for atmospheric pressure and relative humidity. These calculations are for ambient temperature = 5 and 20 C and raw signal voltage = 2100 mv using the coefficients supplied by the IRGA manufacturer for the polynomial used to calculate CO_2 from voltage, temperature , and pressure. Without corrections for barometric and vapor pressure, calculated CO_2 concentration would be 355.5 ppm(v) at 5 C and 375.1 ppm(v) at 20 C

Atmospheric Pressure inches Hg	Atmospheric Pressure kPa	RH %	CO_2 5 C ppm(v)	CO_2 20 C ppm(v)
28.6	97	0	376.8	397.1
28.9	98	0	371.7	391.8
29.2	99	0	366.8	386.6
29.5	100	0	362.0	381.5
29.8	101	0	357.3	376.6
30.1	102	0	352.7	371.8
30.4	103	0	348.3	367.1
30.7	104	0	343.9	362.5
28.6	97	50	378.2	401.2
28.9	98	50	373.1	395.7
29.2	99	50	368.1	390.5
29.5	100	50	363.3	385.3
29.8	101	50	358.6	380.3
30.1	102	50	354.0	375.4
30.4	103	50	349.5	370.6
30.7	104	50	345.2	366.0
28.6	97	100	379.6	405.3
28.9	98	100	374.5	399.8
29.2	99	100	369.5	394.5
29.5	100	100	364.7	389.2
29.8	101	100	359.9	384.1
30.1	102	100	355.3	379.2
30.4	103	100	350.8	374.3
30.7	104	100	346.4	369.6

Table 4. Sites, times, and dates of soil respiration measurements in NW Mississippi for the period December 1996 through January 1998. Explanation of abbreviations is in the text.

Site	Measurement Date	Type of Measurement
Nelson Farm W2 Upper and Lower	12/3/96	Single Point in Time
	3/6/97 - 3/8/97	Diurnal
	4/21/97	Single Point in Time
	5/6/97	Single Point in Time
	5/23/97	Single Point in Time
	7/13/97	Single Point in Time
	8/13/97	Single Point in Time
	9/15/97	Diurnal
	11/10/97 - 11/11/97	Diurnal
	1/27/98 - 1/28/97	Diurnal
Nelson Farm Worm Fallow Rep 2, Trt 2	3/6/97	Single Point in Time
	4/21/97	Single Point in Time
	5/7/97	Single Point in Time
	5/23/97	Single Point in Time
	7/13/97	Single Point in Time
	8/13/97	Single Point in Time
	9/16/97	Single Point in Time
	11/11/97	Single Point in Time
	1/31/98	Single Point in Time
Nelson Farm Worm Fallow Rep 2, Trt 1	11/16/97	Single Point in Time
	1/31/98	Single Point in Time
Nelson Farm Worm Fallow Rep 3, Trt 1	3/7/97	Single Point in Time
	5/6/97	Single Point in Time
	8/13/97	Single Point in Time
	11/16/97	Single Point in Time
	1/31/98	Single Point in Time
Nelson Farm Old Fallow	5/23/97	Single Point in Time
	8/13/97	Single Point in Time
	9/16/97	Single Point in Time
	11/16/97	Single Point in Time
	1/31/98	Single Point in Time
Nelson Farm W2 Ridge	11/16/97	Single Point in Time
	1/31/98	Single Point in Time
Goodwin Creek W10 Upper and Lower	12/4/96	Single Point in Time
	3/9/97	Single Point in Time
	5/8/97	Single Point in Time
	8/12/97	Single Point in Time
	9/15/97	Single Point in Time
	11/14/97	Single Point in Time
	1/29/98	Single Point in Time
Abbeyville, Pine Hardwood W2	1/29/98	Single Point in Time
Coffeville, Pine W2	8/13/97	Single Point in Time
	9/16/97	Single Point in Time

11/14/97 11/15/97	Diurnal
1/28/98 - 1/29/97	Diurnal

Table 5. Soil Respiration Fluxes at the Nelson Farm Watershed No. 2, Upper (eroding) and Lower (depositional) sites.

Date Time	Soil Temp., 10 cm	Air Temp.	Mean C Flux	Standard Deviation
	°C	°C	mg C m^{-2} hr^{-1}	
Upper				
12/3/96 12:00	9.3	6.5	45	16
3/6/97 12:23	11.5	18.0	101	21
3/8/97 15:47	16.6	25.8	122	30
4/21/97 08:48	17.9	21.7	130	45
5/6/97 18:50	22.0	22.1	179	44
5/23/97 11:47	21.9	26.3	198	41
7/13/97 12:56	27.3	27.9	209	43
8/13/97 14:09	25.9	31.3	415	99
9/15/97 15:30	25.5	30.4	91	24
11/10/97 16:24	10.8	8.1	47	21
1/27/98 16:27	6.5	11.1	61	15
Lower				
12/3/96 12:15	9.5	6.4	77	27
3/6/97 13:27	11.9	18.0	176	38
3/8/97 16:23	16.6	25.2	149	17
4/21/97 09:08	19.0	21.7	163	24
5/6/97 19:10	22.0	22.1	243	44
5/23/97 12:15	22.9	26.3	402	127
7/13/97 13:26	27.1	27.9	256	48
8/13/97 15:11	26.1	31.3	437	74
9/15/97 16:30	25.9	30.4	131	17
11/10/97 17:24	10.5	8.1	66	20
1/27/98 17:25	6.3	11.1	65	22

Table 6. Soil respiration fluxes at Goodwin Creek, Watershed No. 10, Upper (eroding) and Lower (depositional) sites.

Upper	Soil Temp, 10 cm	Mean C Flux	Standard Deviation
Date Time	°C	mg C m^{-2} hr^{-1}	
12/4/96 13:00	11.0	102	23
3/9/97 11:09	13.3	103	26
5/8/97 10:25	15.8	173	32
8/12/97 14:52	25.2	349	103
9/17/97 15:11	25.5	183	62
11/14/97 11:40	10.1	83	23
1/29/98 16:35	9.9	51	16
Lower			
12/4/96 14:00	11.04	99	13
3/9/97 10:40	12.9	86	4.8
5/8/97 10:42	14.8	161	28
8/12/97 12:45	24.9	316	61
9/17/97 16:11	25.5	196	35
11/14/97 12:34	9.9	82	30
1/29/98 17:25	9.3	63	20

Table 7. Rainfall, runoff, sediment yield, and grain yield from watershed 2 at the Ne'son Farm, near Como, MS from Dabney et al. 1997)

Year	Rainfall cm	Runoff	Sed Yield Mg/ha	Grain Yield Total Dry Wt. Mg/ha
1988				1.62
1989	157	69	44	0.81
1990	173	69	10	0.89
1991	173	87	33	1.55
1992	116	28	19	2.46
1993	115	30	3	1.71
1994	134	44	21[1]	1.86
1995	107	36	6	1.34
1996		ND[2]	ND	1.34
1997	144	40	9.4	1.96
Mean	140	50	18.2	1.55

[1] In 1994 one storm in August resulted in a sediment yield of 56.8 Mg/ha. This storm followed gully filling with soil brought in from outside the watershed and it was determined that most of the sediment transported came from the gully fill material so this part of the sediment yield for 1994 was subtracted from the annual total before report'ng in this table.

[2] Problems with the flow gaging mechanism resulted in incomplete data for 1996.

Table 8. Rainfall, runoff, sediment concentration, sediment yield, sediment carbon concentration, carbon export, and nitrogen concentration for selected storms during 1997 at the USDA/ARS Nelson Farm Watershed No. 2, near Senatobia, MS.

Storm Date	Rainfall (cm)	Runoff (cm)	Sediment Conc. (ppm)	Sediment Yield (Mt/ha)	Carbon Conc. (%C)	Carbon Export (g m^{-2})	Nitrogen Conc. (%N)
1/15/97	1.68	0.22	1157	0.025	3.44	0.086	0.396
2/13/97	1.96	1.36	66	0.009	5.21	0.047	0.540
2/21/97	1.63	0.59	197	0.012	5.93	0.069	0.559
2/26/97	1.88	0.92	244	0.022	6.09	0.136	0.528
3/7/97	3.40	0.61	126	0.008	5.98	0.046	0.461
4/5/97	1.85	1.51	36	0.005	7.64	0.042	0.762
4/22/97	2.64	0.42	165	0.007	6.74	0.047	0.646
5/27/97	3.45	2.09	54	0.011	1.76	0.020	0.207
6/8/97	5.13	2.90	7431	2.157	1.35	2.908	0.141
6/17/97	11.02	6.01	6175	3.709	0.97	3.598	0.120
7/29/97	4.52	1.38	1876	0.260	1.54	0.400	0.202
9/9/97	2.21	0.06	57	0.000	4.52	0.001	0.472
9/26/97	9.88	4.76	3260	1.552	2.80	4.351	0.423
12/21/97	2.62	1.77	210	0.037	4.09	0.152	0.475

Table 9. Rainfall, runoff, and sediment yield from watershed 10 at Goodwin Creek, near Batesville, MS from Tuttle and Alonso, USDA-ARS National Sedimentation Laboratory, Oxford, MS, written communication, 1998).

Year	Precip Thiessen cm	Runoff cm	Sediment Yield Mg/ha
1982	178.0	40.1	0.220
1983	173.7	57.1	0.325
1984	149.7	40.5	0.370
1985	126.9	18.5	0.172
1986	124.9	19.4	0.127
1987	110.9	17.7	0.194
1988	104.9	9.8	0.076
1989	175.2	50.9	0.302
1990	150.6	37.1	0.323
1991	190.8	73.6	0.475
1992	110.0	12.5	0.099
1993	110.7	10.3	0.036
1994	145.8	21.1	0.136
1995	127.9	13.8	0.086

Table 10. Carbon concentration of suspended sediment collected at Goodwin Cr. Watershed No. 10.

Storm Collect Date	Percent Carbon (%C)
11/30/96	10.1
12/16/96	9.2
12/26/96	7.8
1/23/97	6.8
2/3/97	6.7

Table 11. Rainfall, runoff, and sediment yield from at Pine-Hardwood Watershed No. 1 (later yarded) near Abbeville, MS during the calibration period 1961-1982 (Ursic, 1991).

Year	Precip cm	Runoff cm	Sediment Yield Mg/ha
1960	111.7	13.9	0.016
1961	135.6	23.5	0.079
1962	152.2	41.2	0.332
1963	90.4	1.4	0.002
1964	147.5	19.6	0.206
1965	116.0	34.4	0.103
1966	111.7	10.8	0.044
1967	131.0	10.1	0.097
1968	161.8	29.3	0.099
1969	117.5	22.4	0.270
1970	149.6	35.4	0.328
1972	147.1	15.1	0.039
1973	186.0	71.2	0.664
1974	187.2	47.1	0.117
1975	151.6	33.1	0.057
1976	125.5	24.0	0.072
1977	136.6	20.6	0.168
1978	124.6	17.0	0.028
1979	209.4	56.0	0.351
1980	130.5	32.0	0.329
1981	96.5	1.8	0.007
1982	143.4	11.7	0.608
Mean	139.2	26.0	0.183

Table 12. Rainfall, runoff, and sediment yield at Coffeeville-Pine Watershed No. 1. near Coffeeville, MS (Ursic and Duffy, 1972; Schreiber and Duffy, 1982).

Year	Precip cm	Runoff cm	Sediment Yield Mg/ha
1964	148	34.9	ND[1]
1965	95	14.9	0.120
1966	106	8.89	0.072
1967	126	8.95	0.016
1968	143	34.5	0.085
Mean (1964-1968)	124	19.5	0.073[2]
1976	112	5.6	0.046
1977	120	4.8	0.041
1978	147	19.1	0.081
Mean (1976-1978)	165	21.5	0.119

[1]No data reported for this year because of disturbance caused by weir installation.
[2]Mean for the period 1965 – 1968.

Appendix 1 Management Schedule at Nelson farm Watershed No. 2 (Written Communication Seth Dabney, USDA/ARS, Oxford, MS April 1998).

Date	Management
8/11/87	sprayed Roundup 2 qt (2 lb glyphosate)/acre
8/20/87	took soil samples
9/29/87	5000 lb lime/acre 600 lb 0-20-20/acre
10/6/87	burned plant material chiseled x1
10/14/87	broadcast 40 lb N from ammonium nitrate disked x2
10/22/87	drilled wheat cover crop at 90 lb/acre to prevent erosion.
4/27/88	mowed vegetation
5/6/88	used once-over implement x1 (John Deere mulch finisher or "one pass")
5/17/88	2.4 pt Prowl (1 lb pendimethalin)/a, incorporated with do-all 1x
5/18/88	planted soybean
7/5/88	cultivated x1
11/22/88	harvested soybean
5/2/89	mowed x1
5/11/89	1 qt Prowl (0.83 lb pendimethalin)/a incorporated with mulch-finisher 1x
5/16/89	do-all x1 to kill morning glories planted soybean
6/1/89	cultivated x1
6/20/89	broadcast 1.5 pt Fusilade 2000 (0.19 lb fluazifob-butyl)+ 1 qt oil/acre
6/26/89	cultivated x1 sprayed watershed with methyl parathion for stinkbugs
10/24/89	harvested soybeans
5/8/90	chisel plowed x1

5/11/90	disked x1
5/25/90	200 lbs/a 0-20-20
5/29/90	disked x2 do-all x1
5/30/90	planted inoculated DPL 415 soybean @ 9 seed/ft (44 lbs/a) 0.5 lb Lexone (0.385 lb metribuzin) + 2 pt Dual (2.0 lb metolachlor)/a
6/15/90	1 pt Lorsban (0.5 lb chlorpyrifos)/a 1 pt Blazer (0.25 lb acifluorfen)/a 1 pt Bas agran (0.5 lb bentazon)/a 0.34 pt surfactant/a
6/25/90	cultivated x1
7/16/90	cultivated x1
10/21/90	harvested soybean
3/20/91	took soil samples for fertility need estimation
5/8/91	mowed vegetation
5/15/91	disked 1x
5/23/91	chiseled with sweeps x1; do-all x1 planted soybean 0.5 lb Lexone (0.385 lb metribuzin) + 2 pt Dual (2.0 lb metolachlor)/a
6/13/91	cultivated x1
6/18/91	1 pt Lorsban (0.5 lb chlorpyrifos)/a 1 pt Blazer (0.25 lb acifluorfen)/a 1 pt Basagran (0.5 lb bentazon)/a 0.4 pt surfactant/a
9/91	mowed and tilled areas for two buffer strips and planted fescue
10/7/91	450 lb 13-13-13/a on 0.55 a of fescue buffer strips
10/22/91	harvested soybean
5/6/92	disked x1 chiseled x1
5/10/92	200 lb 0-20-20/a
5/20/92	disk x1

	do-all x1
	plant soybean
	0.5 lb Lexone (0.385 lb metribuzin) + 2 pt Dual (2.0 lb metolachlor)/a
6/16/92	1 pt Lorsban (0.5 lb chlorpyrifos)/a
	1.5 pt Blazer (0.37 lb acifluorfen)/a
	1 pt Basagran (0.5 lb bentazon)/a
	0.4 pt surfactant/a
6/17/92	cultivated x1
10/23/92	harvested
5/7/93	200 lb 0-26-26 /a
	disked x1
5/24/93	disked x1
5/28/93	planted soybean
	0.5 lb Lexone (0.385 lb metribuzin) + 2 pt Dual (2.0 lb metolachlor)/a
6/18/93	cultivated x1
6/23/93	1.5 pt Blazer (0.37 lb acifluorfen)/a
	1 pt Basagran (0.5 lb bentazon)/a
10/26/93	harvested soybean
4/19/94	disk x1
4/20/94	300 lb/a 0-18-36 dry fertilizer broadcast on surface
	chisel plowed x1
5/18/94	disk x1
5/19/94	2 pt Prowl 3.3 (0.83 lb pendimethalin)/a
	disk x1
5/22/94	Planted DPL 415 soybeans at 9 seeds/row ft, 36" rows
5/25/94	2.8 oz Sceptor (0.125 lb imazaquin)/a (equivilent) on 18" band over rows
6/13/94	1.5 pt Poast Plus (0.188 lb sethoxydim)/a + 1% crop oil for Johnsongrass
6/17/94	cultivated x1
6/21/94	3/4 oz Classic 25DF (0.0117 lb chlorimuron)/a + 0.25% surfactant (spot application for sicklepod, about 10% of area treated)
8/94	disturbed waterway, filled gully, installed Geoweb, and seeded fescue, and seeded fescue again after washout

10/25/94	harvested soybean
4/14/95	broadcast 200 lb mixed fertilizer equivalent to 0-18-36 WS2
4/19/95	mowed vegetation disked x1 chiseled plowed x1
5/10/95	disked x1 2 pt Prowl 3.3 (0.83 lb pendimethalin)/a, incorporated with do-all
5/17/95	planted DP 415 soybeans banded 0.625 lb canopy (metribuzin + chlorimuron)/a
6/2/95	transplanted switchgrass above center of lower fescue buffer strip
6/7/95	1.4 oz Scepter (0.0625 lb imazaquin)/a broadcast for cocklebur
6/15/95	cultivated with a row cultivator
6/29/95	cultivated with a row cultivator
10/17/95	harvested soybeans
2/22/96	extended switchgrass above center of lower fescue buffer strip
4/25/96	chiseled x1 disked x1
5/3/96	Prowl 1.5 pt (0.62 lb pendimethalin)+Scepter 2.8 oz (0.125 lb imazaquin)/a 300 lb 0-26-26 disked x1
5/14/96	do-all x1
5/15/96	Planted 9 seed/ft DPL 415 soybean
5/20/96	soybeans emerging
5/30/96	cultivated x1 Scepter 2.8 oz oz (0.125 lb imazaquin)/a effective rate on 18" band
6/17/96	cultivated x1
10/31/96	harvested soybeans
4/25/97	chisel plow 1x

4/30/97	300 lb/A 0-26-26 broadcast
5/6/97	disked 2x Prowl 2.4 pt (1.0 lb pendimethalin)/a; incorporated with do-all plant DPL 415 soybean, 9 seed/ft 0.67 lb Lexone (0.5 lb metribuzin)/a effective rate on 18"band
5/15/97	soybeans 50% emerged
6/3/97	1.46 oz Scepter (0.0625 lb imazaquin)/a
6/20/97	cultivated 1x
6/27/97	cultivated 1x
7/8/97	soybeans blooming
10/23/97	harvested soybeans
3/30/98	chisel plowed 1x
4/20/98	disk 2x 0.5 lb Canopy (metribuzin + chlorimuron) + 1.5 pt Dual (1.5 lb metolachlor)/a broadcast do-all 1x Planted Soybeans (Hutchinson), 9 seeds per ft, 36" row spacing
4/30/98	soybeans have emerged
5/14/98	cultivated 1x
5/20/98	1.43 oz Scepter 70DG (0.0625 lb imazaquin)/a on 18" band over row
5/21/98	cultivated 1x
6/9/98	cultivated 1x
7/20/98	spot spray 6oz Select 2EC (0.0938 lb clethodim) + 1 qt oil/a , for johnsongrass, about 1 acre treated
7/21/98	0.75 oz Classic (0.0117 lb chlorimuron)/a on 18" band over row
7/22/98	cultivated 1x

Appendix 2. Downloadable Data Files
Pathname to Download Files: geochange.cr.usgs.gov

Data Description	Depths (cm)	Location	Period of Record	File Name
Soil Respiration				
Single Time	N/A	NF Upper and Lower	12/3/96	MS-NF-CFlux-12-3-96.xls
Diurnal Measurements	N/A	NF Upper and Lower	3/6/97- 3/8/97	MS-NF-CFlux-3-6&3-8-97.xls
Single Time	N/A	NF Upper and Lower	4/21/97	MS-NF-CFlux-4-21-97.xls
Single Time	N/A	NF Upper and Lower	5/6/97	MS-NF-CFlux-5-6-97.xls
Single Time	N/A	NF Upper and Lower	5/23/97	MS-NF-CFlux-5-23-97.xls
Single Time	N/A	NF Upper and Lower	7/13/97	MS-NF-CFlux-7-13-97.xls
Single Time	N/A	NF Upper and Lower	8/13/97	MS-NF-CFlux-8-13-97.xls
Single Time	N/A	NF Upper and Lower	8/14/97	MS-NF-CFlux-8-14-97.xls
Diurnal Measurements	N/A	NF Upper and Lower	9/15/97 – 9/16/97	MS-NF-CFlux-9-15&9-16-97.xls
Diurnal Measurements	N/A	NF Upper and Lower	11/10/97 – 11/11/97	MS-NF-Cflux-11-10&11-11-97.xls
Diurnal Measurements	N/A	NF Upper and Lower	1/26/98 – 1/27/98	MS-NF-Cflux-1-26&1-27-98.xls
Single Time	N/A	GC Upper and Lower	12/14/96	MS-GC-CFlux-12-14-96.xls
Single Time	N/A	GC Upper and Lower	3/9/97	MS-GC-CFlux-3-9-97.xls
Single Time	N/A	GC Upper and Lower	5/8/97	MS-GC-CFlux-5-8-97.xls
Single Time	N/A	GC Upper and Lower	8/12/97	MS-GC-CFlux-8-12-97.xls
Single Time	N/A	GC Upper and Lower	9/17/97	MS-GC-CFlux-9-17-97.xls
Single Time	N/A	GC Upper and Lower	11/14/97	MS-GC-CFlux-11-14-97.xls
Single Time	N/A	GC Upper and Lower	1/29/98	MS-GC-CFlux-1-29-98.xls
Single Time	N/A	CV Upper and Lower	8/13/97	MS-CV-CFlux-8-13-97.xls
Single Time	N/A	CV Upper and Lower	9/17/97	MS-CV-CFlux-9-17-97.xls
Diurnal Measurements	N/A	CV Upper and Lower	1/28/98 – 1/29/98	MS-CV-Cflux-1-28&1-29-98.xls
Diurnal Measurements	N/A	CV Upper and Lower	4/24/98 – 4/25/98	MS-CV-Cflux-4-24&4-25-98.xls
Single Time	N/A	CV Upper and Lower	7/23/98	MS-CV-CFlux-7-23-98.xls
Single Time	N/A	CV Upper and Lower	7/24/98	MS-CV-CFlux-7-24-98.xls
Diurnal Measurements	N/A	CV Upper and Lower	11/14/98 & 11/15/98	MS-CV-Cflux-11-14&11-15-98.xls
Soil Temperature (hourly)	10, 30, 60, 90	Nelson Farm, WSH 2 Upper and Lower	3/4/97 – 7/9/98	MSNFSoilTemp3(97)-7(98).xls
Soil Water Content (hourly)	0 -to- 20 integrated	Nelson Farm, WSH 2 Upper and Lower	3/7/97 – 7/9/98	MSNFSWatCon10cm3(97)-7(98).xls
Soil Water Potential (hourly)	10 cm	Nelson Farm, WSH 2 Lower	3/4/97 - 2/1/99	MSNFSoilWatPot3(97)-1(99).xls
Hourly: Air Temp.°F, Solar Rad.(Ly), Rainfall (in), Wind Run Daily: Air Temp (avg, max, min), 24-hr Solar Rad, 24-hr Rain, 24-hr wind run, Soil Temp (avg, max, min)	N/A	Nelson Farm, Ridge	4/15/97-7/20/98	MS-NFMet4-15-97to7-20-98.xls
Same as Above	N/A	Nelson Farm, Ridge	7/20/98- 1/21/99	MS-NFMet 7-20-98to1-21-99.xls
Air and Soil Temp. (Max, Min, Avg.), Rainfall, Solar Rad. (daily)	7 cm for Soil Temp.	Nelson Farm, near Senatobia, MS	1/1/97 - 3/7/98	
Tree species, diameter, height	N/A	Goodwin Cr. WSH No. 10	1997	MS-GC-TreeSpp.DBH.HT.xls
Tree species, diameter, height	N/A	Coffeeville-Pine WSH No.1	1997	MS-CV-TreeSpp.DBH.HT.xls
Tree species, diameter, height	N/A	Abbeville Pine-Hardwood WSH No. 2	1997	MS-AB TreeSpp.DBH.HT.xls
Tree Biomass	N/A	Goodwin Cr. WSH No. 10 Upper and Lower Plots Only	1997	MS-NF-TreeBiomass-U&LPlots.xls
FIA Tree Volume Coefficients	N/A	N/A	N/A	FIA.VOLCOEFFs.XLS.
FIA Tree Weight Coefficients	N/A	N/A	N/A	FIATreeWtCoeffs.xls
Tree Biomass Sample Calculations	N/A	N/A	N/A	TreeBiomassSampleCalc.xls

Note: soil temperature and soil moisture time series files contain data gaps

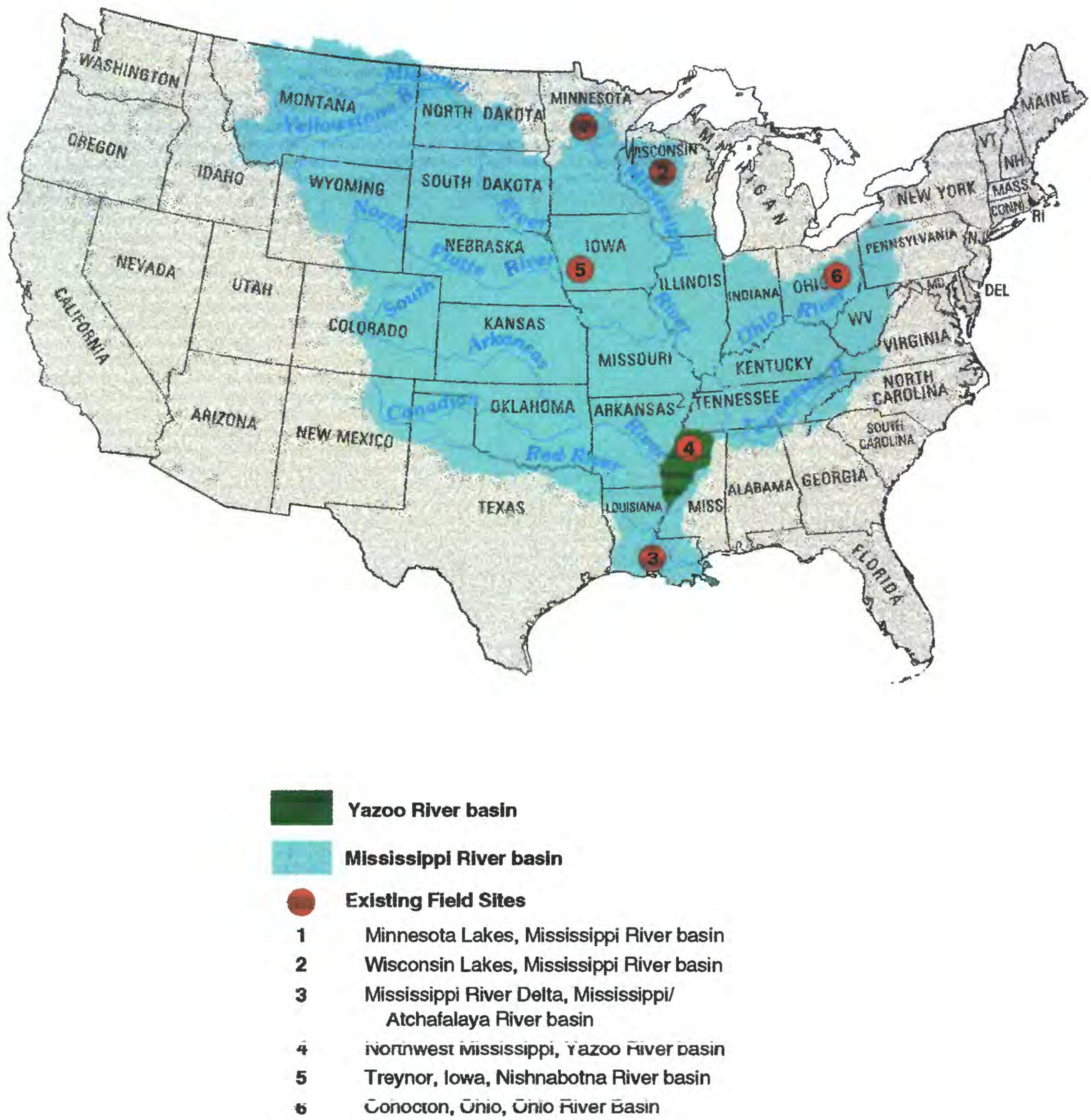


Figure 1. Map showing the Yazoo River basin in relation to the 48 conterminous states of the United Sates and the Mississippi River basin. Also shown are existing research sites of the Mississippi Basin Carbon Project (MBCP).

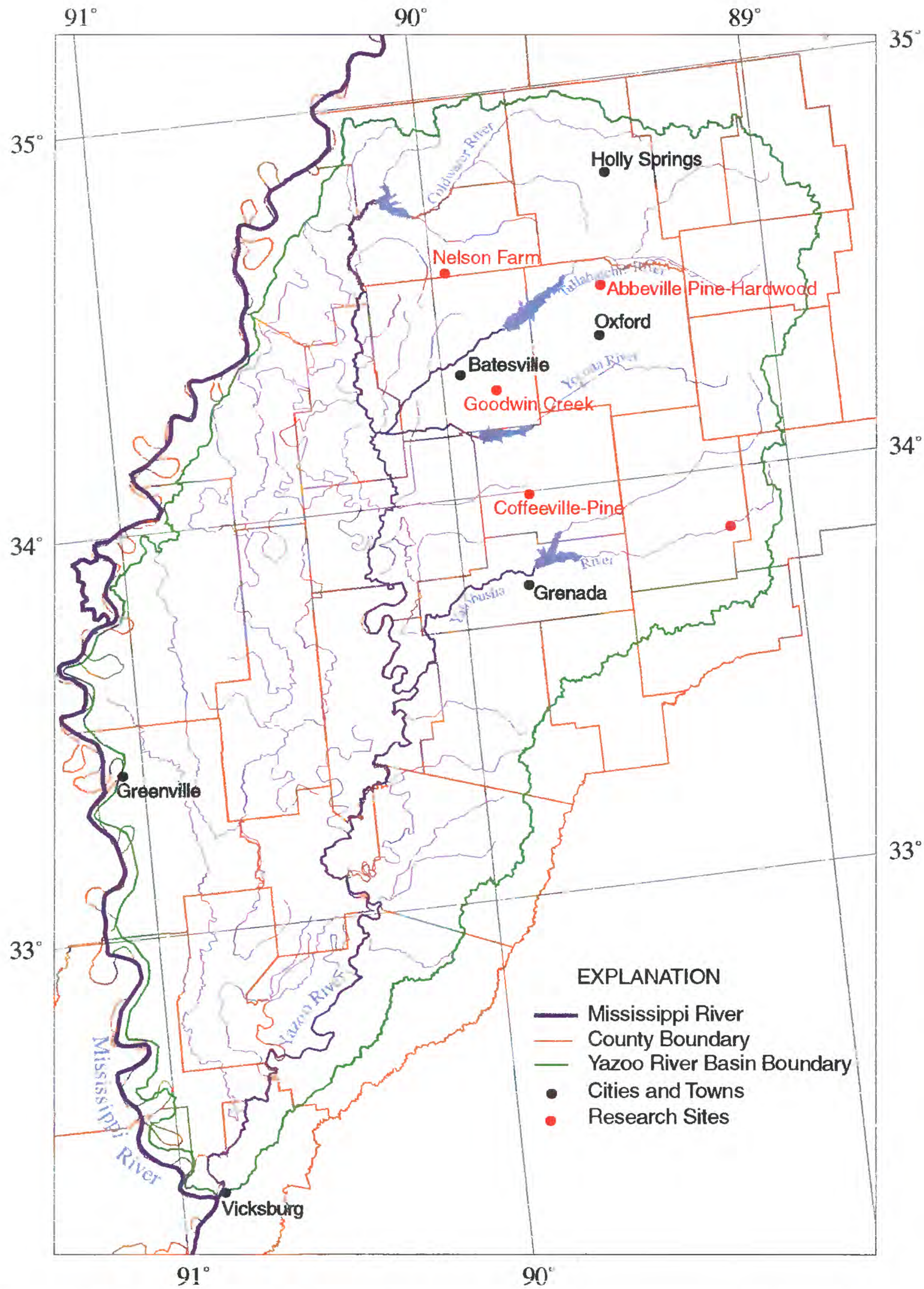


Figure 2. Site map showing Yazoo River basin boundary, major tributaries, county boundaries, and research sites.

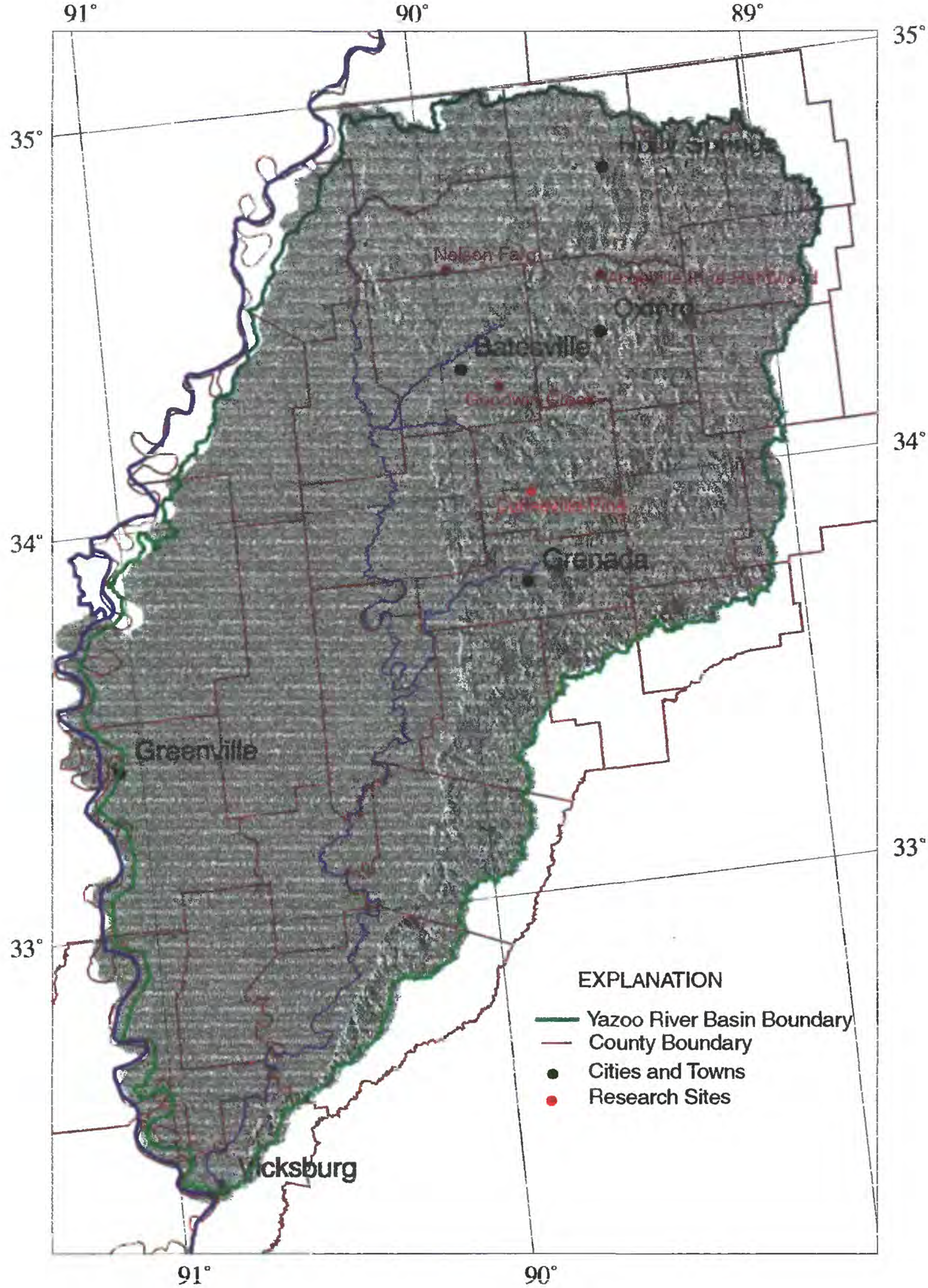
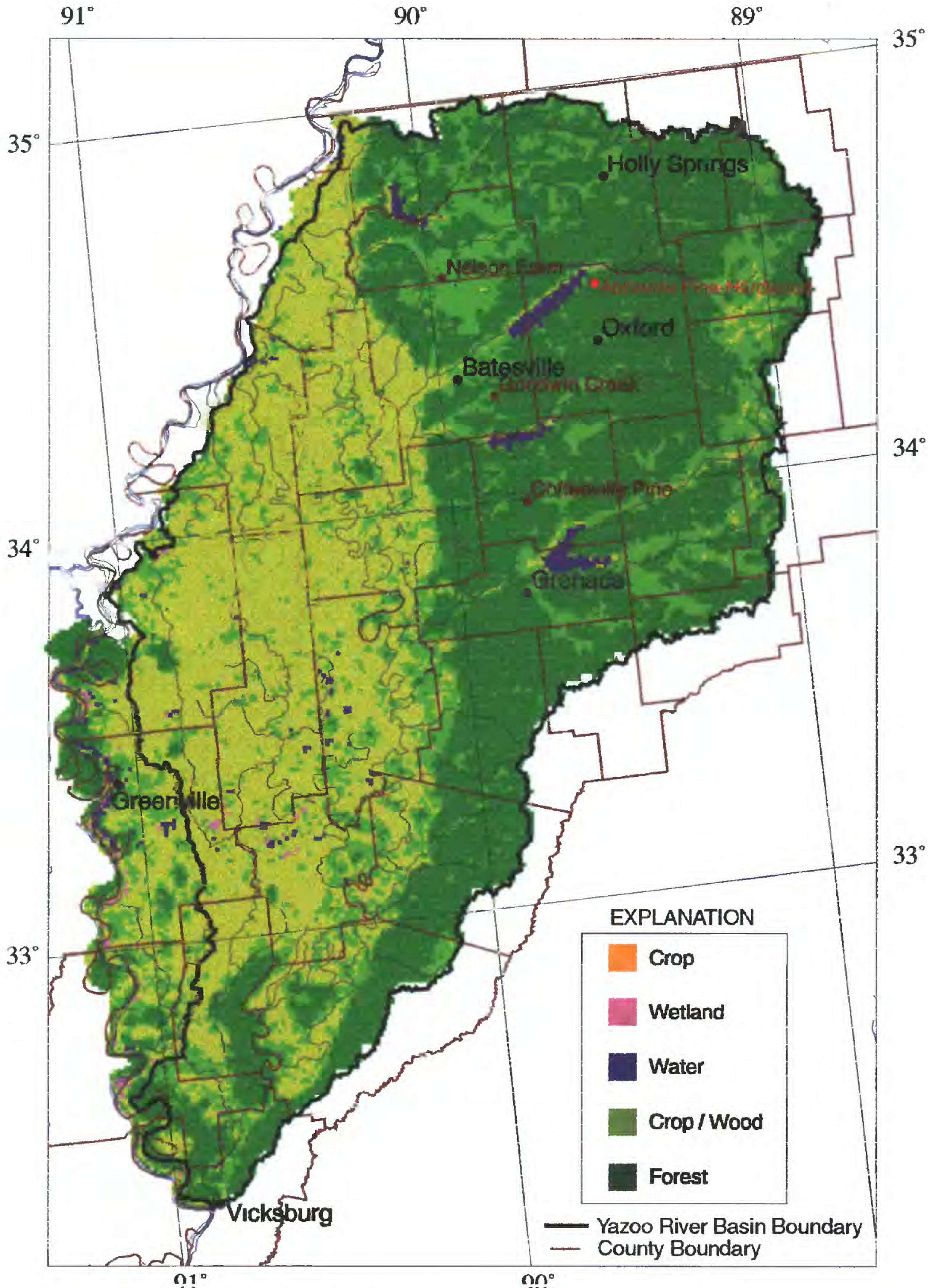


Figure 3. Shaded relief map of the Yazoo River basin derived from 3-arc second digital elevation model (DEM) data. Map developed by Bruce Worstell, USGS.



Scale: 1 Degree Latitude=106.7 km

Figure 4. Land cover for the Yazoo River basin derived from 1990, advanced very high resolution radiometer reflectance data (AVHRR). The resolution (pixel displayed) is one square kilometer. This map was developed by Bruce Worstell, USGS.

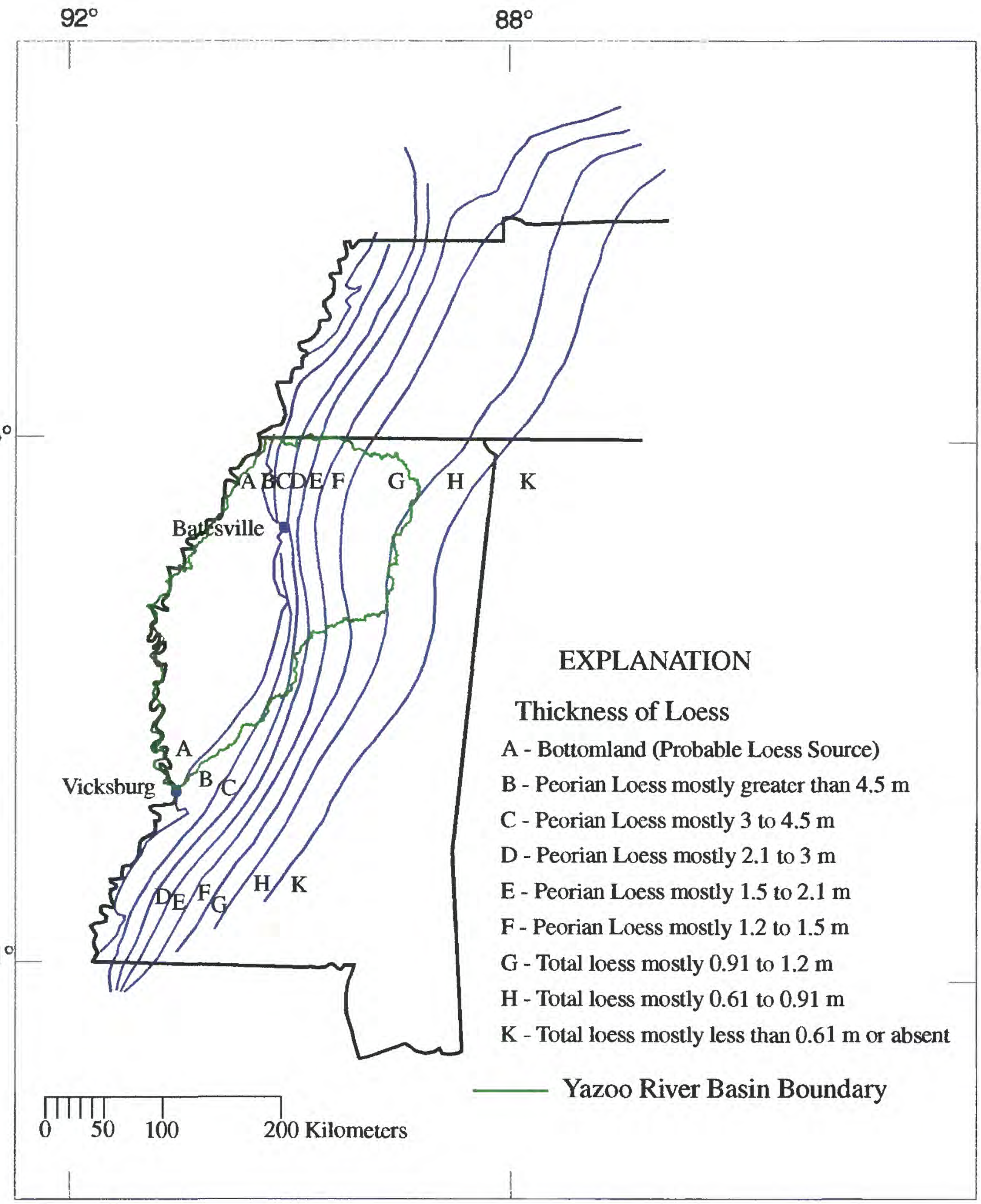


Figure 5. Loess thickness in the southern Mississippi Valley. Approximate maximum thickness of Peorian or total loess. Modified from Wascher et al. (1948).

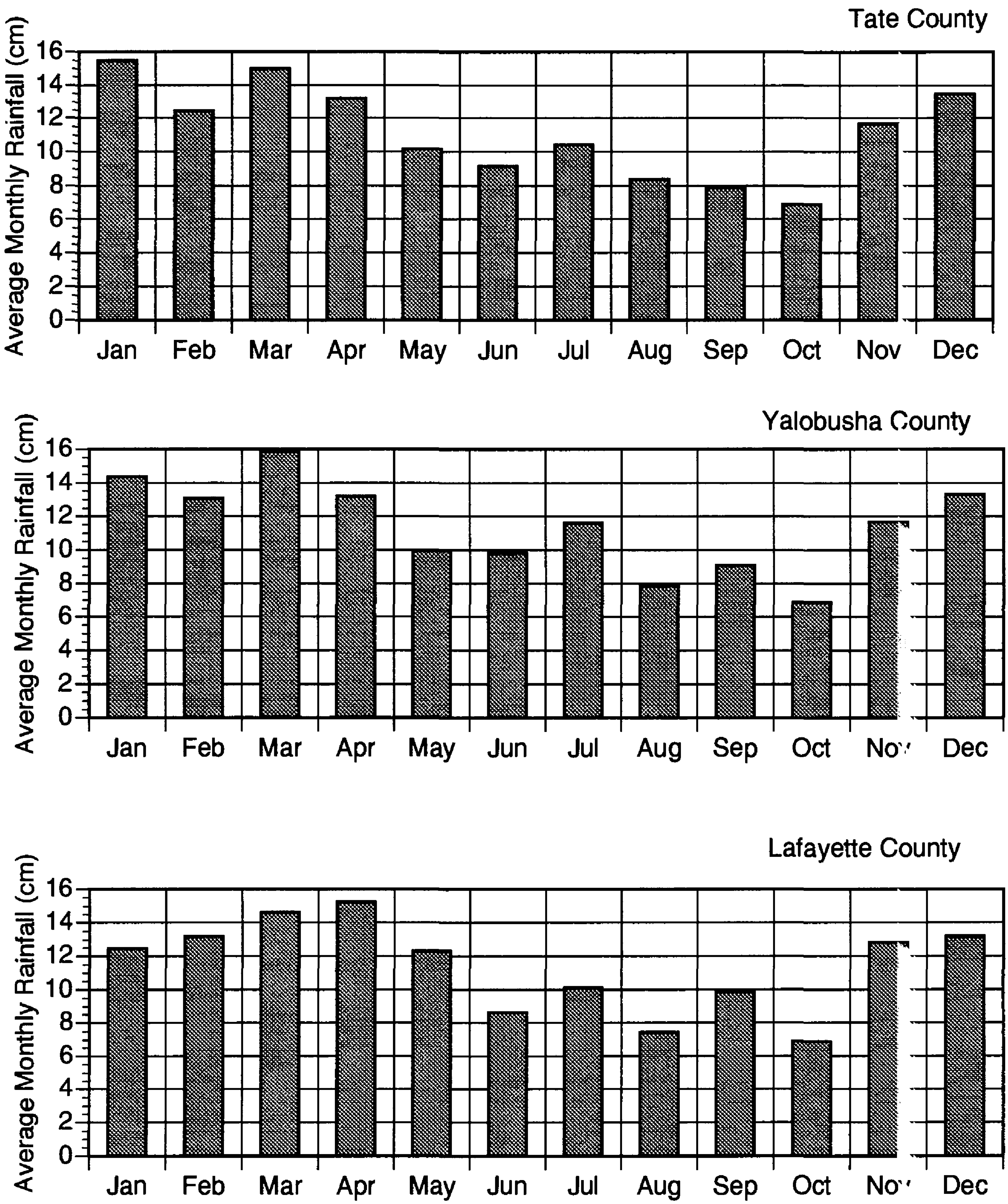


Figure 6. Monthly rainfall in Tate, Yalobusha, and Lafayette Counties, MS

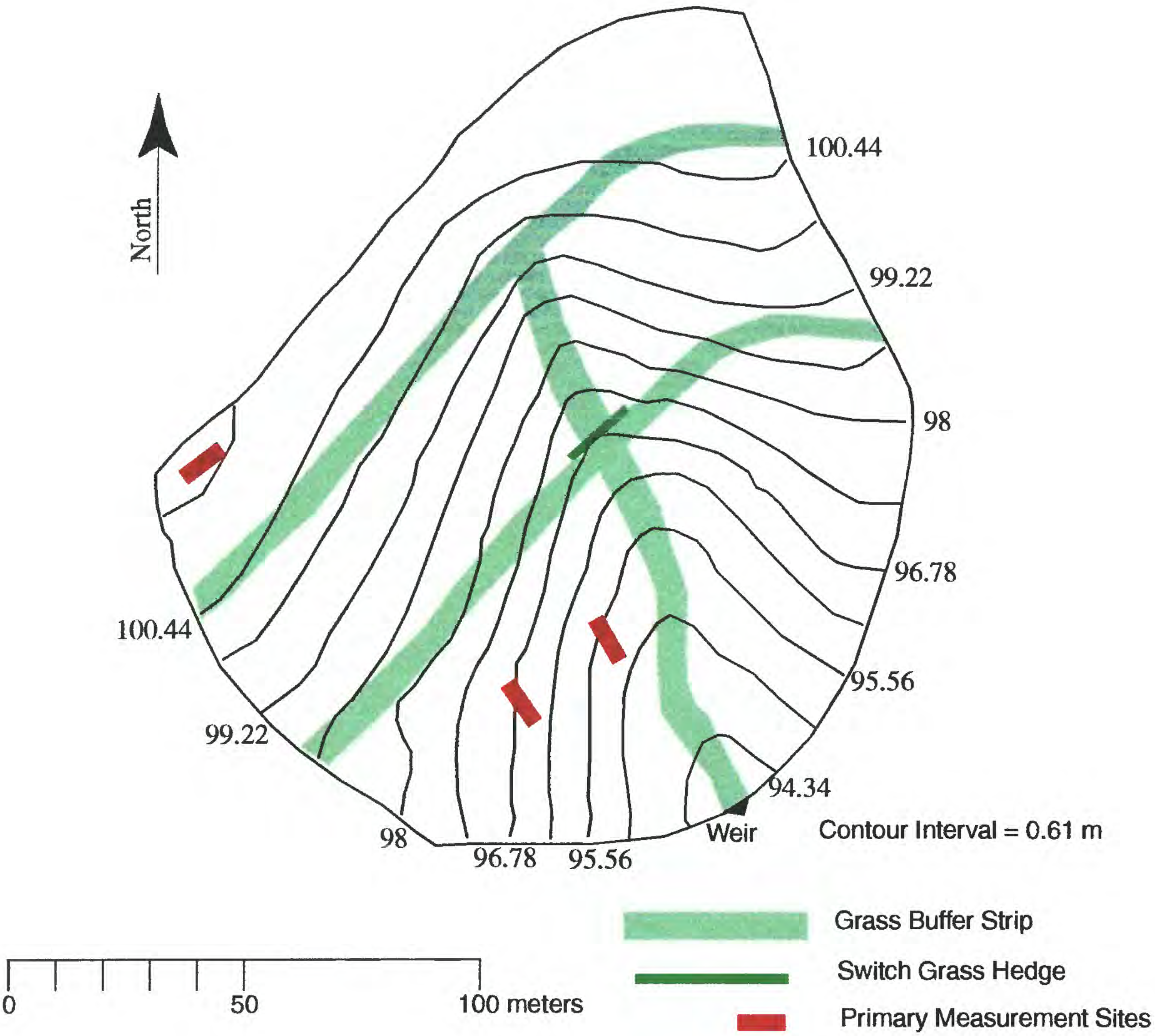


Figure 7a. Topographic map of Watershed No. 2 at the Nelson Farm, near Senatobia, MS. showing locations of primary measurement sites, elevation contours, grass buffer strips, and grass hedge. Map Modifed From Dabney et al. (1997).

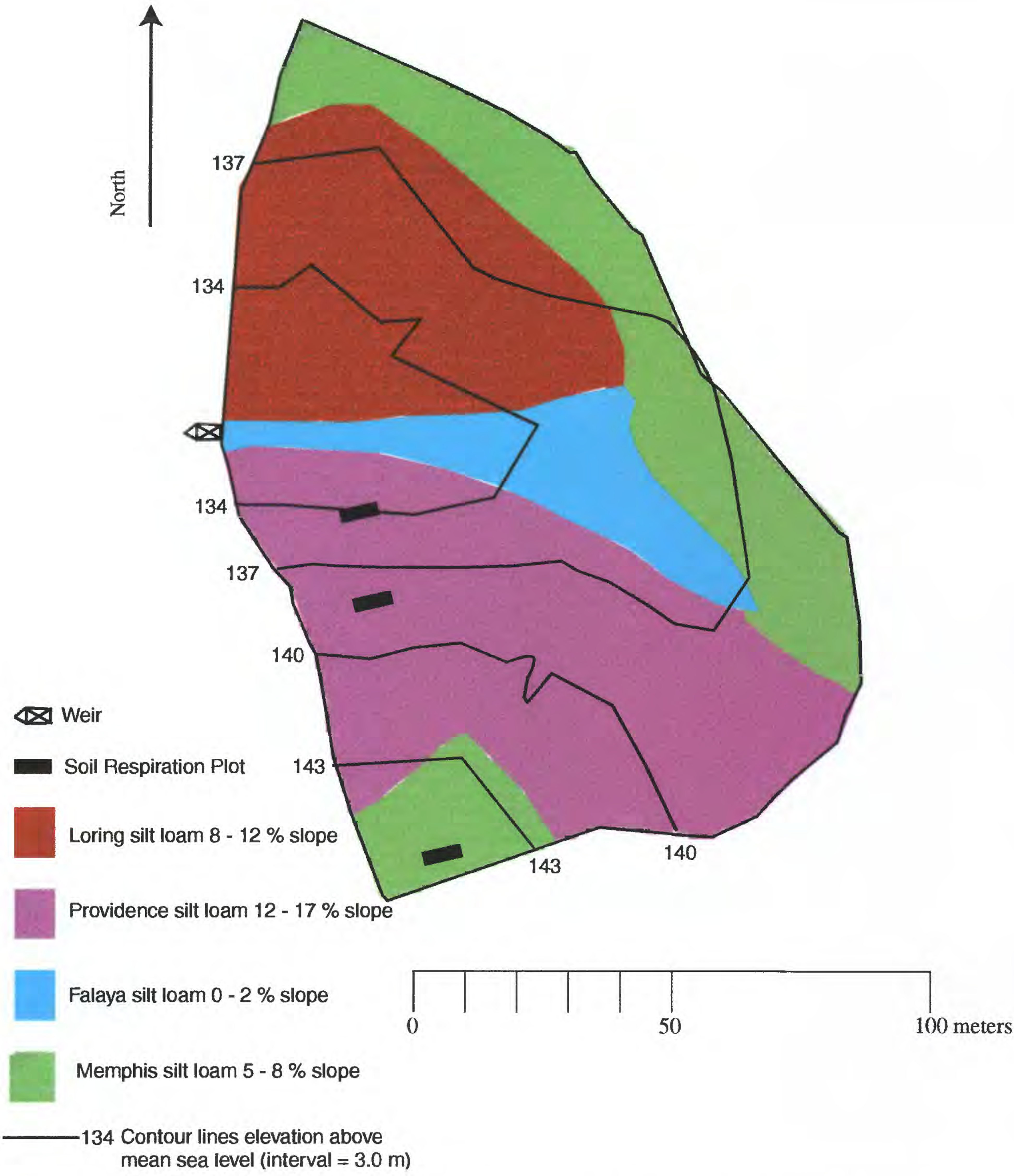


Figure 7b. Topographic map and soil map of Watershed No. 1 at the Coffeeville-Pine site, near Coffeeville, MS

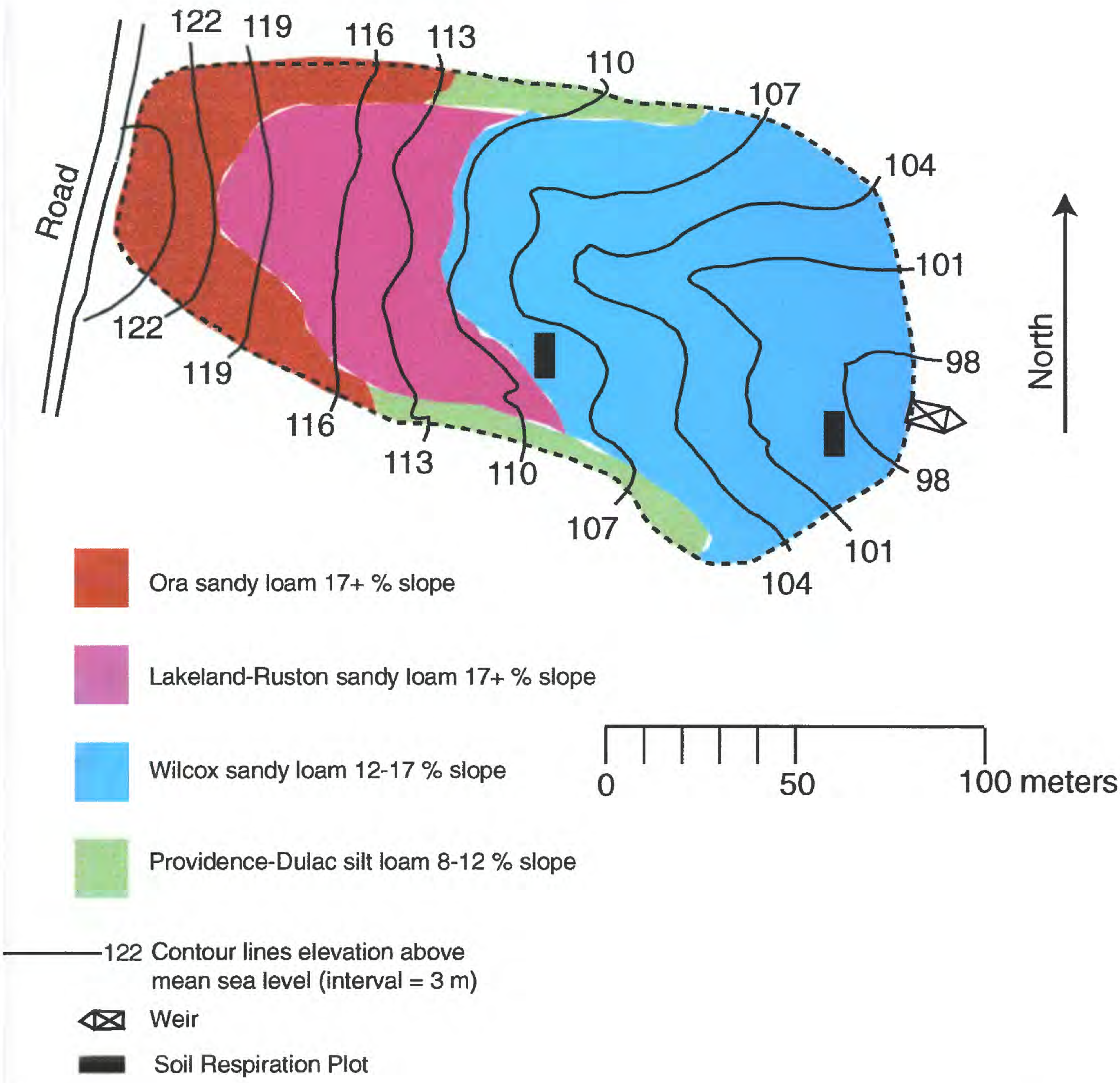


Figure 7c. Topographic map and soil map of Watershed No. 2 at the Pine-Hardwood site, near Abbeyville, MS

Equation 1: Calculation of CO_2 concentration (ppm_v) from raw signal voltage, temperature, barometric pressure, and relative humidity.

$$C \approx \frac{[1+0.5w]\left[a_1\left(\frac{V_sP_o}{[1+0.5w]P}\right)+a_2\left(\frac{V_sP_o}{[1+0.5w]P}\right)^2+a_3\left(\frac{V_sP_o}{[1+0.5w]P}\right)^3\right]*\left[\frac{T+273}{T_o+273}\right]}{1-w}$$

Where:

C = CO_2 concentration (ppm_v), V_s = raw signal voltage (millivolts), T = temperature (degrees celsius), P = barometric pressure (kilo pascals, kPa), and standard pressure (P_o) is 101.3 kPa. For this IRGA Serial Number IRG2 - 226, T_o = 35.4 and coefficients for the third order polynomial are $a_1 = 0.1424$, $a_2 = 1.606*10^{-5}$, $a_3 = 2.695*10^{-9}$. w is the mole fraction of water (moles), or the partial pressure of water vapor in air, which is computed from the relative humidity. In LICOR manuals for the 6252 and 6251 w is defined as w=e/p where e = vapor pressure. Vapor pressure is calculated as e=[RH%*e(T)]/100, where e(T) is the saturation vapor pressure where:

Equation 2: Expression for saturation vapor pressure

$$e(T) = 0.61083 * 10^{\frac{7.6448T}{242.62+T}}$$

Equation 3:

$$w \approx \frac{\frac{RH\% * 0.61083 * 10^{\frac{7.6448T}{242.62+T}}}{100}}{P}$$

Equation 4:

$$CO_2 FluxDensity \frac{mgC}{m^2 hr} = \Delta CO_2 \frac{\mu mole}{mole-\min} \times 1.5176 \frac{\frac{mg}{kg}}{\frac{\mu mole}{mole}} \times 1.293 \frac{kg}{m^3} \times ChamberVolume(m^3) \times \frac{1}{ChamberArea(m^2)} \times 60 \frac{\min}{hr} \times 0.2727 \frac{gC}{gCO_2}$$

Figure 8. Equations used to calculate CO_2 concentration and make corrections for temperature, vapor pressure and barometric pressure.

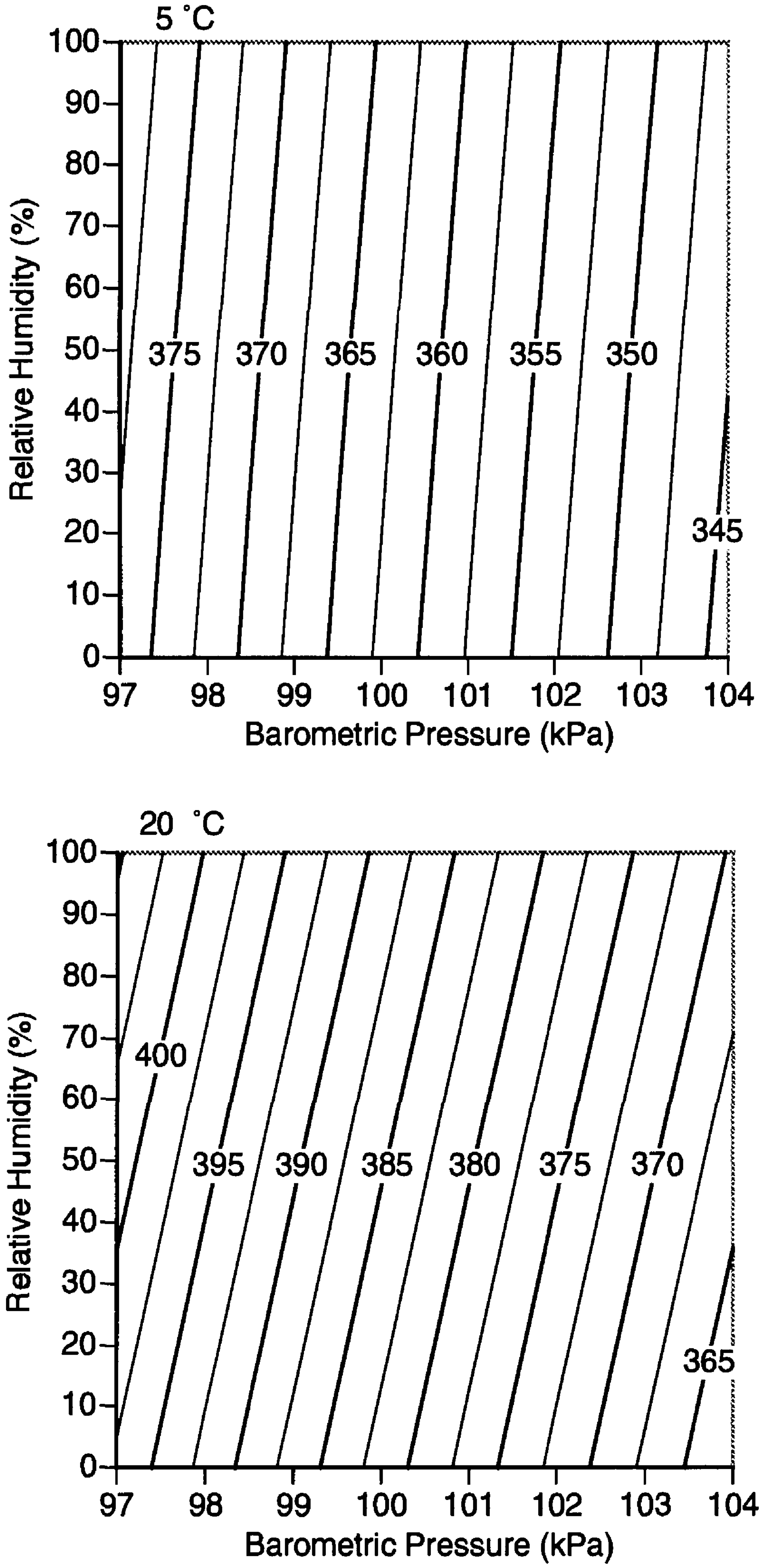


Figure 9. Contour plot showing calculated CO concentration (ppmv) as a function of barometric pressure and relative humidity when temperature is held constant (20 ˚C and raw signal voltage is 2100 mv. Without corrections the absolute CO_2 concentration reported would be 375 ppm(v) at 20 ˚C and 355 ppm(v) at 5 ˚C.

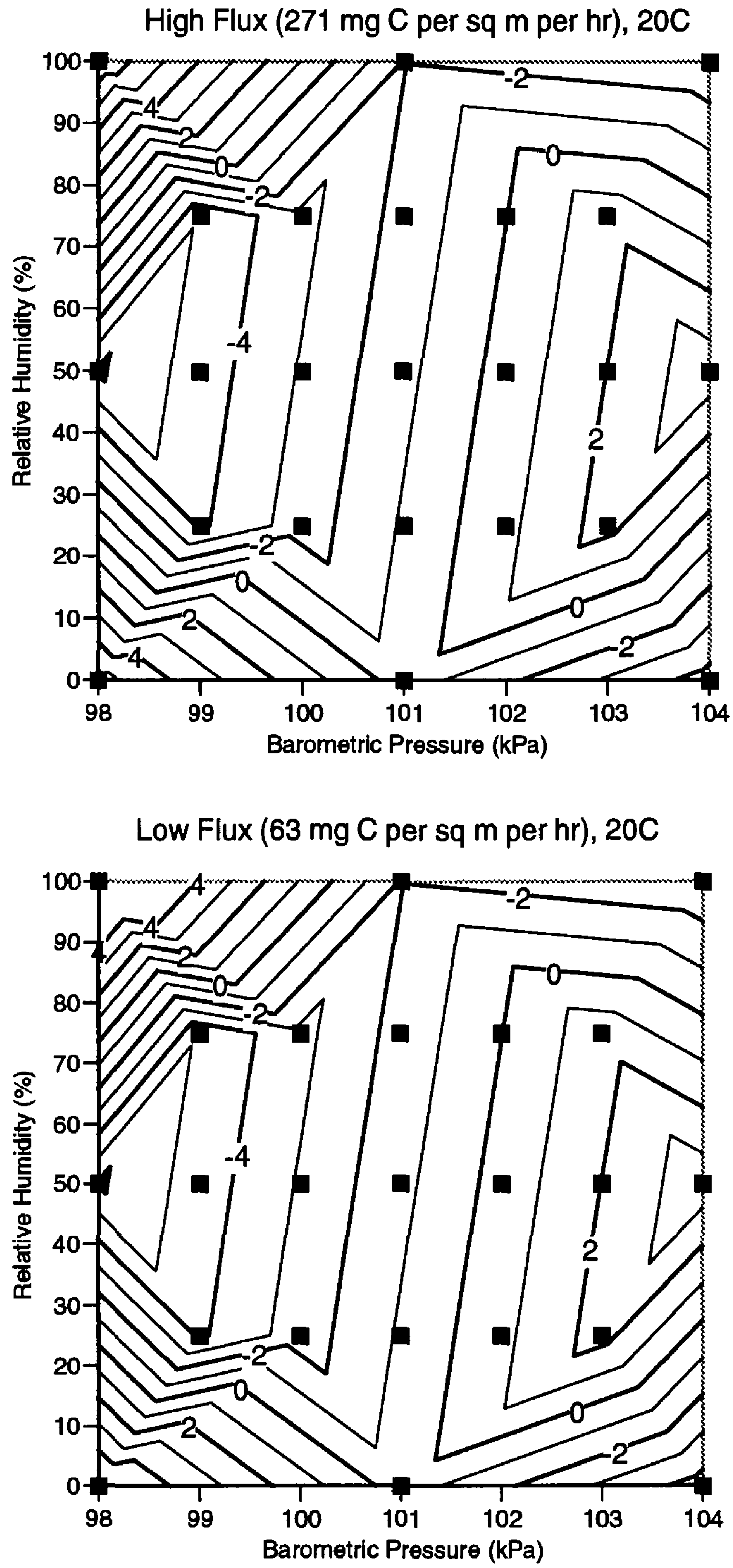
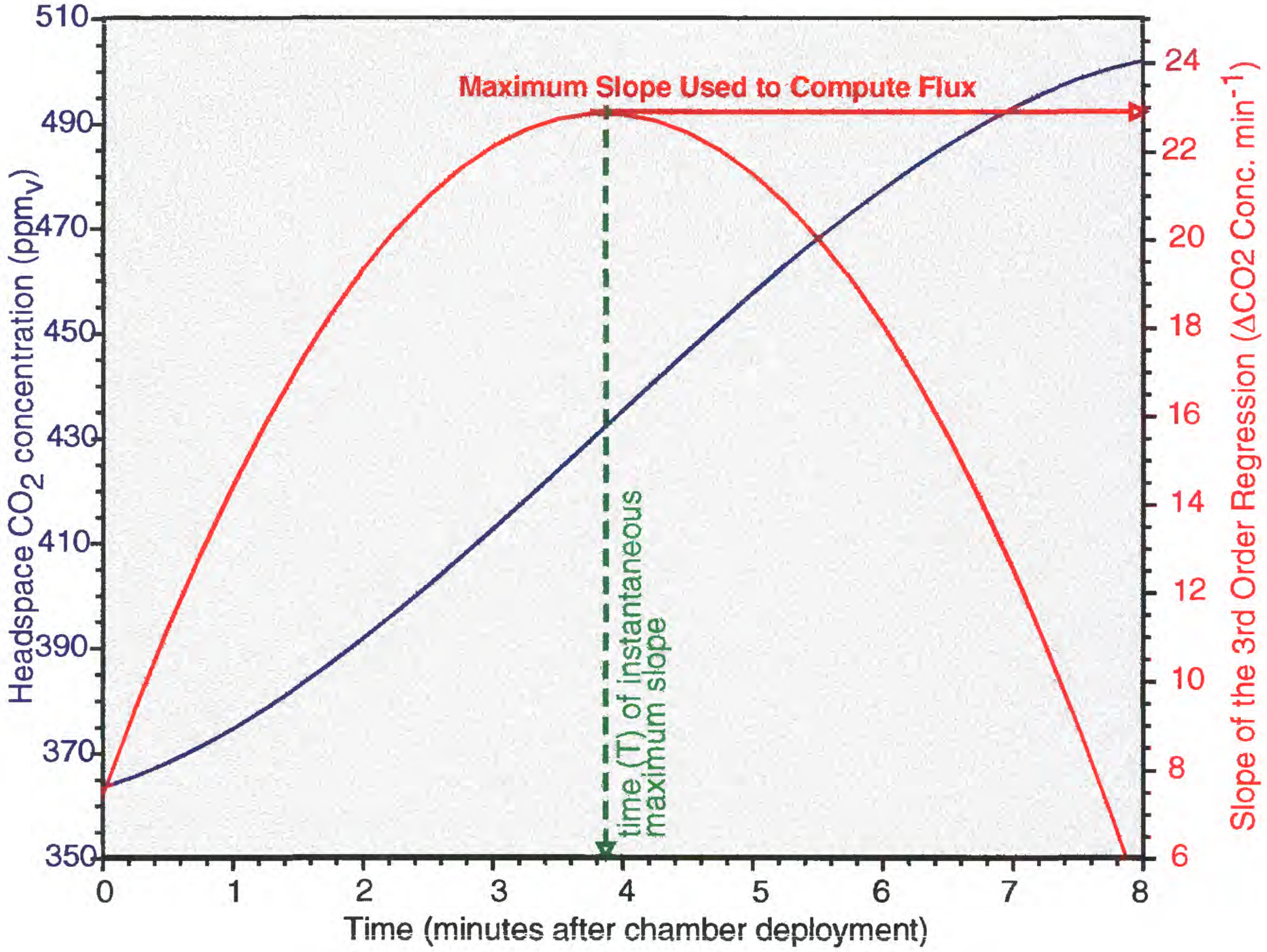


Figure 10. Contour plots showing structure of error for flux estimation as a function of barometric pressure and relative humidity at 20 °C for two different flux rates. Error is calculated as the difference between the true flux (when barometric and vapor corrections are used compared with flux when no corrections are used) divided by the true flux.



Summary of Method

1. Obtain the equation for the 3rd order regression from the headspace CO_2 concentration by time data series:

$$Y = w + xT + yT^2 + zT^3 \quad \textbf{[Eqn 1]}$$

2. Obtain the first derivate (slope) of **[Eqn 1]**:

$$dY/dT = x + 2yT + 3zT^2 \quad \textbf{[Eqn 2]}$$

3. Obtain the second derivate of **[Eqn 1]** (slope of **[Eqn 2]**):

$$d^2Y/dT^2 = 2y + 6zT \quad \textbf{[Eqn 3]}$$

4. Solve **[Eqn 3]** for $d^2Y/dT^2 = 0$ (the time (T) of instantaneous maximum slope of **[Eqn 1]**:

$$T = -2y/6z$$

5. Substitue **T** (**-2y/6z**) into **[Eqn 2]** and solve for the instantaneous maximum slope.

6. Using this slope and the chamber volume and soil surface area compute the instantaneous maximum CO_2 flux density (soil respiration).

$$CO_2FluxDensity\frac{mgC}{m^2hr} = \Delta CO_2\frac{\mu mole}{mole-\min}\times 1.5176\frac{\frac{mg}{kg}}{\frac{\mu mole}{mole}}\times 1.293\frac{kg}{m^3}\times ChamberVolume(m^3)\times\frac{1}{ChamberArea(m^2)}\times 60\frac{\min}{hr}\times 0.2727\frac{gC}{gCO_2}$$

Figure 11. Headspace carbon dioxide concentration time series showing graphical solution to estimation of "true" flux density and summary equations.

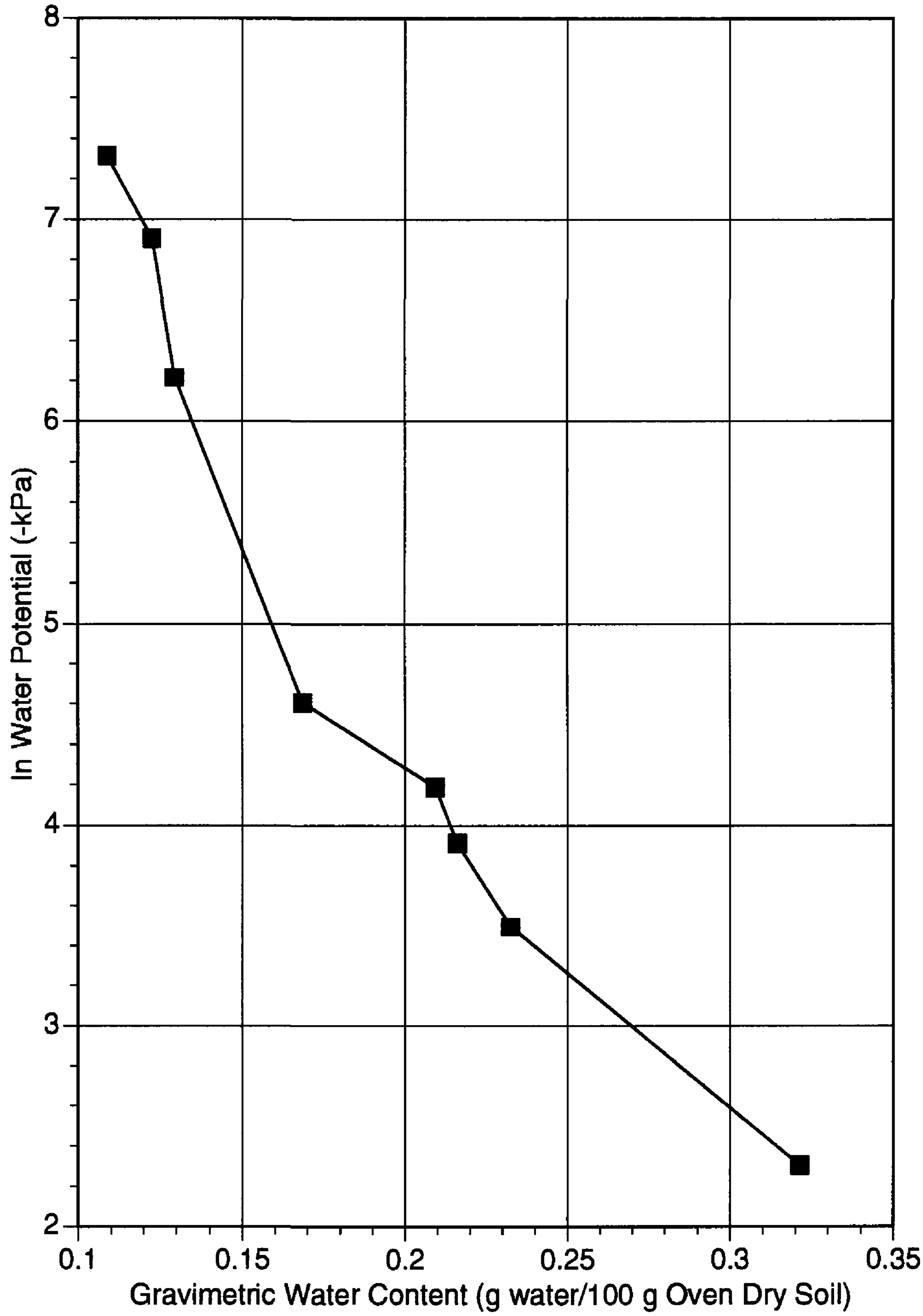


Figure 12. Soil Moisture Release Curve for Grenada Silt Loam soil for Ap Horizon (0 to 13 cm). Data from Romkens et al (1986), used with permission.

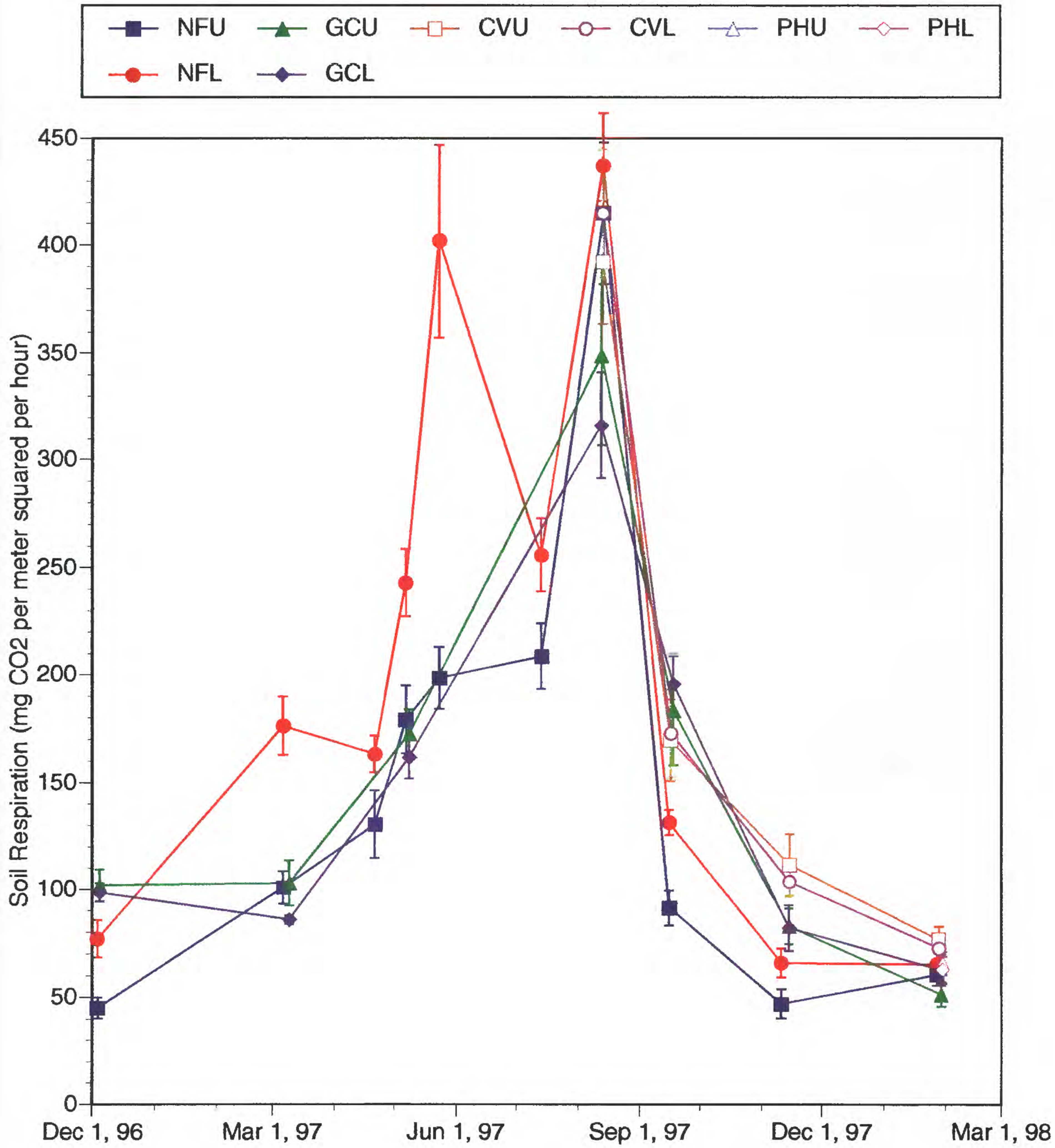


Figure 13. Temporal pattern of soil respiration at forested sites: GC=Goodwin Creek, CV=Coffeeville, PH = Pine Hardwood, and an agricultural site NF = Nelson Farm in northwestern Mississippi. U designates upper (eroding) and L designates toe slope (depositional) Error bars are standard errors of the mean for n=8 or 9 sites at each location.

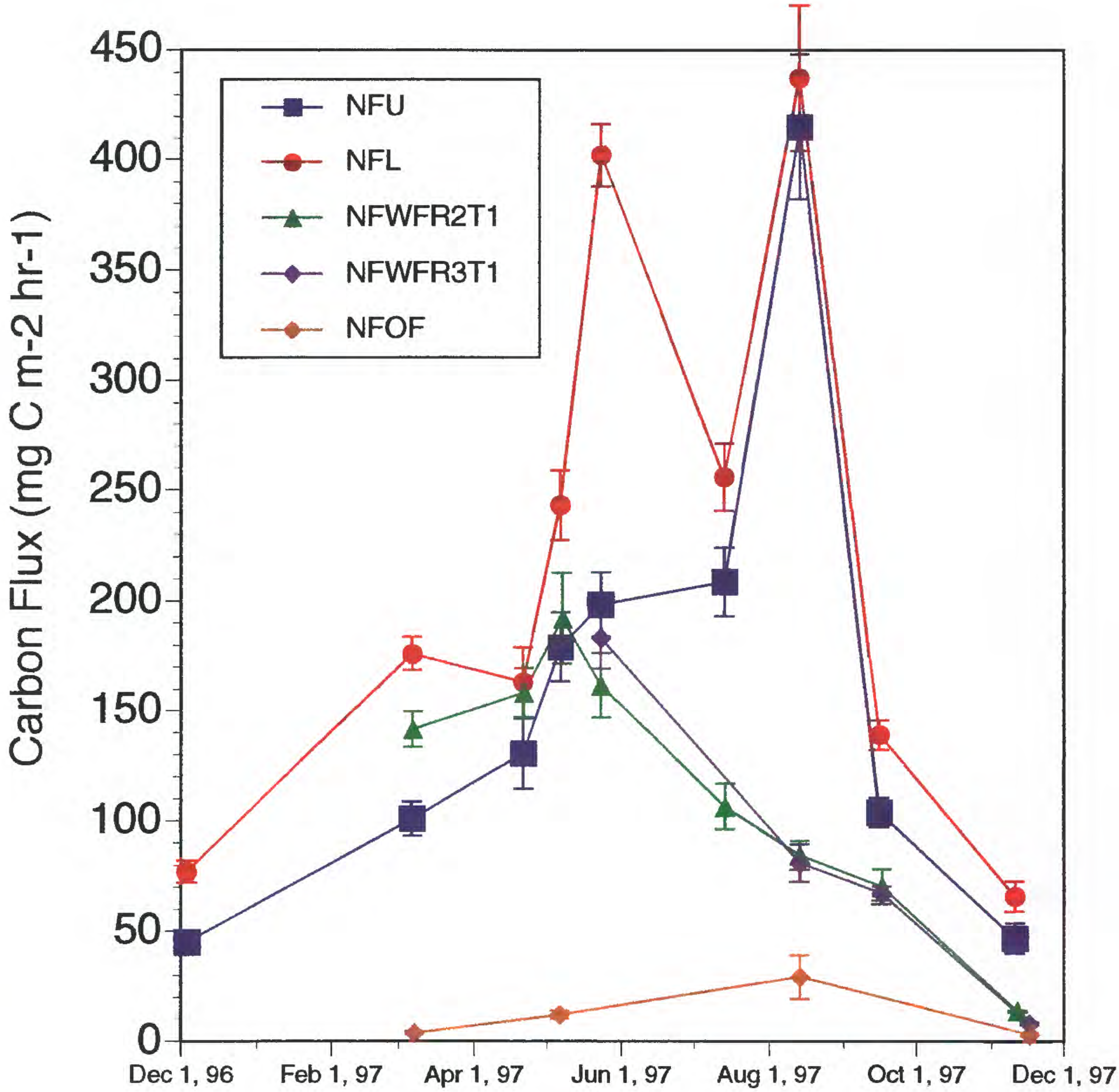


Figure 14. Temporal pattern of soil respiration in cropped (soybean) and fallow plots at the Nelson Farm in northwestern Mississippi for the period December 1996 through January 1998.

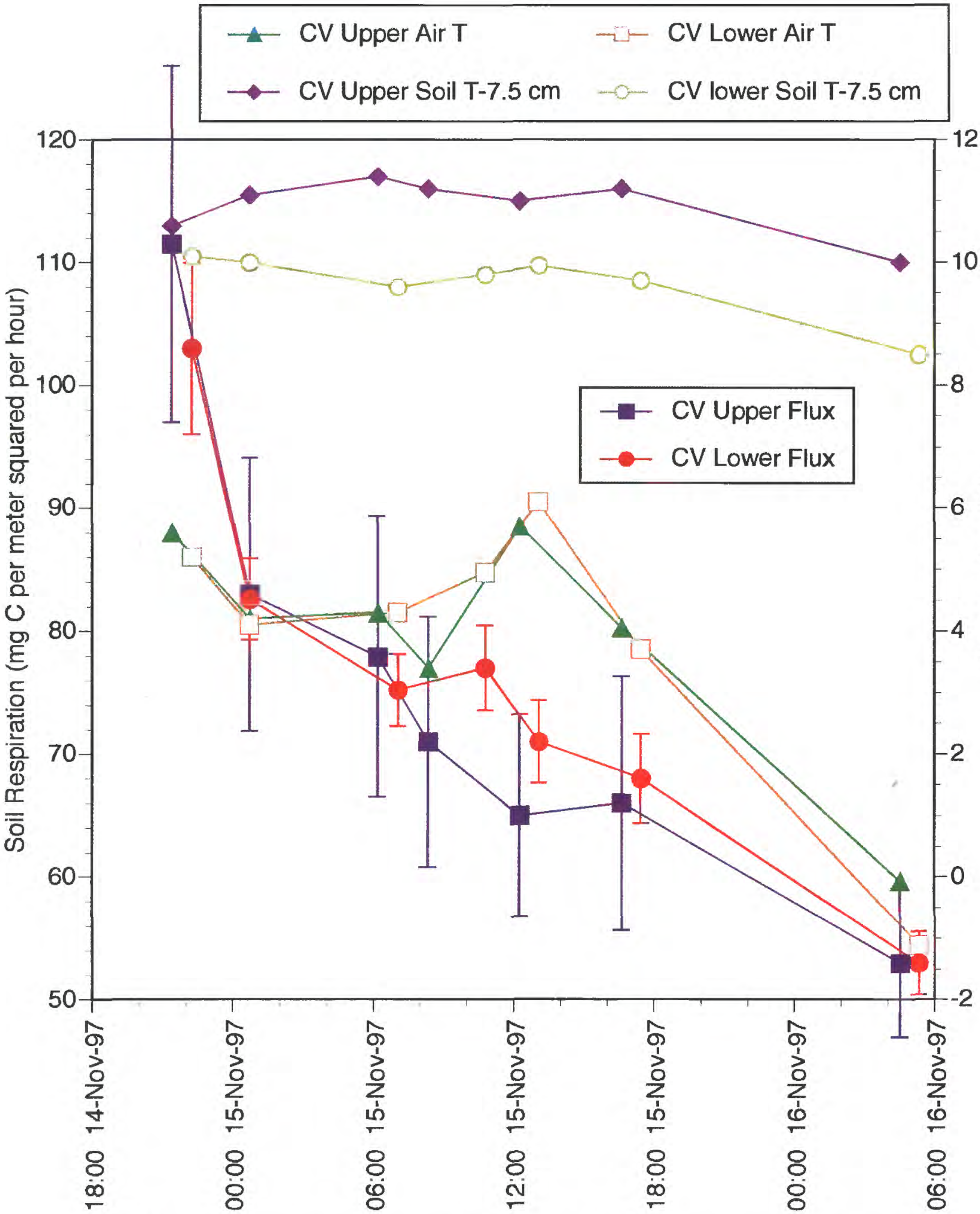


Figure 15. Diurnal pattern of soil respiration and soil and air temperature in forested (CV, Coffeeville) plots in northwestern Mississippi for the period November 14 - 16, 1997. Upper site is eroding and Lower site is toe slope (depositional).

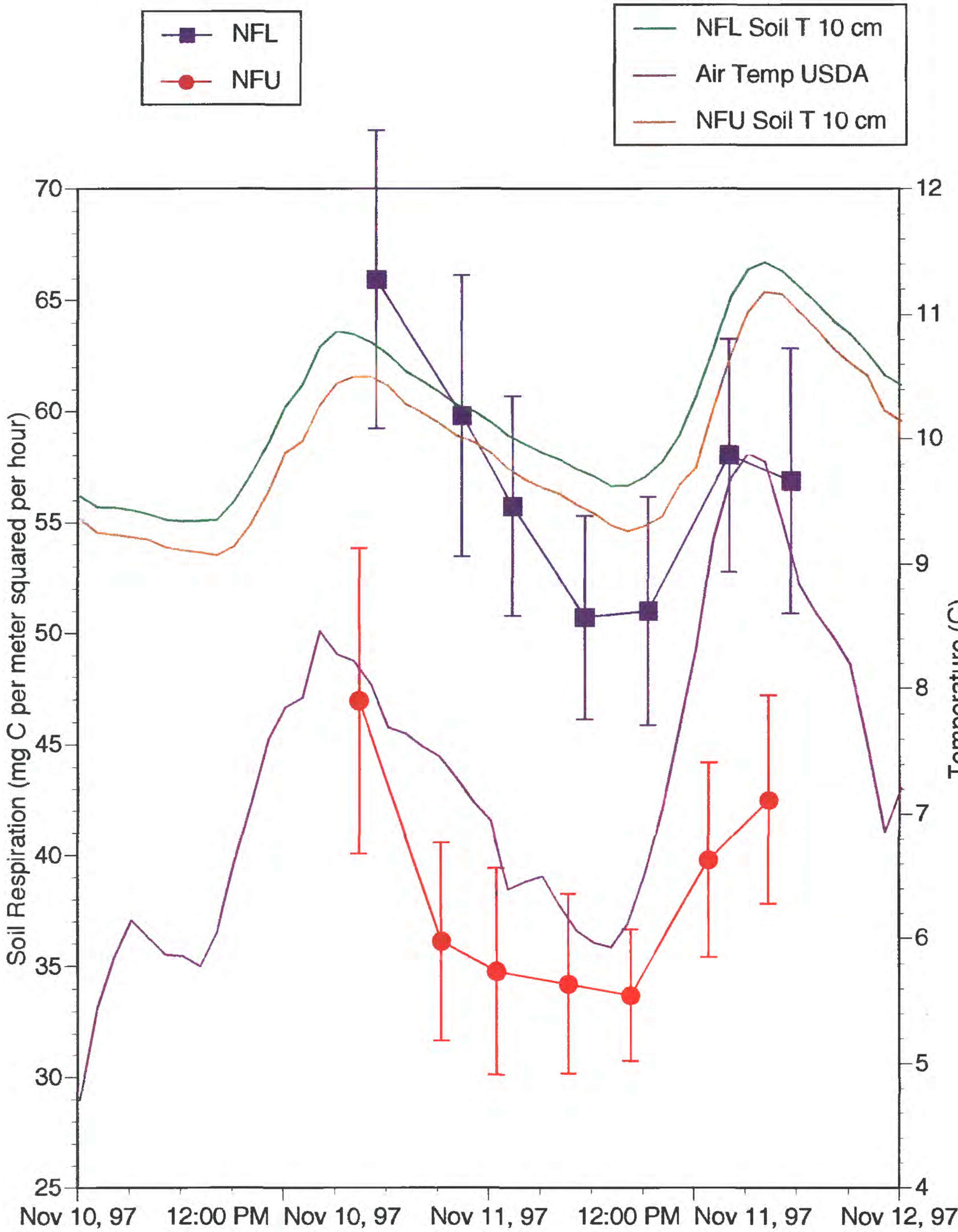


Figure 16. Diurnal pattern of soil respiration and soil and air temperature in cropped (soybean) plots at the Nelson Farm in northwestern Mississippi for the period November 10 - 11, 1997.

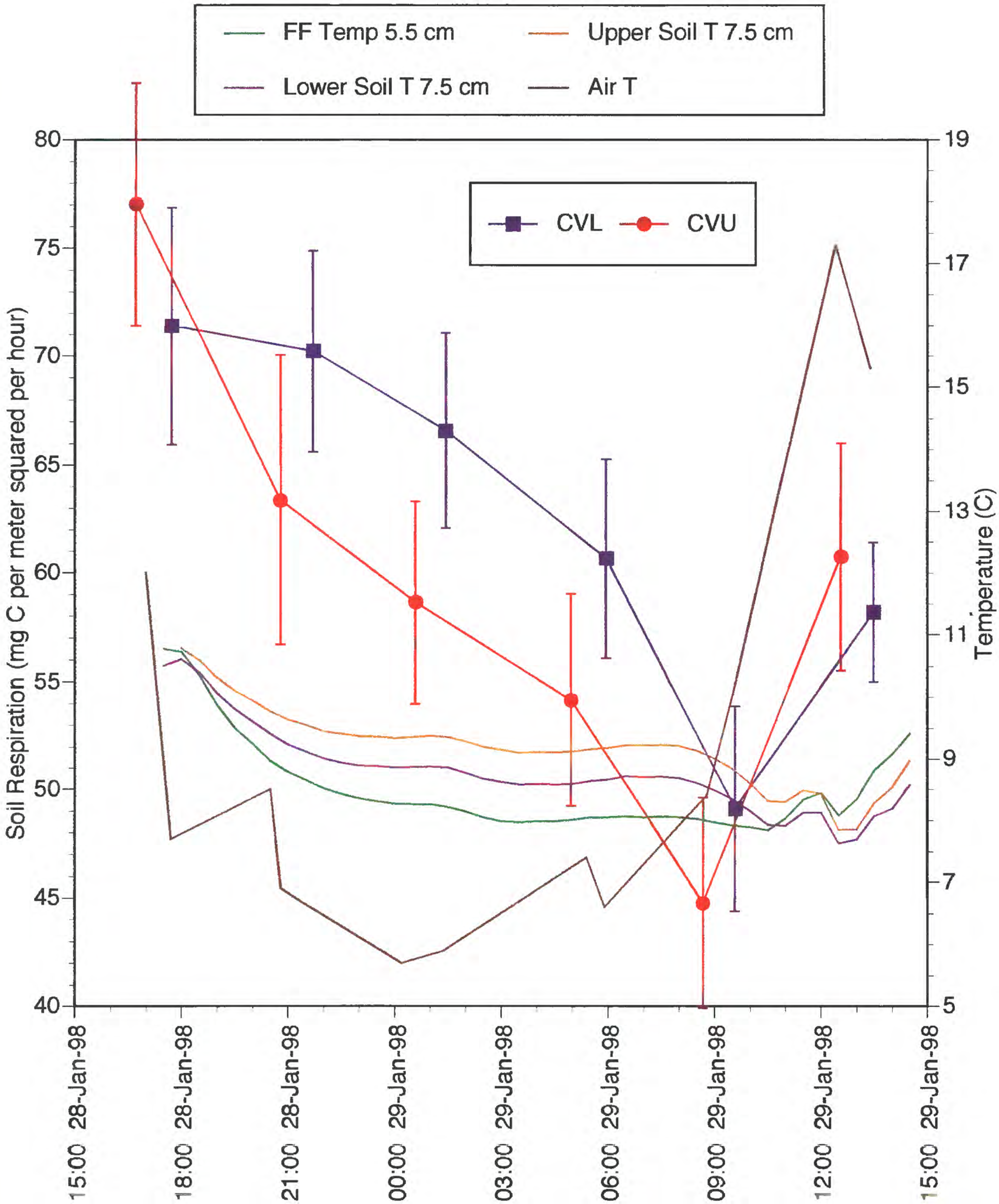


Figure 17. Diurnal pattern of soil respiration and soil and air temperature in forested (Coffeeville) plots in northwestern Mississippi for the period January 28 - 29, 1998.

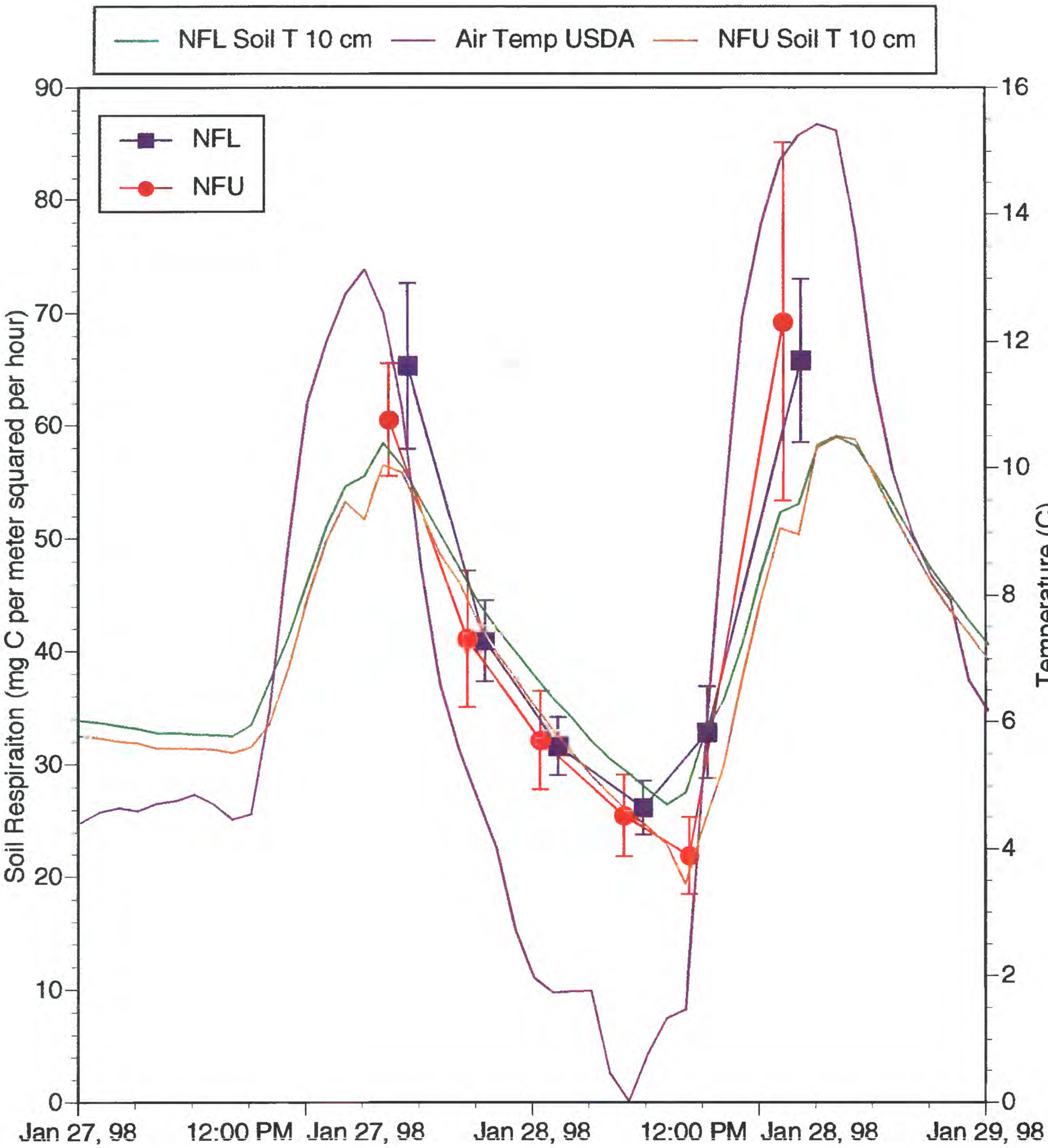
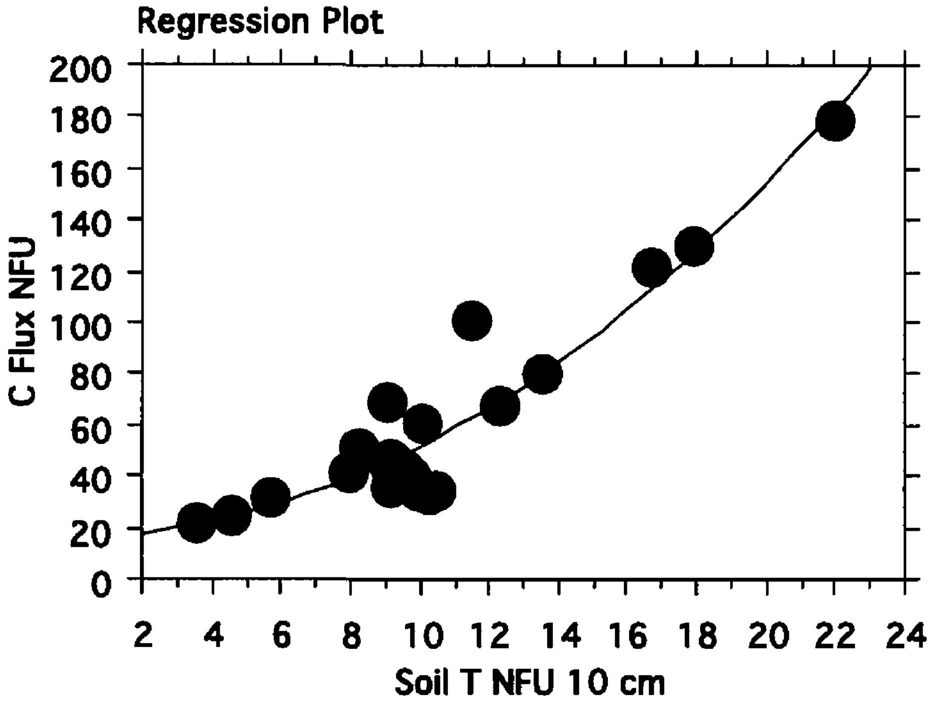


Figure 18. Diurnal pattern of soil respiration and soil and air temperature in cropped (soybean) plots at the Nelson Farm in northwestern Mississippi for the period January 27 - 28, 1998.

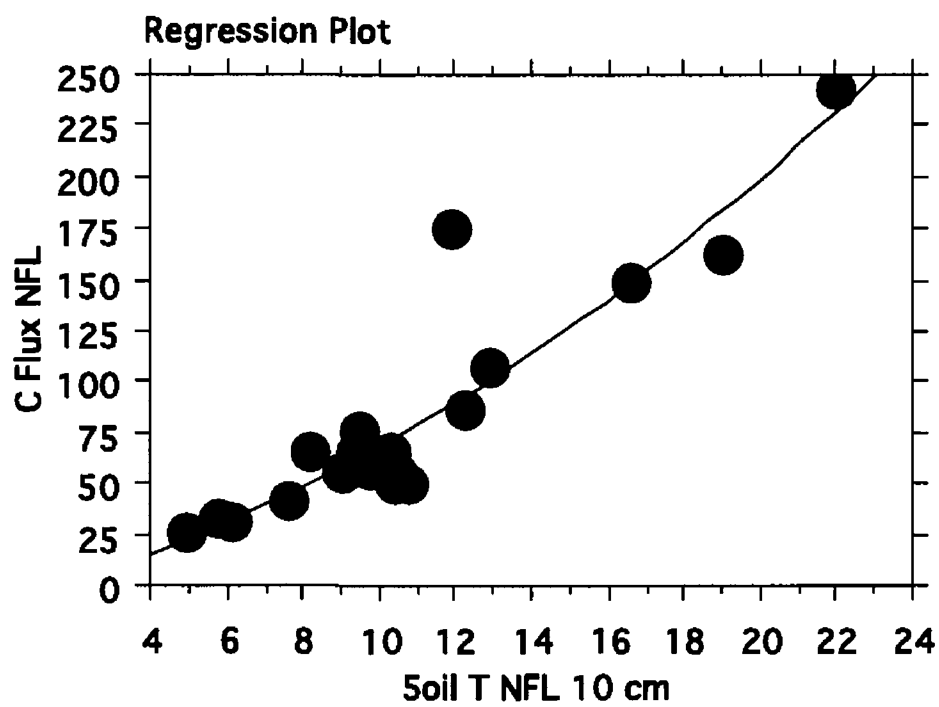


Y = 17.01 + .152 * X + .338 * X^2; R^2 = .888

ANOVA Table

C Flux NFU vs. Soil T NFU 10 cm

	DF	Sum of Squares	Mean Square	F-Value	P-Value
Regression	2	29157.763	14578.882	75.018	<.0001
Residual	19	3692.423	194.338		
Total	21	32850.186			



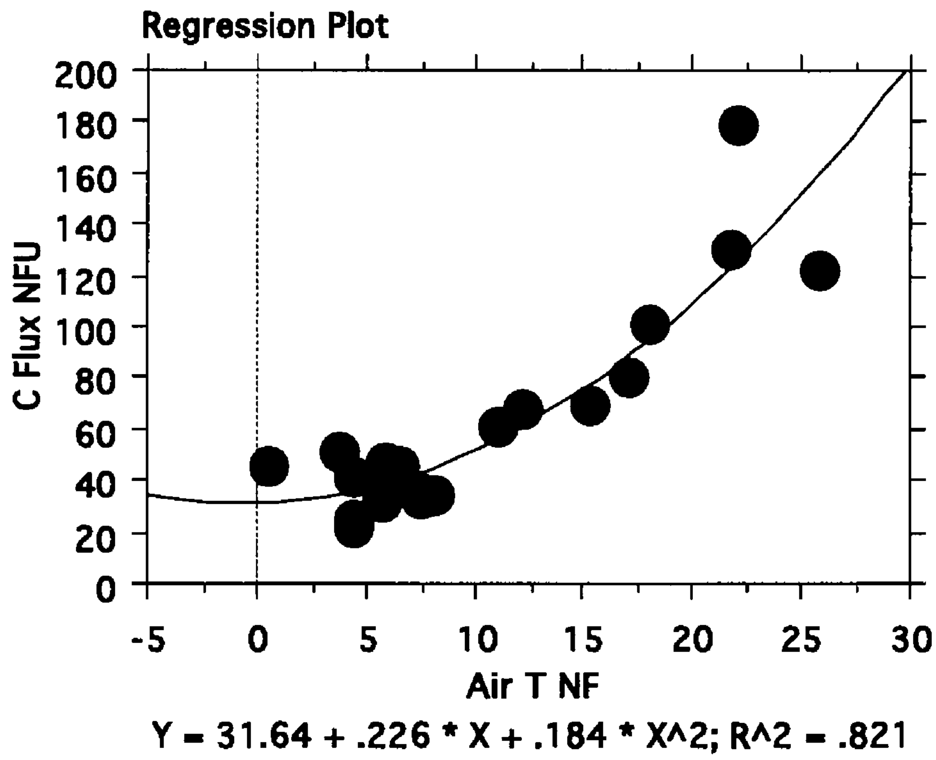
Y = -7.951 + 5.014 * X + .27 * X^2; R^2 = .832

ANOVA Table

C Flux NFL vs. Soil T NFL 10 cm

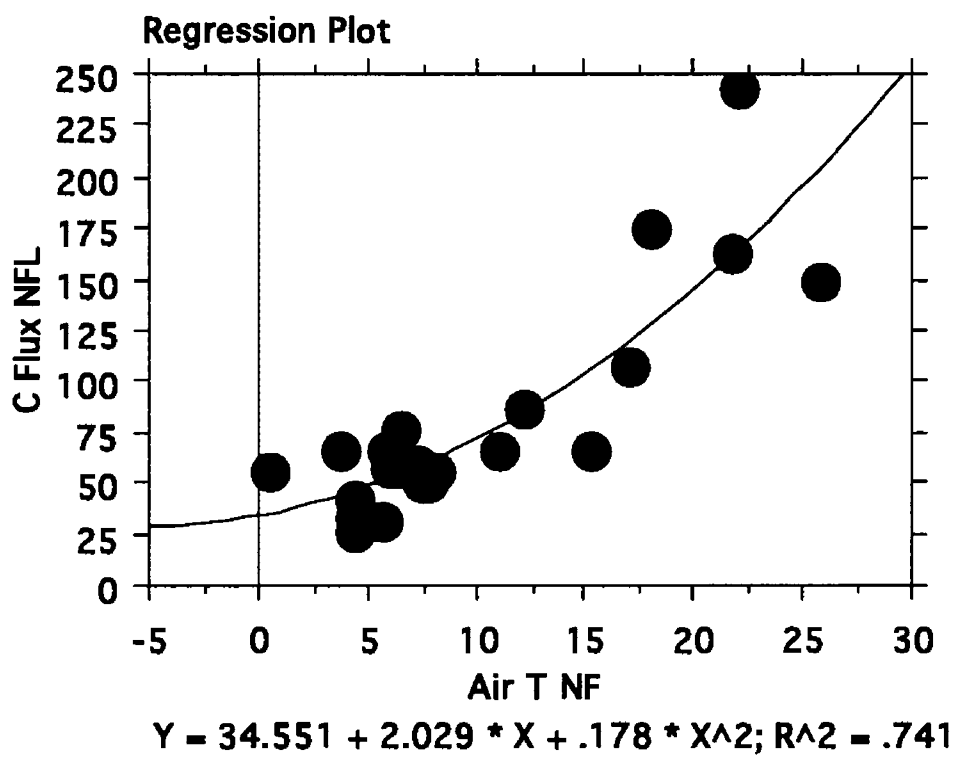
	DF	Sum of Squares	Mean Square		
Regression	2	51971.837	25985.919	F-Value	P-Value
Residual	19	10511.281	553.225	46.972	<.0001
Total	21	62483.119			

Figure 19. Plot showing relationship between carbon flux (soil respiration) and soil temperature at 10 cm depth for plots at eroding and depositional sites at the Nelson Farm in northwestern Mississippi for the period December 1996 through January 1998.



ANOVA Table
C Flux NFU vs. Air T NF

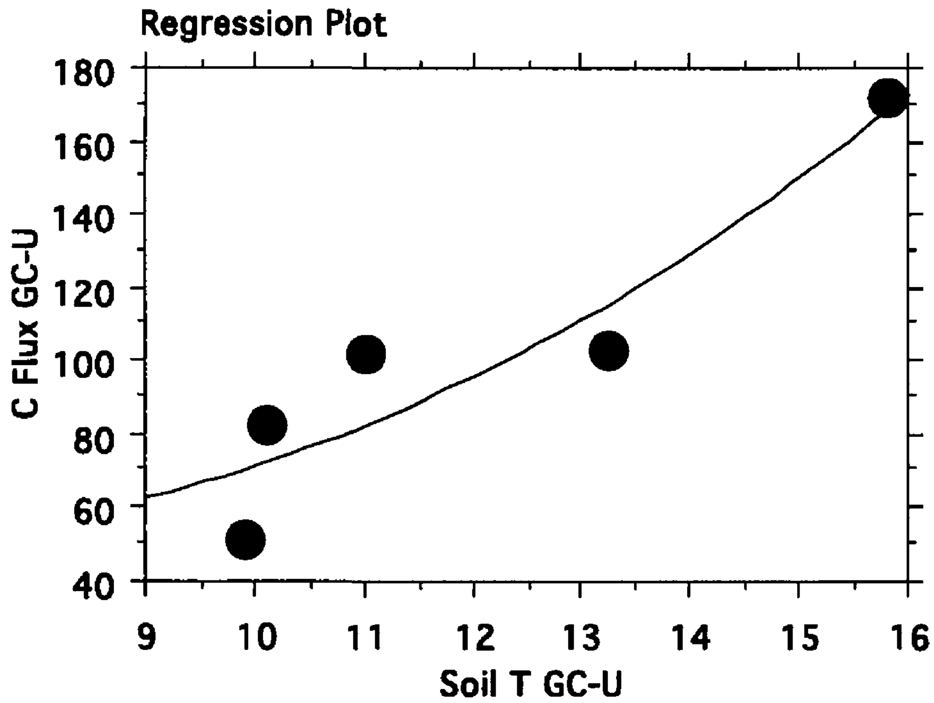
	DF	Sum of Squares	Mean Square	F-Value	P-Value
Regression	2	26964.808	13482.404	43.526	<.0001
Residual	19	5885.379	309.757		
Total	21	32850.186			



ANOVA Table
C Flux NFL vs. Air T NF

	DF	Sum of Squares	Mean Square	F-Value	P-Value
Regression	2	46298.867	23149.433	27.177	<.0001
Residual	19	16184.252	851.803		
Total	21	62483.119			

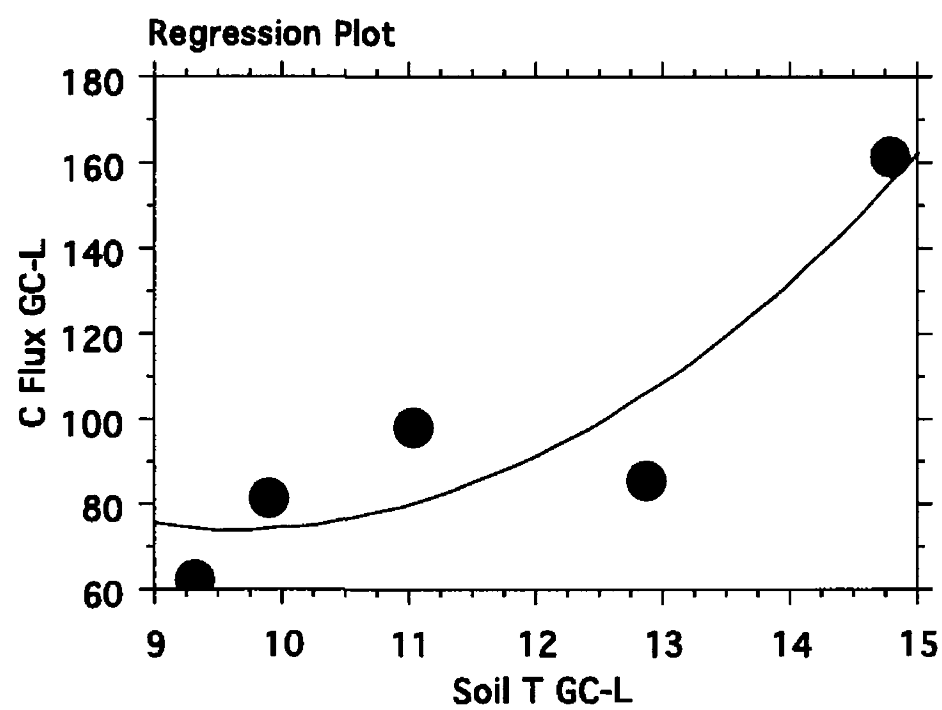
Figure 20. Plot showing relationship between carbon flux (soil respiration) and air temperature at 10 cm depth for plots at eroding and depositional sites at the Nelson Farm in northwestern Mississippi for the period December 1996 through January 1998.



Y = 92.057 - 13.878 * X + 1.185 * X^2; R^2 = .87

ANOVA Table
C Flux GC-U vs. Soil T GC-U

	DF	Sum of Squares	Mean Square	F-Value	P-Value
Regression	2	6877.558	3438.779	6.677	.1303
Residual	2	1030.013	515.006		
Total	4	7907.570			



Y = 353.562 - 58.137 * X + 3.026 * X^2; R^2 = .825

ANOVA Table
C Flux GC-L vs. Soil T GC-L

	DF	Sum of Squares	Mean Square	F-Value	P-Value
Regression	2	4705.130	2352.565	4.710	.1751
Residual	2	998.910	499.455		
Total	4	5704.039			

Figure 21. Plot showing relationship between carbon flux (soil respiration) and soil temperature at 10 cm depth for plots at eroding and depositional sites at the Goodwin Cr. in northwestern Mississippi for the period December 1996 through January 1998.

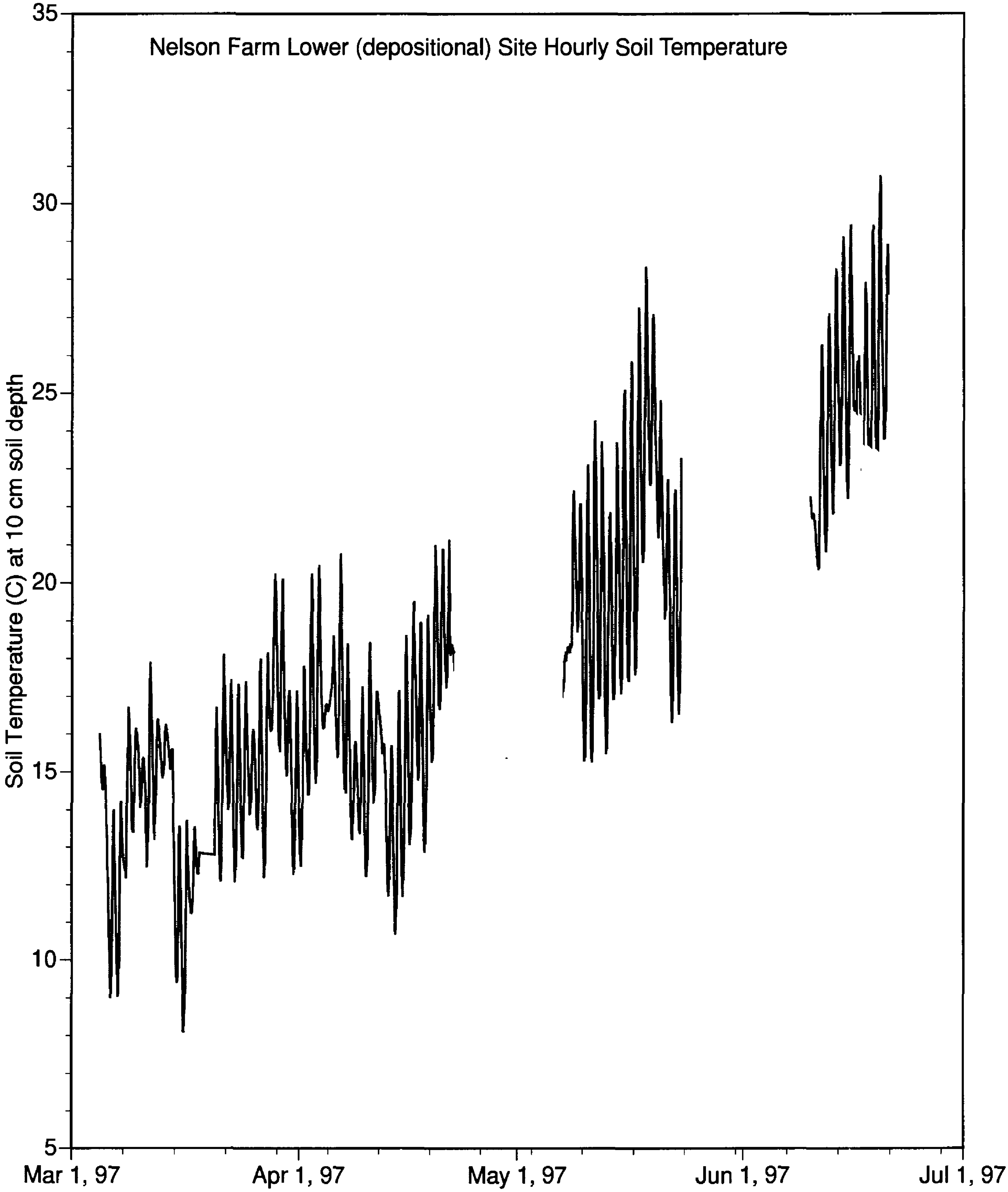


Figure 22A. Plot showing soil temperature at 10 cm depth for the lower (depositional) site at the Watershed 2 Nelson Farm, in northwestern Mississippi for the period March 4, 1997 through June 20, 1997.

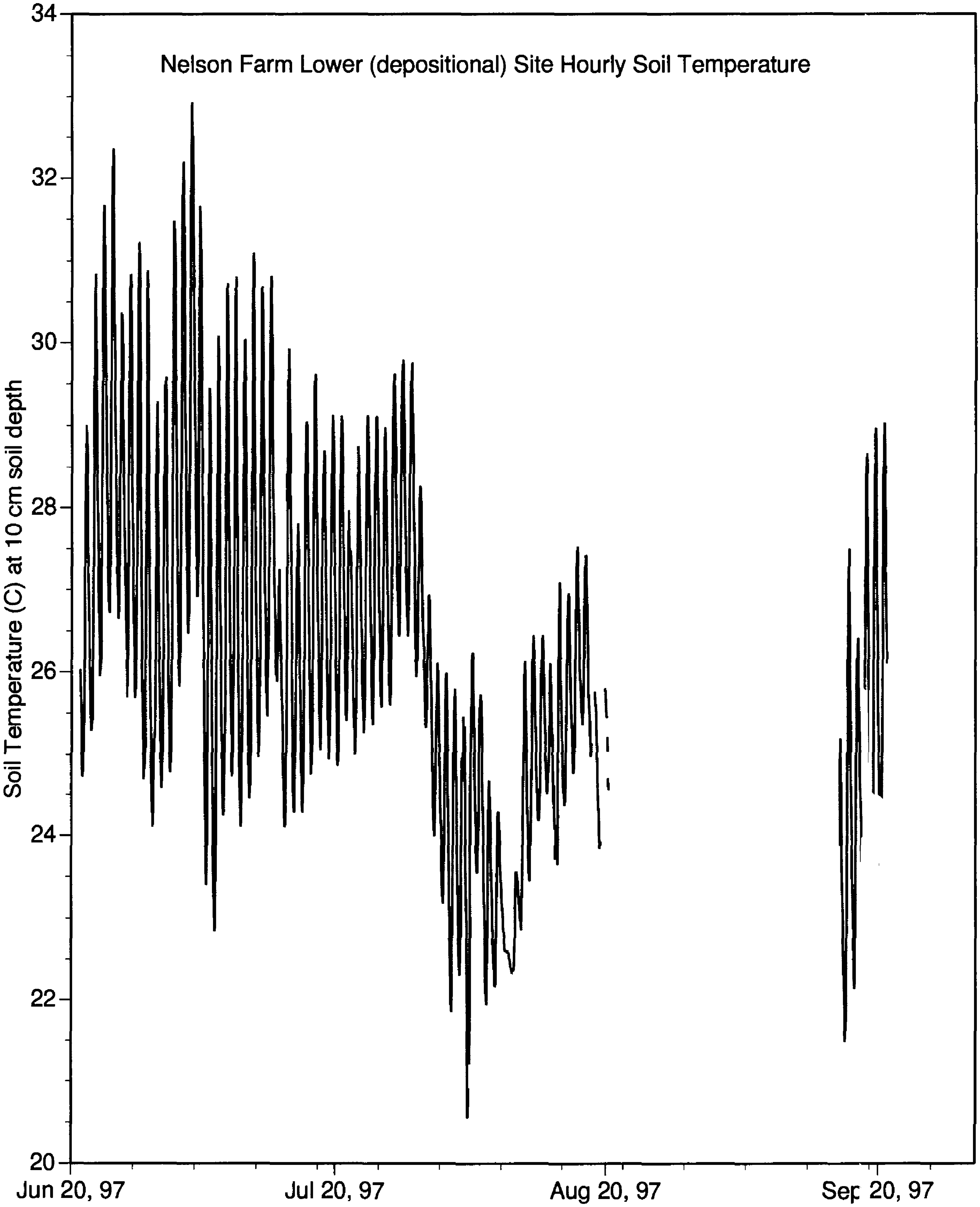


Figure 22B. Plot showing soil temperature at 10 cm depth for the lower (depositional) site at the Watershed 2 Nelson Farm, in northwestern Mississippi for the period June21, 1997 through September 20, 1997.

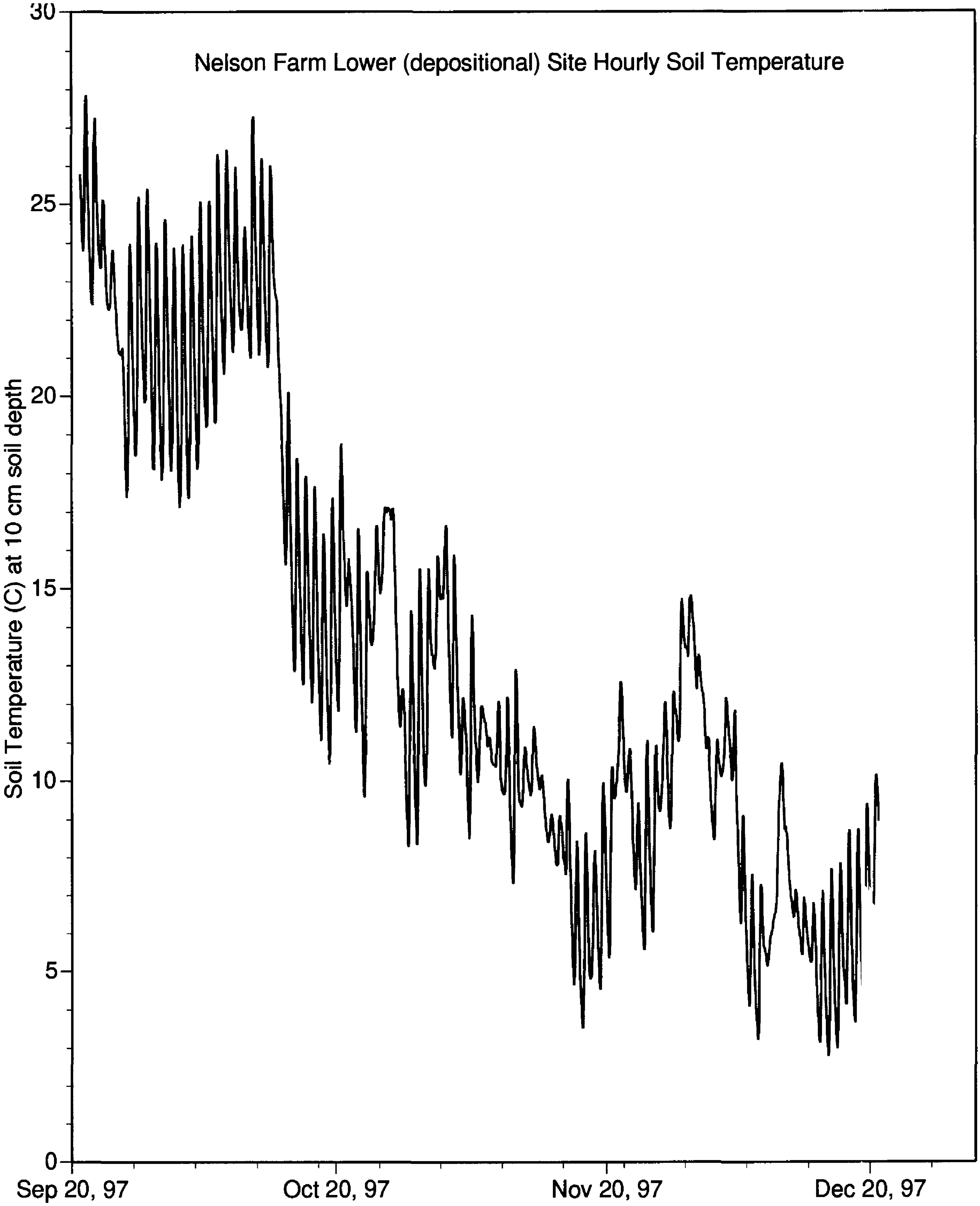


Figure 22C. Plot showing soil temperature at 10 cm depth for the lower (depositional) site at the Watershed 2 Nelson Farm, in northwestern Mississippi for the period September 21, 1997 through December 20, 1997.

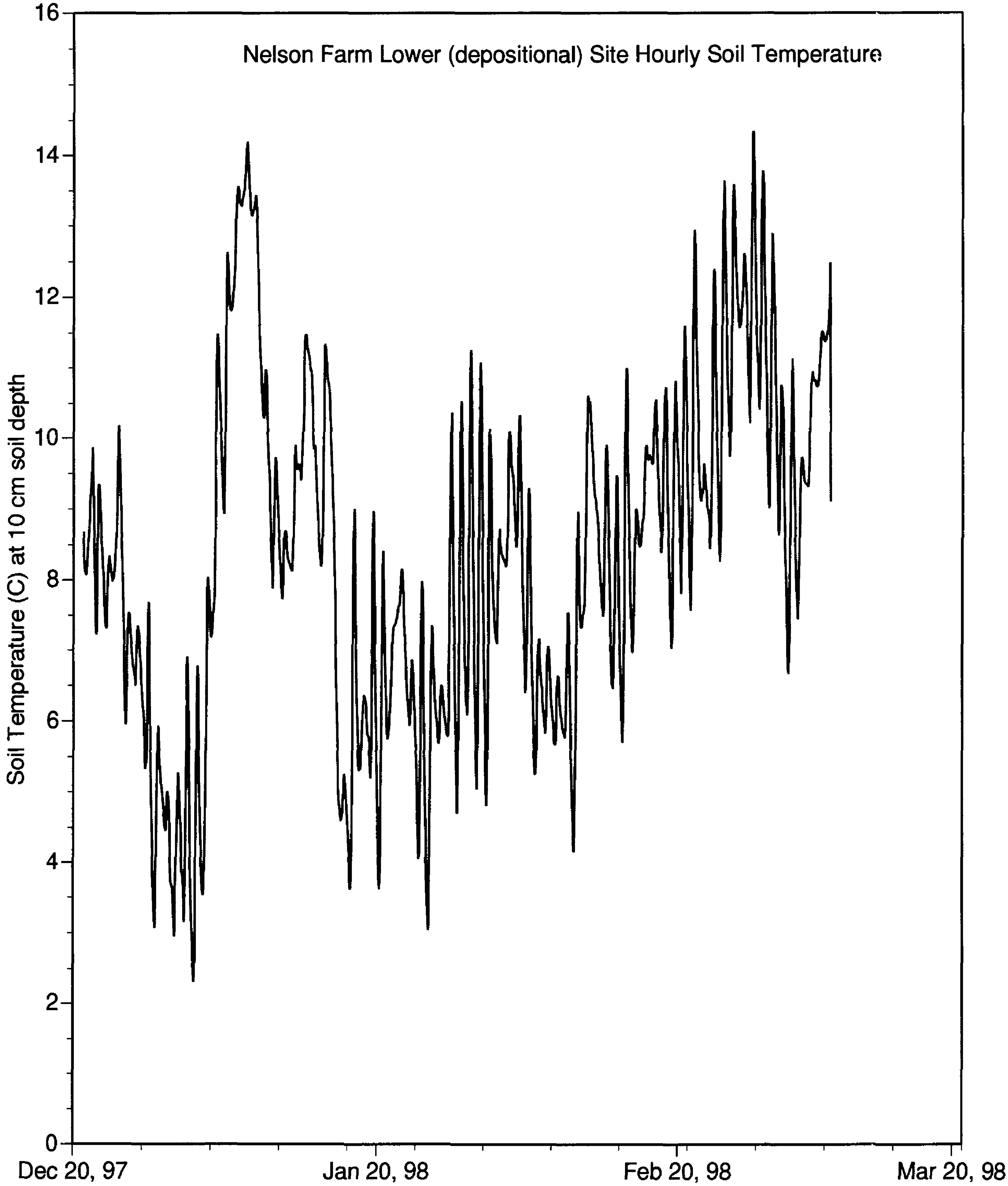


Figure 22D. Plot showing soil temperature at 10 cm depth for the lower (depositional) site at the Watershed 2 Nelson Farm, in northwestern Mississippi for the period September 21, 1997 through December 20, 1998.

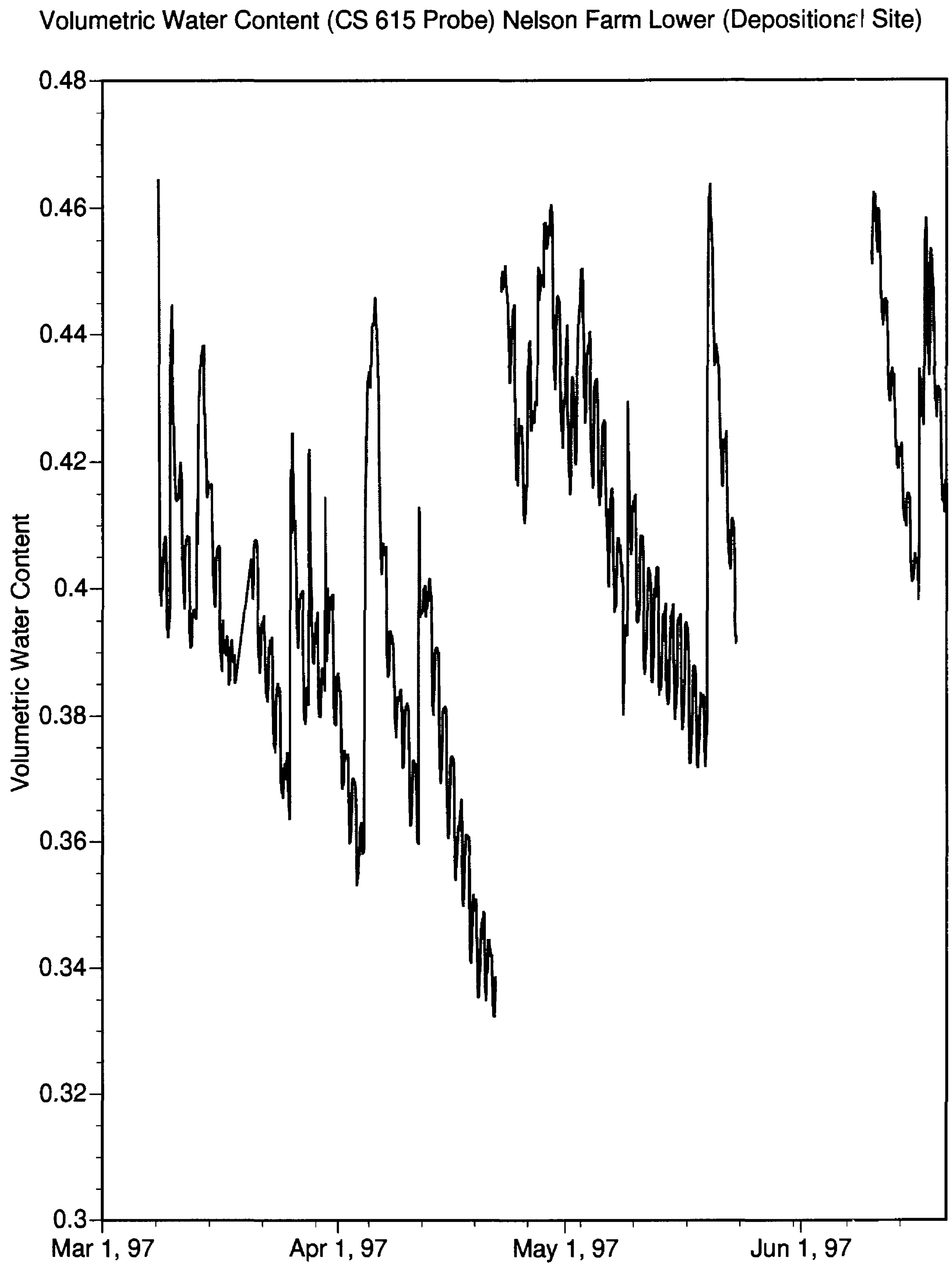


Figure 23A. Plot Showing soil volumetric water content for surface 20 cm for the lower (depositional) site at the Watershed 2 Nelson Farm, in northwestern Mississippi f for the period March 4, 1997 through June 20, 1997.

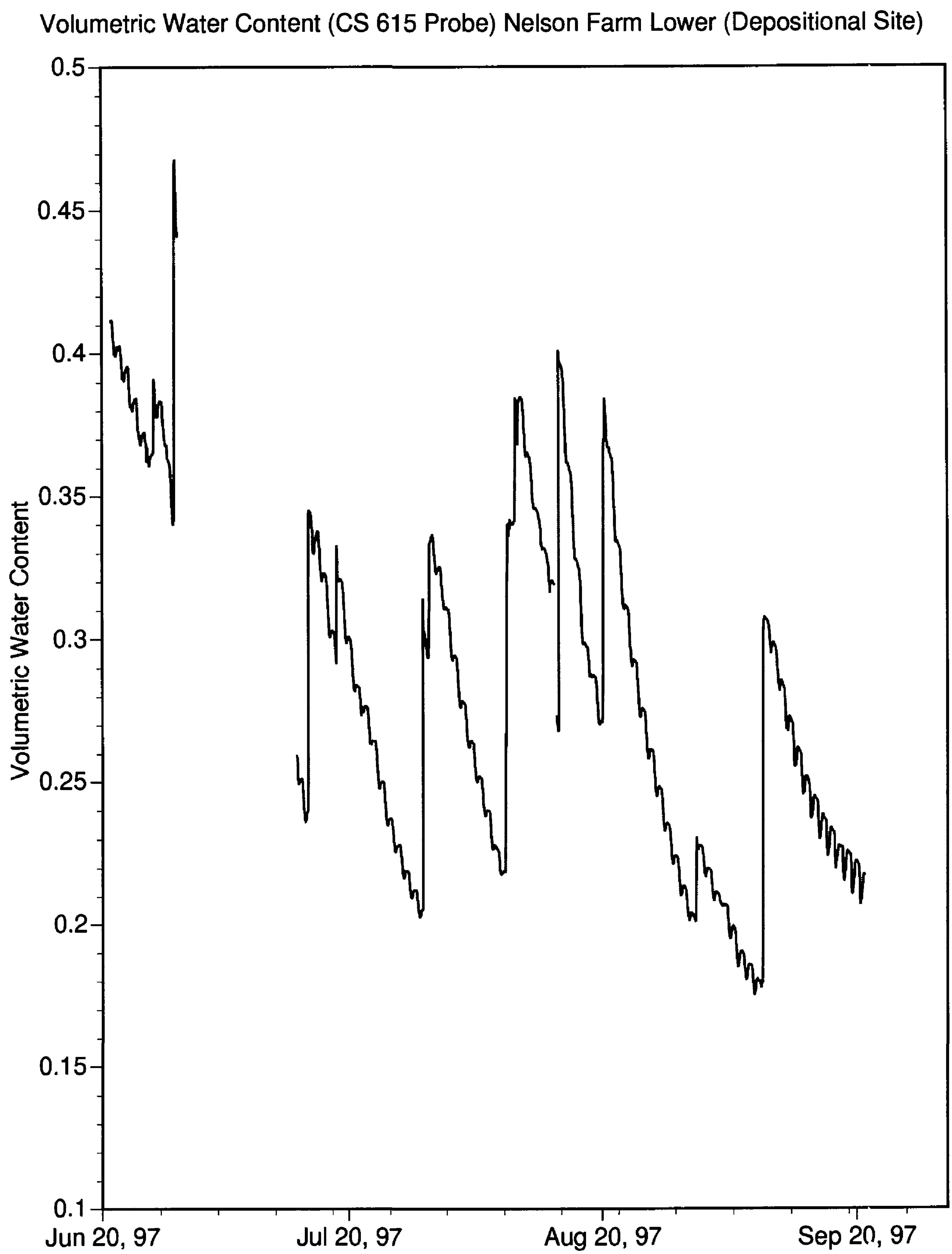


Figure 23B. Plot Showing soil volumetric water content for surface 20 cm for the lowe-(depositional) site at the Watershed 2 Nelson Farm, in northwestern Mississippi f for the period June 21, 1997 through September 20, 1997.

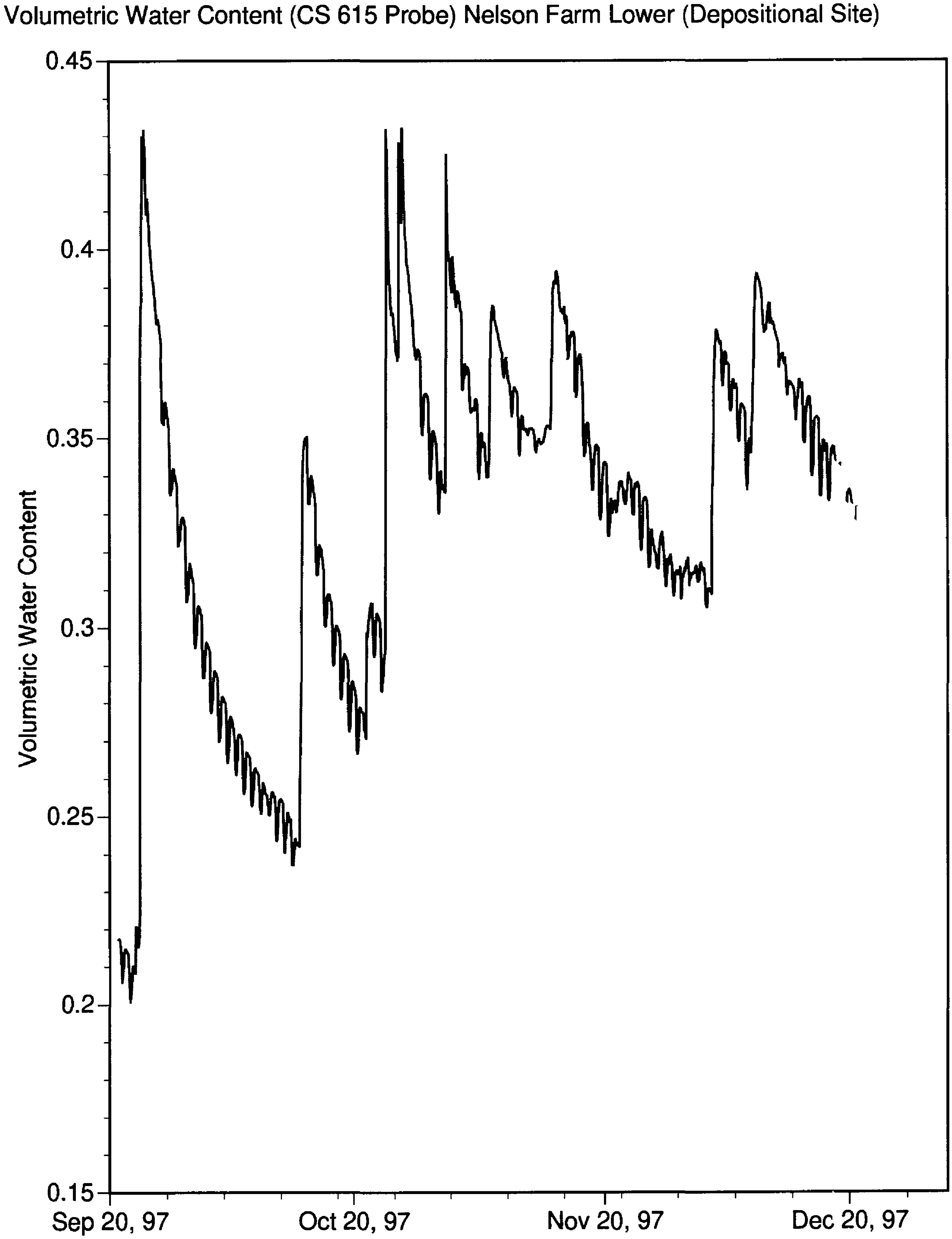


Figure 23C. Plot Showing soil volumetric water content for surface 20 cm for the lower (depositional) site at the Watershed 2 Nelson Farm, in northwestern Mississippi f for the period September 21, 1997 through December 20, 1997.

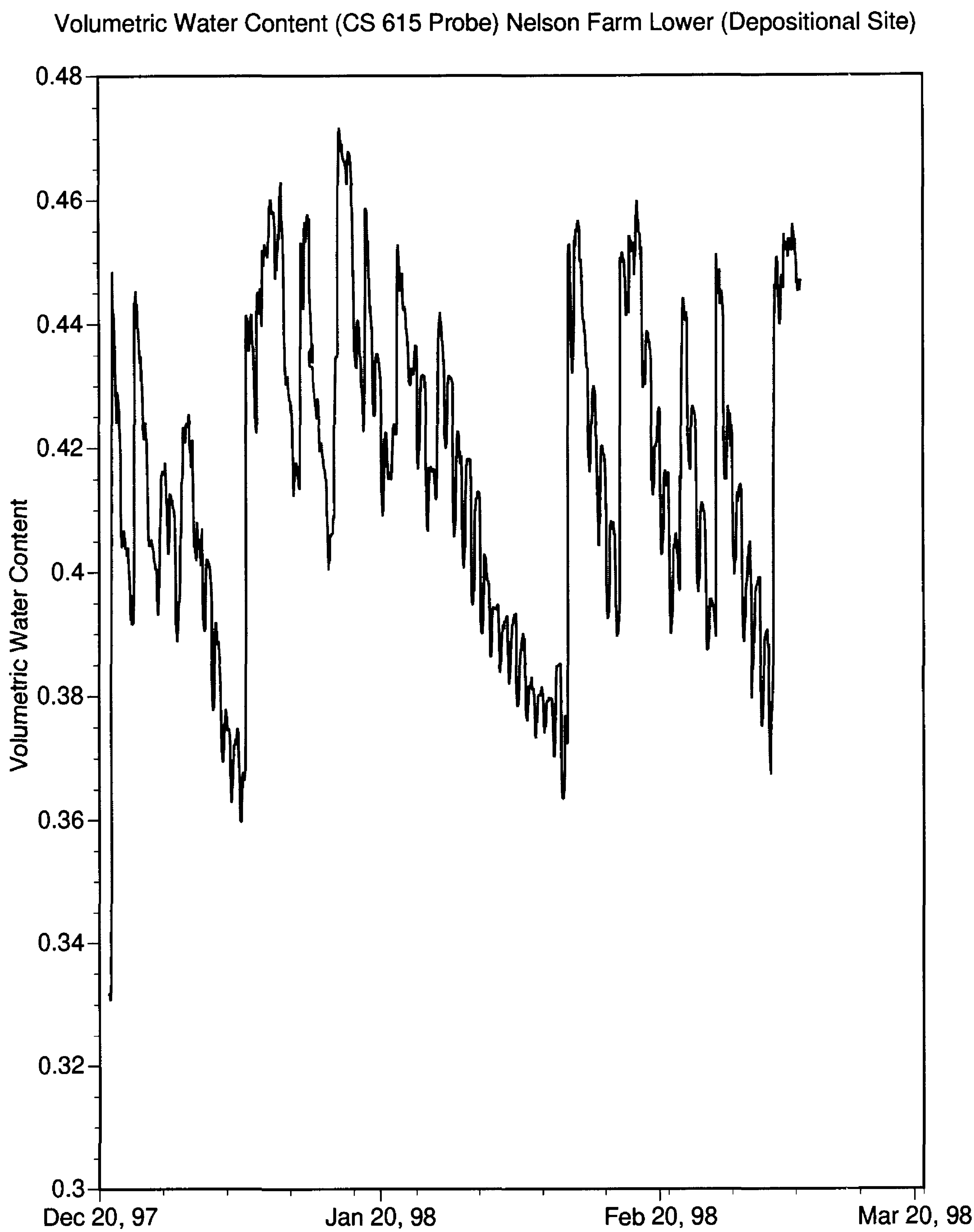


Figure 23D. Plot Showing soil volumetric water content for surface 20 cm for the lower (depositional) site at the Watershed 2 Nelson Farm, in northwestern Mississippi f for the period December 21, 1997 through March 21, 1998.

Nelson Farm Lower Site Mean of Three Sensors at 10 cm

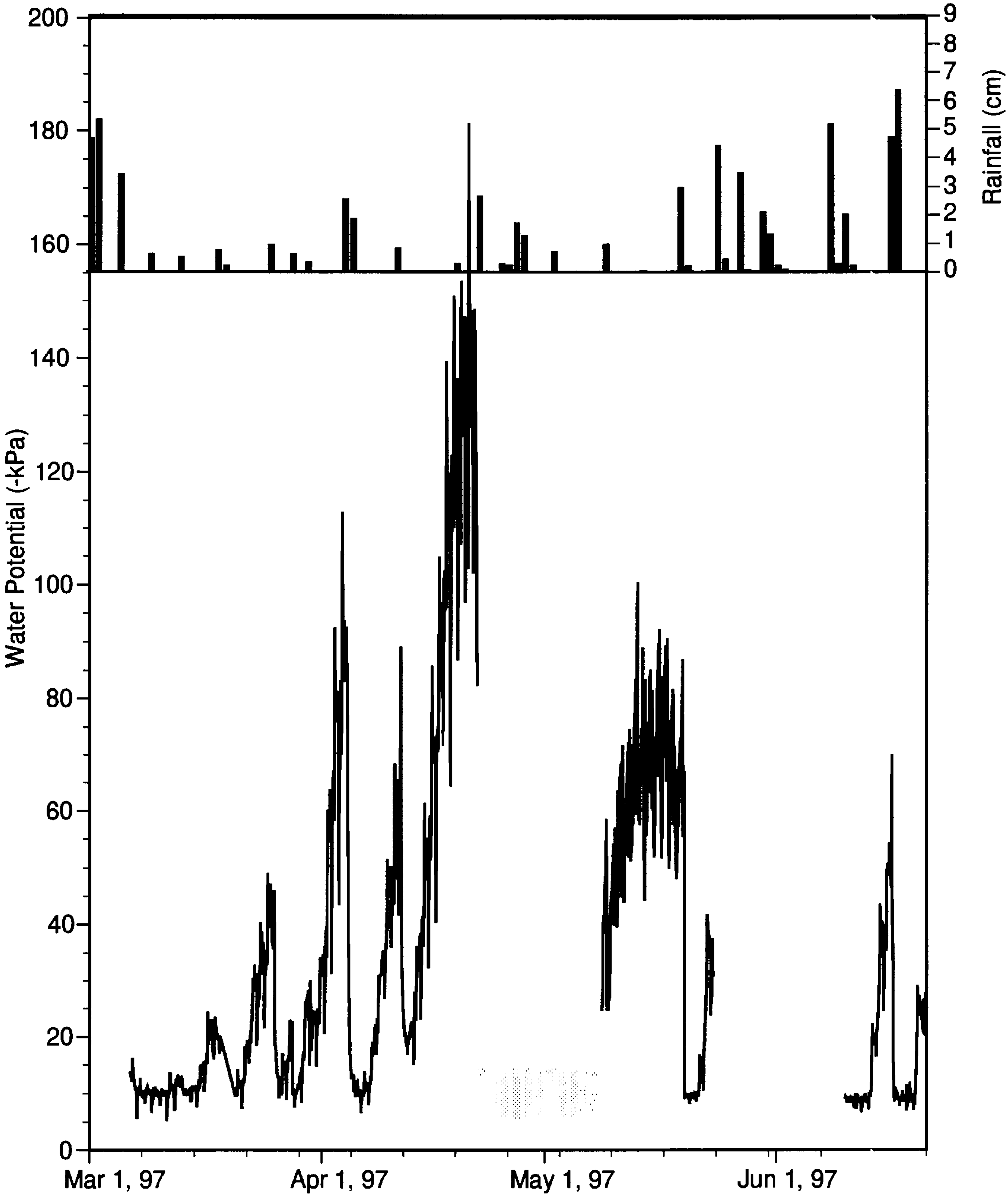


Figure 24A. Rainfall and water potential at 10 cm depth for the lower (depositional) site at the Watershed 2 Nelson Farm, in northwestern Mississippi for the period March 4, 1997 through June 20, 1997. Values of water potential are means of three replicate sensors. Data gap around May 1, 1997 due to burying sensors to avoid damage during tillage. Data gap around June 1, 1997 due to data logger failure.

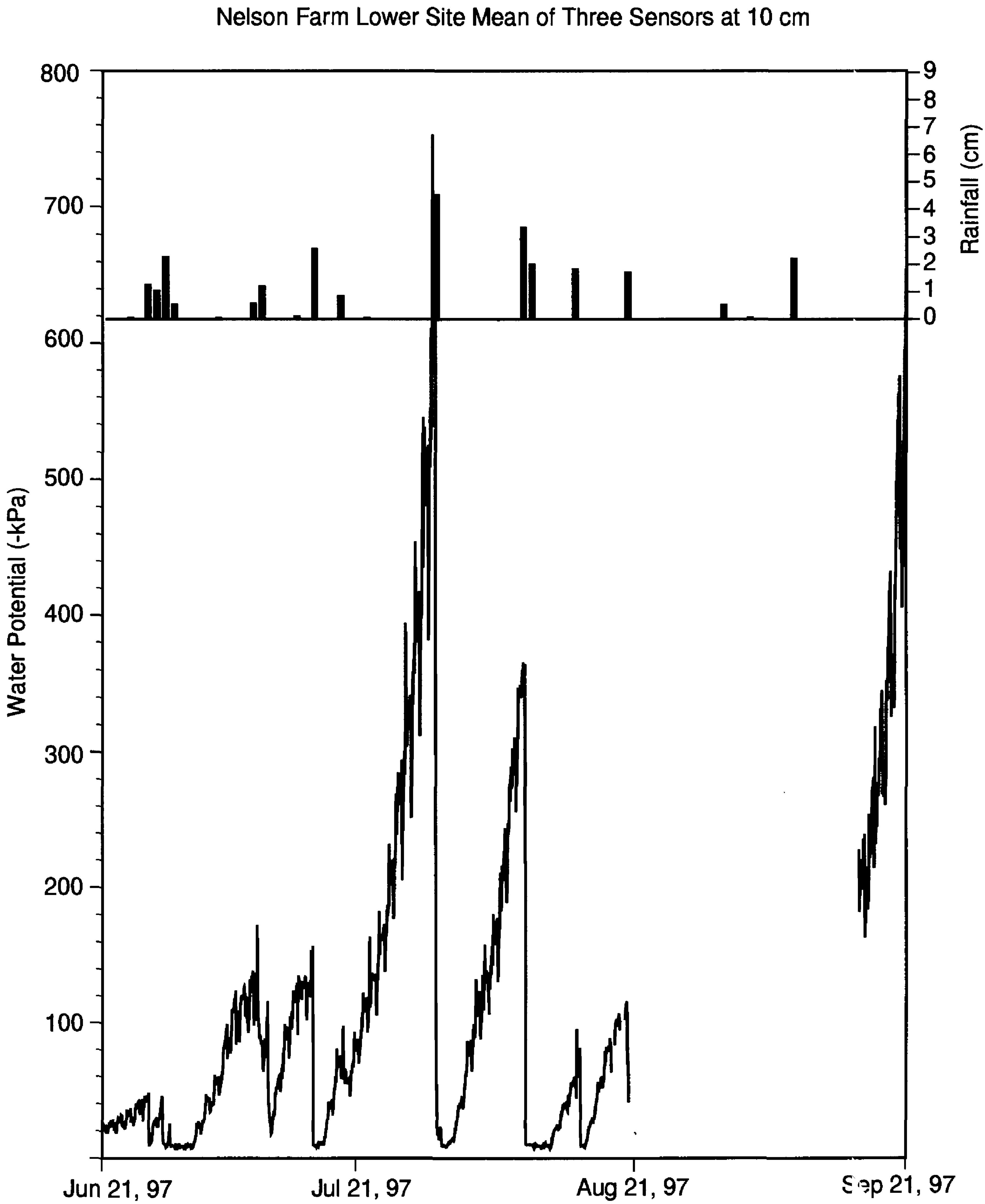


Figure 24B. Rainfall and water potential at 10 cm depth for the lower (depositional) site at the Watershed 2 Nelson Farm, in northwestern Mississippi for the period June 21, 1997 through September 20, 1997. Values of water potential are means of three replicate sensors. Data gap around September 1, 1997 due to data logger failure.

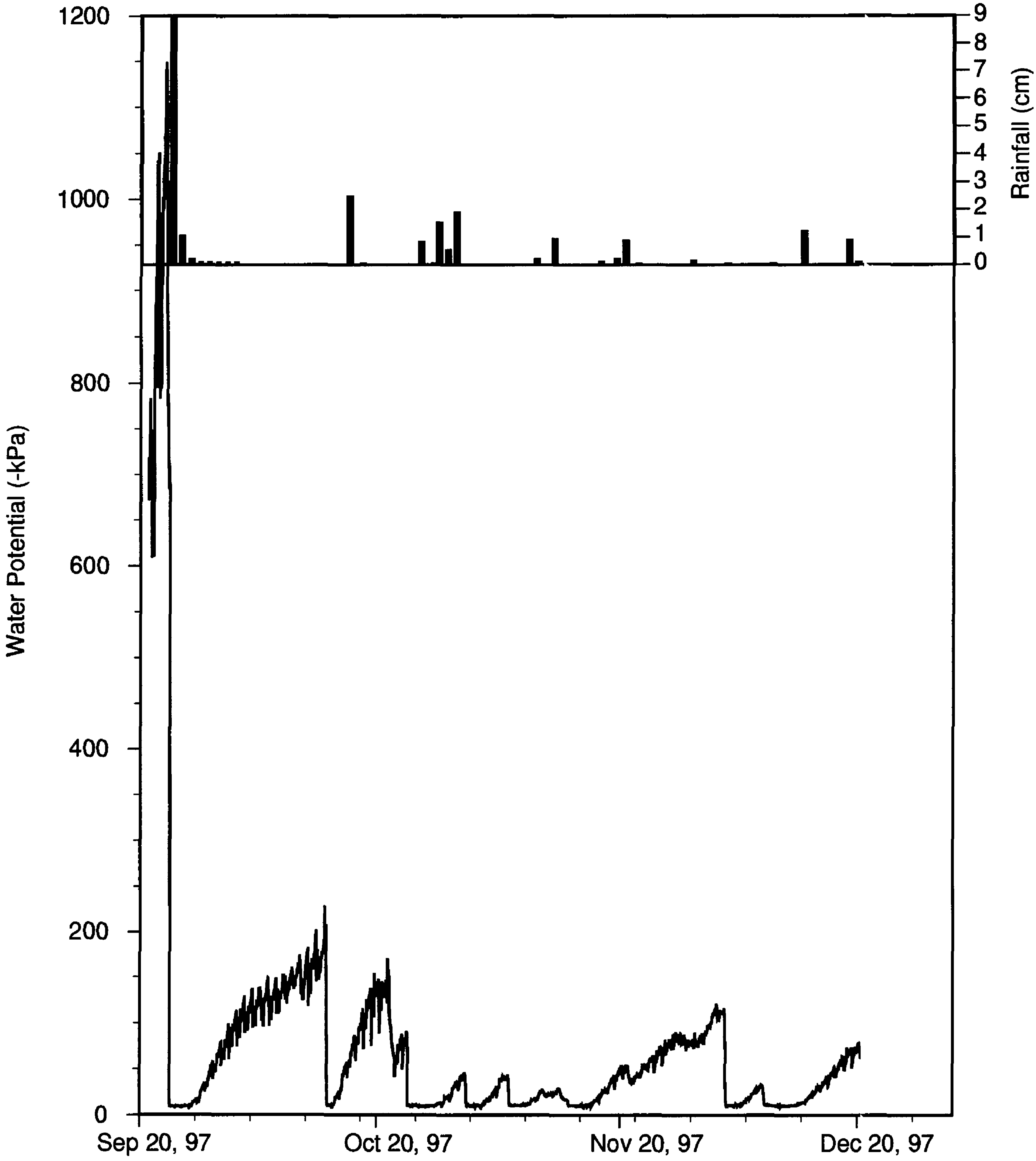


Figure 24C. Rainfall and water potential at 10 cm depth for the lower (depositional) site at the Watershed 2 Nelson Farm, in northwestern Mississippi for the period September 20, 1997 through December 21, 1997. Values of water potential are means of three replicate sensors.

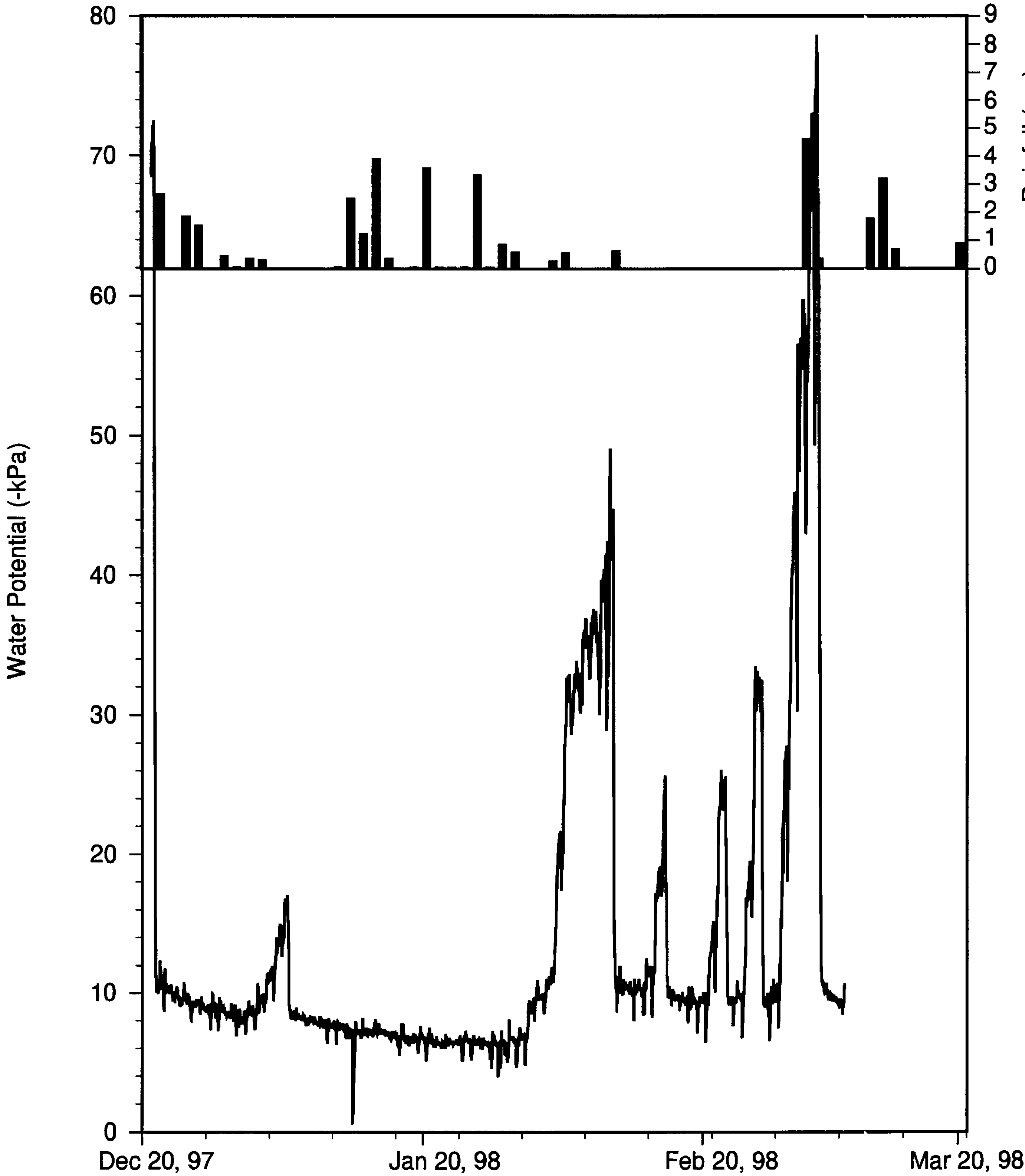


Figure 24D. Rainfall and water potential at 10 cm depth for the lower (depositional) site at the Watershed 2 Nelson Farm, in northwestern Mississippi for the period December 21, 19?7 through March 6, 1998. Values of water potential are means of three replicate sensors.