USE AND OCCURRENCE OF PESTICIDES IN THE APALACHICOLA-CHATTAHOOCHEE-FLINT RIVER BASIN, GEORGIA, ALABAMA, AND FLORIDA, 1960-91

By Susan M. Stell, Evelyn H. Hopkins, Gary R. Buell, and Daniel J. Hippe

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CONTENTS

ILLUSTRATIONS

ILLUSTRATIONS--Continued

TABLES

CONVERSION FACTORS, VERTICAL DATUM, AND ACRONYMS AND ABBREVIATIONS

CONVERSION FACTORS

Multiply	by	to obtain
	Length	
inch (in.)	25.4	millimeter
foot (ft)	0.3048	meter
mile (mi)	1.609	kilometer
cubic foot per second (ft^3/s)	0.2832	cubic meter per second
	Volume	
gallon (gal)	0.003785	cubic meter
	3.7854	liter
	Area	
square mile (mi^2)	2.590	square kilometer
acre	0.4047	hectare
	0.004047	square kilometer

Temperature

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

C = F -32) / 1.8

VERTICAL DATUM

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

ACRONYMS AND ABBREVIATIONS

ACF	Apalachicola-Chattahoochee-Flint
CES	Cooperative Extension Service
EPA	U.S. Environmental Protection Agency
FIFRA	Federal Insecticide Fungicide and Rodenticide Act
MSA	Metropolitan Statistical Area
NAWQA	National Water-Quality Assessment
NWIS	National Water Information System
SCS	Soil Conservation Service
STORET	**Sto**rage and **Ret**rieval System
USDA	U.S. Department of Agriculture
USGS	U.S. Geological Survey

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ABSTRACT

The Apalachicola-Chattahoochee-Flint (ACF) River basin was one of the first 20 study units selected in 1991 by the U.S. Geological Survey for its National Water-Quality Assessment (NAWQA) program. Because pesticide contamination of surface water and ground water is a concern nationwide, a major emphasis of the NAWQA program is to examine the occurrence and distribution of pesticides in the water resources of these study unit basins. An understanding of the types and distribution of land uses; pesticide properties, pest-control practices, and pesticide use; and an evaluation of the occurrence and distribution of pesticides in the water resources of the ACF are necessary to meet this objective of the NAWQA program. This report describes land use and pesticide use at a county level, and the occurrence and distribution of pesticides in the water resources of the ACF River basin on the basis of previously-collected data.

About 33 percent of the ACF River basin is used for agriculture, 16 percent is used for silviculture, and about 5 percent of the basin is in urban and suburban settings; primarily the Columbus, Albany, and Atlanta Metropolitan areas. The remainder is in wetlands and non-silvicultural forest. A broad range of synthetic-organic herbicides, insecticides, and fungicides are applied to land in agricultural, silvicultural, urban, and suburban areas. The period of intensive pesticide applications extends from March to October.

Pesticide data available for the period from 1971 through 1989 in the U.S. Geological Survey National Water Information System (NWIS) and for the period from 1960 through 1991 in the U.S. Environmental Protection Agency Storage and Retrieval System (STORET) were analyzed to describe the occurrence and distribution of pesticides in water resources of the ACF River basin. Collectively, the NWIS and STORET databases contain about 19,600 individual analyses for pesticide concentration in the ACF River basin. Pesticide concentrations were at or above a minimum reporting level in about five percent of all analyses. Most of the pesticide analyses and most of the analyses having concentrations above minimum reporting levels in these databases are for organochlorine insecticides in samples collected five or more years before this study. With few exceptions, most of organochlorine insecticides are now banned from use in the United States. Concentrations of currently (1991) used pesticides were at or above a minimum reporting level in about 0.3 percent of the analyses.

The geographic patterns in the occurrence and distribution of pesticides in the ACF River basin (as defined by data collected during 1960-91) are, as expected, somewhat defined by land-use patterns. DDT (together with DDD and DDE) were detected in wide distribution in the sediments and aquatic biota of primarily mainstem and reservoir sites in the Chattahoochee, Flint, and Apalachicola drainages. DDT was used through 1973 as an insecticide on cotton, fruits, and vegetables; and for mosquito control, so its widespread occurrence in both urban and agricultural settings is consistent with its use. Chlordane, heptachlor, dieldrin, and related compounds were agriculturally used through 1974, but predominantly as termiticides through the late 1980’s. Compounds in these groups have been found in the sediments and aquatic biota of tributary streams draining the Atlanta Metropolitan area and of mainstem reaches and reservoirs of the Chattahoochee River downstream from the Atlanta and Columbus, Ga., Metropolitan areas. The phenoxy-acid herbicides are widely used in residential, commercial/ industrial, agricultural, and silvicultural areas of the ACF River basin. Detectable concentrations of 2,4-D were found in most of the surface-waters sampled in the Atlanta Metropolitan area.

It is unfortunate that only limited inference can be drawn on temporal patterns. Many of the Federal and State agency pesticide-monitoring programs have been targeted to known sources and areas of contamination, an approach consistent with regulatory requirements focused on human health; and either were synoptic in nature or were conducted during a limited period of time. Thus, the composite temporal picture represented by these sampling efforts is inherently patchy.

INTRODUCTION

In 1991, the U.S. Geological Survey (USGS) began full-scale implementation of the National Water-Quality Assessment (NAWQA) program (Leahy and others, 1990). The Apalachicola-Chattahoochee-Flint (ACF) River basin was among the first of 20 NAWQA study units selected in 1991 for study under the full-scale implementation plan (Wangsness and Frick, 1991). A major emphasis of the NAWQA program is to examine the occurrence and distribution of pesticides in the Nation's surface- and ground-water resources.

The ACF River basin drains about 19,600 mi^2 in western Georgia (73 percent of the basin), southeastern Alabama (14 percent), and the Florida panhandle (13 percent). The basin is comprised of the Chattahoochee and Flint River drainages that meet in Lake Seminole to form the Apalachicola River. The Apalachicola River flows through Florida into the Apalachicola Bay, and discharges into the Gulf of Mexico. The location of the ACF River basin and its rivers is shown in figure 1, and the counties in the basin are shown in figure 2. The ACF River basin lies in three physiographic provinces: the Blue Ridge Province, which includes headwaters of the Chattahoochee River in the northwestern part of the study area; the Piedmont Province, which includes the upper and middle Chattahoochee River and the upper Flint River; and the Coastal Plain Province, which includes the southern part of the basin (fig. 3). Dominant land uses in the ACF River basin are forestry and agriculture. Most agricultural land in the northern part of the ACF River basin is used for pastures and, to a lesser extent, poultry production; while most agricultural land in the southern part of the ACF River basin is used for row crops and, to a lesser extent, orchards. In 1990, the population of the ACF River basin was about 2.64 million people, 60 percent of whom lived in the Metropolitan Atlanta area. For a more thorough description of the environmental setting of the ACF River basin, see Couch and others (1996).

Purpose and Scope

The purpose of this report is to (1) describe county-level data for farmland and silvicultural acreage, and agricultural chemical use; (2) identify and estimate the quantity of many of the currently used pesticides by land use in the Apalachicola-Chattahoochee-Flint River basin; and (3) describe the occurrence and distribution (both spatial and temporal) of pesticides in water, bottom sediment, and aquatic biota on the basis of historical data.

The commonly used pesticides were identified on the basis of published pesticide-use surveys, communications with personnel at Federal and State agencies, and examination of products available for sale at retail stores in urban and suburban areas. Estimates of the quantities of pesticides currently applied to land in the basin are on the basis of published county-level crop acreage statistics and recommended pesticide application rates. The historical data used to describe the occurrence and distribution of pesticide residues in various media are from data in USGS and U.S. Environmental Protection Agency (USEPA) digital databases. These data were collected for the periods from 1971 through 1989 for the USGS database, and from 1960 through 1991 for the USEPA database.

Most historical water-quality data that are available on pesticide occurrence in the ACF River basin are represented by the organochlorine insecticides and PCB's. The uses of most of the organochlorine compounds have been banned in the United States because of serious health risks to humans, aquatic biota, and consumers of aquatic biota (USEPA, 1990). Most pesticides that are currently used in the basin are more degradable than the organochlorine compounds; and therefore, are environmentally less persistent. Environmental monitoring of currently-used (1991) pesticides is primarily restricted to the organophosphate insecticides, and the phenoxy-acid and triazine herbicides. Some of these compounds are represented in the historical water-quality data, but the sparsity of those data prohibits comparison, in this report, of pesticide use and occurrence in surface and groundwaters. However, one of the goals of the USGS NAWQA program is to examine the relation between land use and the occurrence of many of the currently used pesticides. One component of the study in the ACF River basin is basinwide monitoring of many currently used pesticides, and intensive monitoring of small watersheds draining specific land uses to examine temporal patterns in pesticide occurrence. Future reports will discuss the relations between various land uses and the occurrence of many of the currently-used pesticides in surface and ground waters of the ACF River basin.

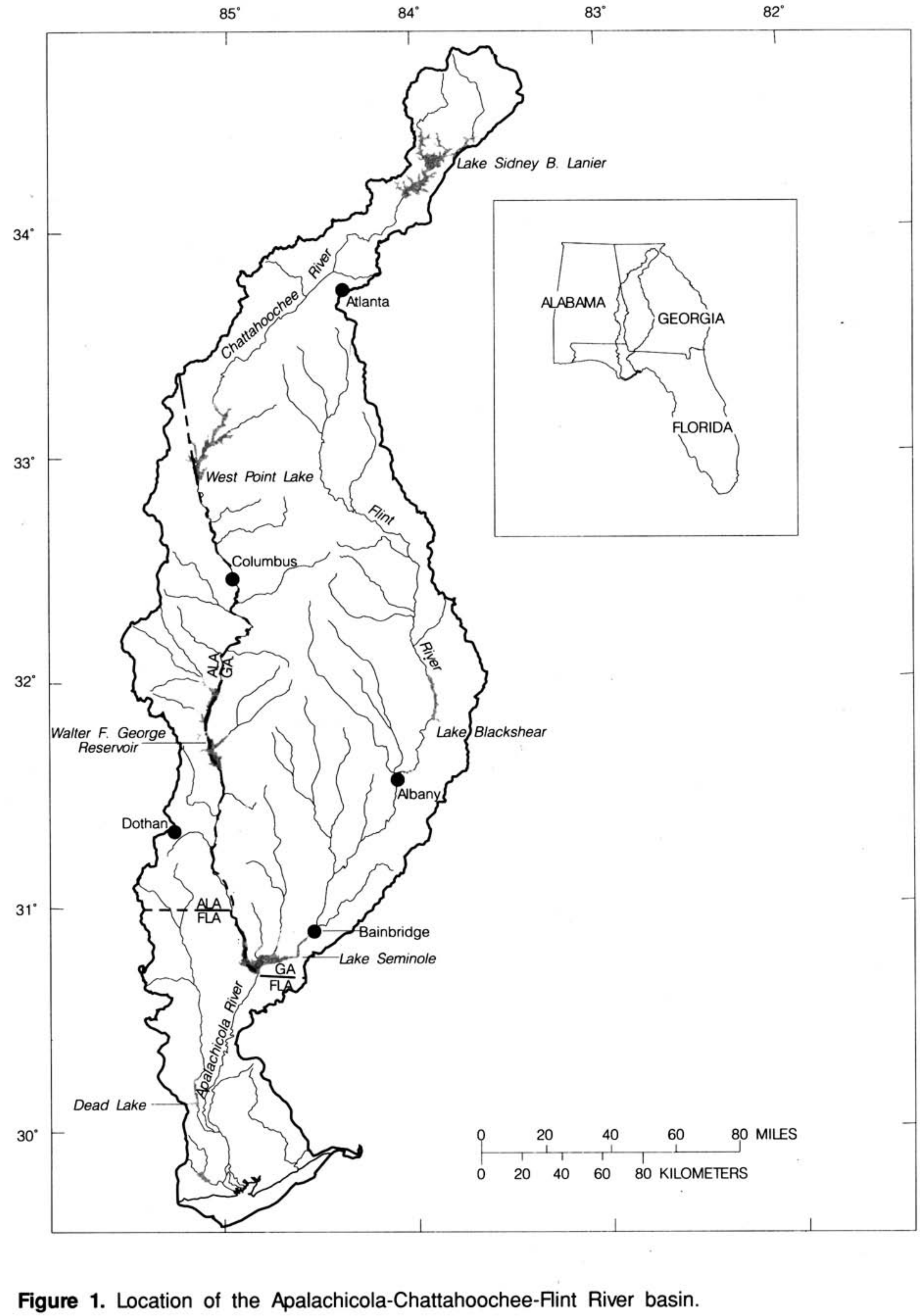

Figure 1. Location of the Apalachicola-Chattahoochee-Flint River basin.

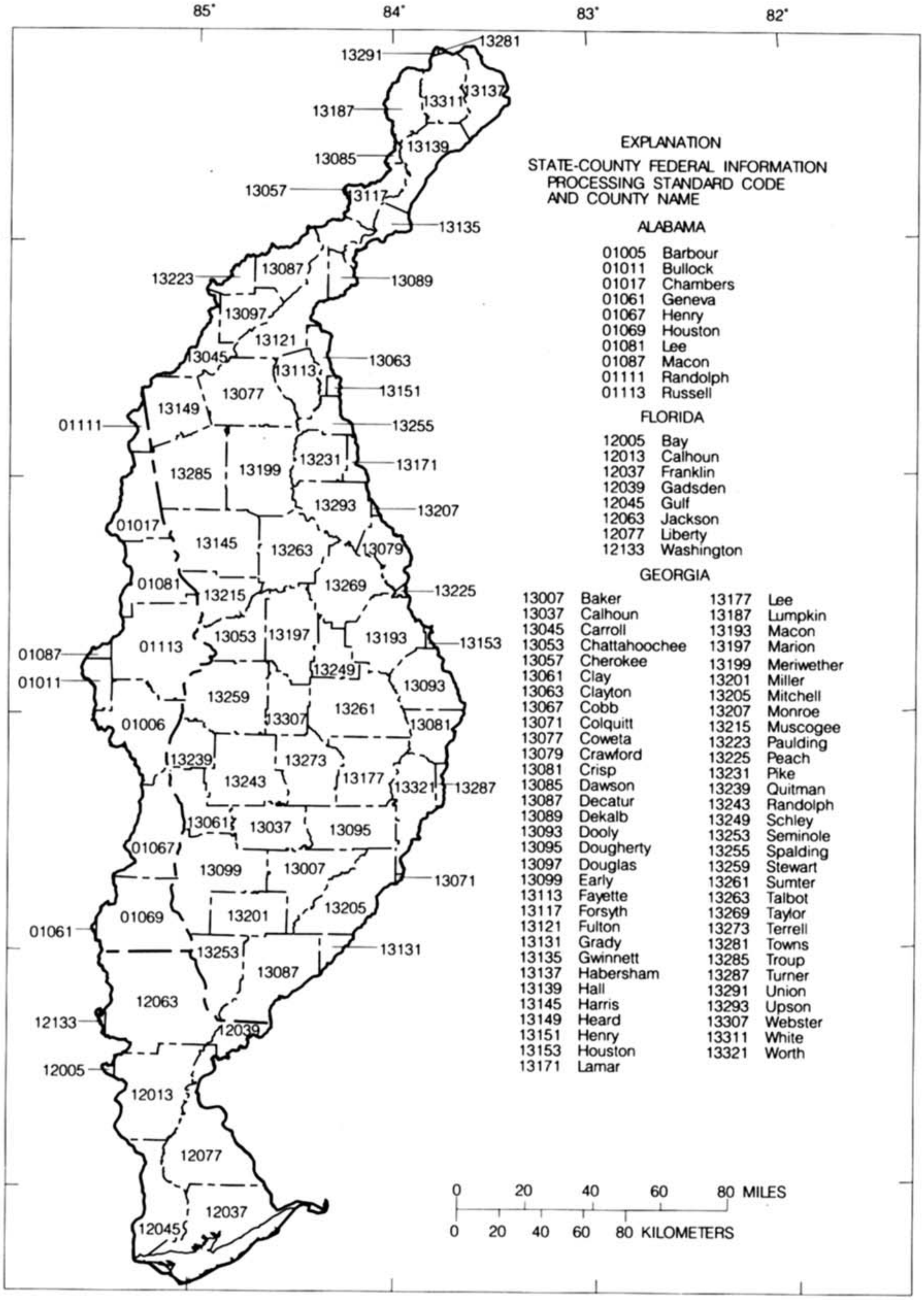

Figure 2. Locations and names of the counties in the Apalachicola-Chattahoochee-Flint River basin.

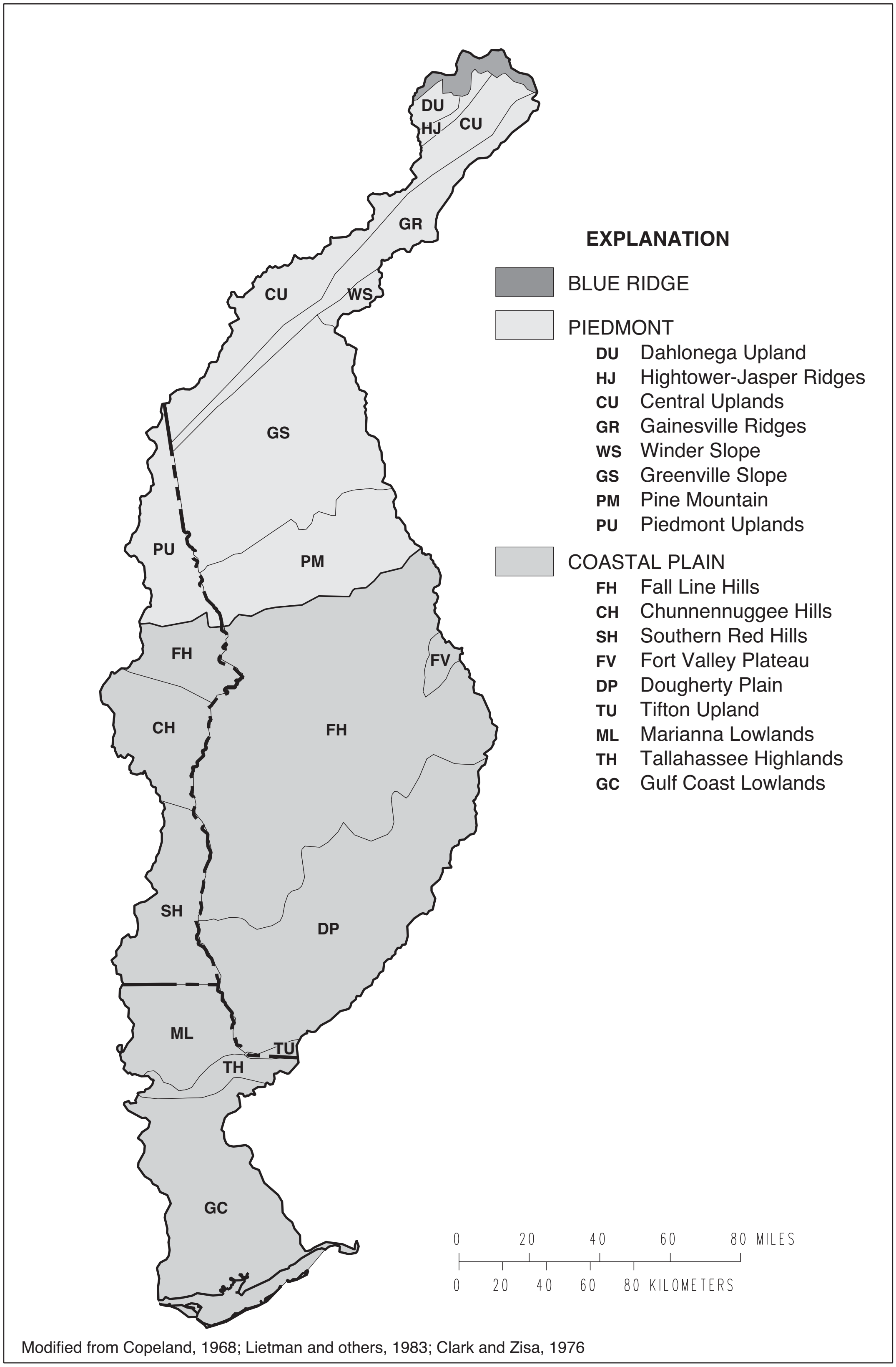

Figure 3. Physiographic provinces in the Apalachicola-Chattahoochee-Flint River basin.

Pesticide Characteristics and Properties

A pesticide is defined as any substance or mixture of substances intended to prevent, destroy, repel, or mitigate any pest or intended for use as a plant regulator, defoliant, or desiccant, according to the Federal Insecticide, Fungicide and Rodenticide Act (FIFRA) (Meister, 1992, p. D15). Pesticides are used to control insects, mites, nematodes, fungi, molds, weeds, birds, rodents, and microorganisms. Pesticides specifically applied to treat plants are called herbicides. Other kinds of pesticides are insecticides, nematocides, fungicides, bactericides, algicides, miticides (also called acaricides), and rodenticides. Pesticides are comprised of several classes of compounds on the basis of their chemical structure. Major classes of pesticides include the organochlorines or chlorinated hydrocarbons, organophosphates, carbamates, thiocarbamates, substituted acid amides, phenoxy acids, triazines, substituted ureas, dinitroanilines, bypyridiums, benzoic acids, synthetic pyrethrins or pyrethroids, aliphatic hydrocarbons, organometallic complexes, and inorganic pesticides (Delaplane, 1991, p. 403). Environmental fate and transport of pesticides is dependent in part upon their physical and chemical properties and the degradation processes for these compounds. Important physical and chemical properties include solubility in water, vapor pressure, octanol-water partitioning coefficient (K_{ow}), soil-sorption coefficient (K_{oc}), acid/base ionization equilibrium constants, and field half-life.

Pesticides that have the greatest tendency to be transported to ground water (leached) are those compounds that are relatively persistent in the soil and have little tendency to sorb onto soil organic material and clay minerals. The physical and chemical properties listed in table 1 (in the pocket in the back of the report) that are associated with increased pesticide-leaching potential are high solubility in water; low vapor pressure, K_{oc}, and K_{ow}; and long field-half life. The pesticides having the greatest leaching potentials generally have water solubilities greater than 30 mg/L, soil K_{oc} of less than from 300 to 500; or field half-lives greater than 21 days (U.S. Environmental Protection Agency, 1979). Climatic factors, agricultural practices, and soil and aquifer properties also influence the transport of agricultural chemicals to ground water.

Pesticides are transported to streams in surface runoff by two modes, either dissolved in runoff water (in solution) or attached to soil organic matter or clay minerals that are entrained in runoff (in suspension). Pesticides with appreciable transport in surface runoff in solution are those compounds with high water solubility, low K_{ow} and K_{oc}, low vapor pressure, and long field half-lives. Pesticides with appreciable transport in surface runoff in suspension also have low vapor pressures and long field half-lives, but with low water solubility, and high K_{ow} and K_{oc}. Climatic factors, agricultural practices, soil properties, and topographic relief also strongly influence the transport of agricultural chemicals in surface runoff to streams. Agricultural practices that reduce soil erosion also tend to reduce transport of pesticides in suspension in surface runoff; however, have less affect on pesticides in solution. Pesticides present in bottom sediments and aquatic biota generally are highly persistent, hydrophobic compounds.

Data Sources and Methods of Analyses

The “Land Use and Pesticide Use” and “Pesticide-Concentration Data” sections describe the types and sources of data that have been used and summarized with data limitations and assumptions. The data were compiled to estimate county and basin-wide pesticide use by various land uses.

U.S. Bureau of Census, Census of Agriculture Data

County-level data for 1974, 1978, 1982, and 1987 obtained from the U.S. Bureau of Census (1981a,b,c; 1989a,b,c) were used to estimate trends in crop acreage, the amount of land in farms, the amount of irrigated land, and amounts of agricultural chemicals applied to farmland in the ACF River basin. The U.S. Bureau of Census periodically collects data for a variety of agricultural land-use categories such as acreages of total farmland, total cropland, harvested cropland, pastureland, and farm woodland. Data are collected for both total and harvested cropland because harvested cropland can be substantially less than total cropland because some soil-improvement crops are not harvested, some crops fail and are abandoned, and some cropland is allowed to lie fallow. Harvested cropland is defined as land from which crops were harvested or hay was cut, and includes lands in orchards, citrus groves, vineyards, nurseries, and greenhouses. Data are also collected on the amount of farmland that is irrigated.

The agricultural chemical data collected by the U.S. Bureau of Census includes commercial fertilizers, lime, and pesticides. The data include types and amounts of pesticides used to control insects on hay and other crops; nematodes in crops; diseases in crops and orchards; weeds, grass or brush in crops and pasture; and chemicals used for defoliation or for growth control of crops or thinning of fruit. Data are also collected on harvested acres of corn, wheat, tobacco, soybeans, peanuts, cotton, and hay (U.S. Bureau of Census, 1989b). Data for land used to grow a variety of vegetables are also collected as part of the census; acreages for land double or triple cropped are counted only once. Census data collected for fruit and nut production includes total orchard acreage, pecan acreage, and peach acreage. Peach-acreage data were not available from the Bureau of Census for the 1974 census year. Crop categories cited in this report include most of the harvested cropland in the ACF River basin.

County-level data were used in all cases. All data in each category were assumed to be evenly distributed throughout a county. Because the basin boundary divides many of the counties along the edge of the basin (see figure 2), the numbers listed for the various data categories were multiplied by the percent of the county in the ACF River basin. County totals for the various data then were summed for each census year. The county totals were divided by total land area of a county to yield the density of data category so that comparisons among counties of varying sizes could be evaluated. Bar graphs were made to illustrate the changes over time and maps of density data were constructed to show comparisons among counties.

Some data were withheld by the U.S. Bureau of Census to avoid identification of individual farms; consequently, the following assumptions were made. When data were not available for one year, but were available for the other census year listed, the number of farms in the two years were compared to estimate the missing data. For example, if there were 50 farms and 10,000 acres of a crop in 1982, and 40 farms and crop acreage data withheld to avoid identification of individual farms in 1987, then a value of 8,000 acres was entered for 1987. In some cases, the number of acres was withheld for both census years. When this occurred, a value of zero was entered. The total yearly estimates used in the bar graphs treated missing data as zero values; consequently, the yearly estimates for the various items are biased on the low side.

Agricultural Statistics for Georgia, Alabama, and Florida

County-level data for 1989 and 1990 obtained from the Alabama, Florida, and Georgia Agricultural Statistics Services (1990) were used to estimate total acres harvested for corn, cotton, peanuts, and soybeans in the ACF River basin. Harvested acres were used so that the estimates could be compared to the U.S. Bureau of Census (1989a,b,c) data from earlier years.

Some assumptions were made about the data from each State. For Alabama, counties having less than 500 harvested acres of a crop are not published to avoid disclosing individual operations. These counties were treated as having zero acres (Alabama Agricultural Statistics Service, 1990). The Florida Agricultural Statistics Service (1990) lists county-level data for the major counties that grow corn, cotton, peanuts, and soybeans. The term “major” is not defined explicitly; however, the lowest reported value for the four crops is 500 acres. The Georgia Agricultural Statistics Service (1990) does not report data for counties having less than 100 acres for corn and soybeans and those having less than 50 acres for cotton and peanuts. Counties in Georgia without a number listed for a specific crop were treated as having zero acreage for that crop. Crops were assumed to be evenly distributed throughout the county.

The amount of harvested acreage for the various crop types per county was multiplied by the percent of the county in the ACF River basin. County totals of each crop type were summed to estimate the total acres harvested for corn, cotton, peanuts, and soybeans in the ACF River basin for 1989-90. Crop densities for each county in 1990 were calculated by dividing the total acres harvested for the various crop types by the number of square miles of land in the county. Maps were constructed using the county density numbers so that comparisons could be made among counties of varying sizes.

The Georgia Agricultural Statistics Service (1990) lists county-level data for several years. Georgia data for 1987 were compared to the U.S. Bureau of Census (1989a,b,c) data for corn, cotton, peanuts, and soybeans to test comparability of data. Agreement was generally good between the two data sets. The Georgia Agricultural Statistics Service data generally were higher than the U.S. Bureau of Census by about 5 percent.

Georgia Cooperative Extension Service

A survey of herbicides applied to agricultural land and the number of acres treated is taken in Georgia by the Georgia Cooperative Extension Service (CES) about every three years. Data collected as part of these surveys include the number of acres treated in each Extension District, crop type, herbicide trade name, and type of application. The data were used to estimate the amount of herbicides applied, and acreage treated, in the Georgia part of the ACF River basin in 1990 (Monks and Brown, 1991).

Total areas in each Cooperative Extension District were calculated and the percentage of each District in the ACF River basin was determined. Total acreage treated by each herbicide was calculated for each Cooperative Extension District. The total acreage treated was then multiplied by the percent of each District in the ACF River basin and summed for each herbicide type. This calculation estimates the total acres treated by each herbicide. Application rates recommended by the University of Georgia (Delaplane, 1991) were used to estimate the total amount of each herbicide (pounds of active ingredient) used. All application usage rates used were specific for the herbicide, crop type, and type of application. The application rates were multiplied by the acres treated, and the amount of active ingredient for each herbicide was summed to estimate the total herbicide use in the Georgia part of the ACF River basin.

U.S. Forest Service, Summary of Forestry Data

The U.S. Department of Agriculture, Forest Service, compiles forest statistics for states on a rotating temporal basis. Statistics are available for Alabama for 1990 (Vissage and Miller, 1991), for northwest Florida for 1987 (Brown, 1987), and for Georgia for 1989 (Thompson, 1989). County-level data listed in these reports were compiled to estimate the total number of forested acres in the ACF River basin and the distribution of the forested acres in various ownership classes. Ownership classes include national forests; miscellaneous Federal, State, county and municipal; forest industry; farmland; corporate; and individual. The last three ownership classes also are referred to collectively as nonindustrial private forest land.

Estimates of the acreage and distribution of forests in the basin were on the basis of county-level data in all ownership classes multiplied by the percent of the county in the ACF River basin (forest land was assumed to be evenly distributed throughout a county). Acreages in each ownership class were summed to estimate the amount and distribution of forest land in the ACF River basin. Also, forest density for each county was estimated by dividing the total acres of forested land in each county by the number of square miles of land in the county. Maps showing forest density by county were prepared so that comparisons could be made among counties. Data for the three States were combined although the data were not collected the same year.

U.S. Geological Survey and U.S. Environmental Protection Agency Water-Quality Databases

Pesticide-concentration data were obtained from the U.S. Geological Survey's National Water Information System (NWIS), and the U.S. Environmental Protection Agency's Storage and Retrieval System (STORET) databases. NWIS database contains data for 70 pesticides representing about 4,400 individual analyses for the period 1971-89, and the STORET database contains data for 99 pesticides representing about 15,200 individual analyses for the period 1960-91 for the ACF River basin. Pesticide analyses in these databases are summarized by compound class, sample medium, and occurrence above or below the minimum reporting levels. (Note: Analyses above a minimum reporting level are listed as a quantifiable concentration; analyses identified as being below a minimum reporting level are an indication that the laboratory analyst determined that the compound was present in the sample, but not at a quantifiable concentration.) The media included surface and ground water, bottom sediment, and aquatic biota. Bottom sediment refers to both fluvial transported material and material deposited at the bottom of impounded bodies of water. Data also are summarized by compound and data collection period so that temporal trends, if any, could be identified. The spatial distribution of selected pesticide-concentration data in the NWIS and STORET databases are presented in illustrations.

Minimum reporting levels of analyses performed at the USGS National Water Quality Laboratory were provided by William R. White (U.S. Geological Survey, written commun., 1993). For the ACF River basin these values are included in various tables of this report. Analyses have been contributed to the STORET database by 14 governmental agencies over a 31-year period (USGS data were eliminated in the original retrievals, so that double reporting would not occur). Consequently, most compounds having concentrations reported as below minimum reporting levels in STORET listed multiple minimum reporting levels. Many of the analyses were pre-1985 and a significant number were pre-1970, which made determination of minimum reporting levels of samples collected by 14 governmental agencies impractical. Therefore, reporting levels included in records with values below minimum reporting levels were assigned to records having values above minimum reporting levels. The most common reporting level and the range of reporting levels for most pesticides have been incorporated in various tables of this report. In a few cases, reporting levels were not entered or a value of zero was entered. These exceptions are so noted in the various tables. The analytical methods also are not referenced in many sample records. Differing analytical methods introduces additional variability into the data sets that may complicate direct comparisons of these data.

Spatial and temporal densities of data for specific pesticide compounds typically are too low to support analysis of degradation or environmental-processing pathways. For this analysis, concentration data for specific compounds were aggregated to the compound groups indicated in the following text. Information on metabolites, mixtures, and isomers was compiled from reports by USEPA (1979) and Lucius and others (1992). The DDT group includes DDD, *o,p'*-DDD, *p,p'*-DDD, DDE, DDE suspended, *o,p'*-DDE, *p,p'*-DDE, DDT, *o,p'*-DDT, *p,p'*-DDT, and the sum of DDT+DDE+DDD. The lindane group includes the *alpha*, *beta*, *delta*, and *gamma* isomers of BHC. The chlordane group contains *cis*- and *trans*-chlordane, chlordane technical mixture, *cis*- and *trans*-nonachlor, oxychlordane, 1-OH-chlordene, *cis*- and *trans*-chlordane + nonachlor, and hexachlorocyclopentadiene. Heptachlor is a component of the chlordane technical mixture but was also produced separately. Heptachlor has one major metabolite—heptachlor epoxide. The phenoxy-acid group includes 2,4-D, 2,4-DP, 2,4,5-T, and silvex. The dieldrin group includes dieldrin, aldrin, endrin, and endrin aldehyde. All of these compounds, with the exception of 2,4-D, 2,4-DP, and lindane are now banned by USEPA for use in the United States.

Federal and State Agency Programs Associated with Historical Pesticide Data

The USGS data in the NWIS database represent the efforts of both case-specific studies and routine monitoring programs designed to assess the occurrence and distribution of pesticides in aquatic environments. Surface-water and sediment samples were collected at several sites in the Peachtree Creek basin during the late spring and early summer of 1974 and analyzed for selected organochlorine compounds, phenoxy-acid herbicides, atrazine, and diazinon, as part of a Metropolitan Atlanta stormwater management project conducted in cooperation with the U.S. Army Corps of Engineers (USACOE), Savannah District, and DeKalb County, Ga. (J.R. George, written commun., 1973). The Chattahoochee River and several of its tributaries in the vicinity of Metropolitan Atlanta were sampled for selected pesticides in 1976 and 1977 as part of a study of the effects of point and nonpoint stormwater runoff on stream quality (McConnell, 1980).

The Chipola River near Altha, Fla., was sampled for pesticides in water and sediment during the period 1975-82, as a sampling site in the 180-station Pesticide Monitoring Network (PMN). The PMN was co-designed by the USGS and the USEPA to monitor pesticide occurrence in surface-water and sediment in the Nation’s major rivers as related to agricultural practices (Gilliom and others, 1985).

Two water-quality studies were conducted in the late 1970’s to provide data on the effects of intensive row-crop agriculture in southwestern Georgia. One study focused on water availability and water use, primarily in the Upper Floridan aquifer, as related to agriculture (Pollard and others, 1979), but included a synoptic survey of representative wells for pesticide contamination. The other study focused on surface-water runoff in the Spring Creek watershed, which drains approximately 485 square miles of the lower Coastal Plain into Lake Seminole. Surface-water samples were collected monthly and during six storm events from winter 1976 through summer 1978, and analyzed for selected organochlorine compounds, phenoxy-acid herbicides, total polychlorinated biphenyls (PCB’s), and total polychlorinated naphthalenes (PCN’s) (Radtke and others, 1980). Follow-up sampling was done in the Spring Creek watershed in 1986 and 1987 for comparison.

The USGS implemented a River-Quality Assessment (RQA) Program during the late 1970’s and early 1980’s to provide information on pollution-related water-quality issues in selected river basins in the United States. Two of these studies were conducted in the ACF River basin and included some data collection for pesticides. The Upper Chattahoochee RQA was conducted on the Chattahoochee River from its headwaters to West Point Dam, approximately 100 river miles downstream from Metropolitan Atlanta, during 1977-78 (Cherry and others, 1976). Sediment samples were collected from Lake Sidney Lanier, just upstream from Buford Dam, and from the Chattahoochee River near Suwanee, upstream from Atlanta, and analyzed for pesticides. The Apalachicola RQA, conducted during 1979-81, emphasized nutrient-detritus flow in the ecosystem as mediated by hydrodynamics, but included some sampling for organochlorine compounds, organophosphate insecticides, phenoxy-acid herbicides, and PCB’s in fine-grained sediments, whole-body Asiatic clam (*Corbicula manilensis*), and bottom-load organic detritus (Elder and others, 1988). Five mainstem sites along the full length of the Apalachicola River were sampled for pesticides.

West Point Reservoir, a 40-mile impoundment on the Chattahoochee River approximately 60 miles downstream from Metropolitan Atlanta, has been operated by the USACOE, Mobile District, since 1974. This reservoir, as the receiving body for much of the pollutant load from Metropolitan Atlanta, has been the focus of several water-quality studies. The USGS conducted a study of the reservoir during 1978-79. Bottom-sediment samples were collected at seven sites in the reservoir and three sites in the Chattahoochee River downstream from West Point Dam, and analyzed for organochlorine compounds, total PCB’s, and total PCN’s (Radtke and others, 1984).

A number of wells have been sampled, both temporally and synoptically, for pesticides, primarily in the southwestern Georgia and Florida panhandle portions of the ACF River basin. The most intensive synoptic sampling was done in 1981. A number of the Florida wells are public-supply wells.

STORET, although readily identified with the USEPA, was developed in 1962 by the U.S. Public Health Service (USPHS) as a repository for water-quality data, and placed into production as a National database in 1964 (Louis Hoelman, USEPA, oral commun., 1995). In 1970, when the USEPA was established by the Nixon administration, STORET and the water-quality monitoring activities represented in the database were given over to the newly-formed agency. Thus, pesticide data in the STORET database represent the collective efforts of many Federal and State agency programs targeted to (1) large-scale synoptic patterns in the occurrence and distribution of pesticides, (2) long-term monitoring of pesticides, or (3) small-scale assessments of contamination. Several USEPA programs are represented. The ‘core’ dataset represented in STORET is the National surface-water monitoring network designed and operated by the USPHS. Pesticides in surface waters were monitored during 1960-67, with three network sites in the ACF River basin, the Chattahoochee River at Atlanta (municipal water intake), the Chattahoochee River downstream from Columbus, Ga., and the Apalachicola River downstream from Lake Seminole (Jim Woodruff Dam).

In 1975, the USEPA undertook a National study of raw and finished drinking-water supplies that included three sites on the Chattahoochee River. Finished water from the DeKalb County (Metropolitan Atlanta) and City of Columbus, Ga., waterworks and raw water from the City of Atlanta waterworks were sampled for pesticides as part of this program. A National Organics Monitoring Survey was conducted by the USEPA in 1976, and the Chattahoochee River at Atlanta (municipal water intake) was one of the sites sampled for this survey. Pesticide occurrence within the distribution systems of major municipal and industrial waste-treatment facilities was the focus of a 1979 study conducted under contract to the USEPA. Seven sites in the Chattahoochee River near Metropolitan Atlanta were sampled in this program.

Three USEPA programs, born of concern for the harmful effects of organochlorines on aquatic life, provided data on the contamination of fish and shellfish with these compounds. Shellfish were collected at three sites in the estuary of the Apalachicola Bay during 1965-72 and analyzed for DDD, DDT, and dieldrin. In 1976, fish were collected at three sites on the Chattahoochee River, one downstream from Atlanta, and two downstream from Walter F. George Reservoir, and analyzed for PCB's as part of a National study on PCB residues in fish tissue. The National Study of Chemical Residues in Fish (USEPA, 1992), conducted during 1987, was a synoptic sampling of 388 stream sites Nationwide. Fish tissues collected at these sites were analyzed for selected organochlorine compounds, chlorpyrifos, PCB's, polychlorinated dibenzo-*p*-dioxins (PCDD's), and polychlorinated dibenzofurans (PCDF's).

The USACOE, Mobile District, conducted intensive synoptic surveys of bottom sediments and fish tissue in Lake Sydney Lanier, Walter F. George Reservoir, the lower Chattahoochee River navigation channel, Lake Seminole, and the Apalachicola River during 1978-79. Sediment and tissue samples were analyzed for most of the organochlorine compounds agriculturally used, 2,4-D, and PCB's.

The States of Florida and Georgia have ambient monitoring programs for surface-waters, sediments, and aquatic biota in cooperation with the USEPA. The Florida Department of Environmental Protection performed limited sampling of surface-waters for pesticides at two tributary sites along the lower Apalachicola River in 1972 and just upstream from the mouth of the Apalachicola River in 1976. During the early 1980's, several sites along the Chipola and Apalachicola Rivers, and in the Apalachicola Bay were sampled for pesticides in surface waters, sediments, and aquatic biota. The Georgia Department of Natural Resources, Environmental Protection Division, has been conducting ambient monitoring for pesticides in sediments and fish tissues since 1973 and in surface-water samples since 1990, at mainstem river sites in the ACF River basin (Georgia Department of Natural Resources, 1994). Two of the 'core' sites in their network (sites sampled annually) are located at the Chattahoochee and Flint Rivers downstream from Metropolitan Atlanta. Several other sites along both mainstems are sampled on a three-year rotation.

The Georgia Department of Natural Resources, Georgia Geologic Survey, has been conducting ambient monitoring of the State's deep aquifer systems for pesticides since 1984 (Davis, 1990), primarily in the Coastal Plain physiographic province where ground-water availability and use are the most extensive. Approximately 50 of these monitoring wells are located in the ACF River basin.

Acknowledgments

The USGS acknowledges the Cooperative Extension Service (CES) and U.S. Soil Conservation Service (SCS) personnel in many counties in the ACF River basin, and the crop specialists (CES) at the Rural Development Center, Tifton, Ga., for assisting in identifying commonly used pesticides. The USGS also acknowledges personnel at the U.S. Department of Agriculture (USDA), Agricultural Research Service, Tifton, Ga., for providing data on pesticide characteristics, fate, and transport.

LAND USE AND PESTICIDE USE

Pesticide-use data were evaluated to determine types of compounds used and when possible, the quantities applied in the basin and the principal application areas in the basin. Table 1 lists many of the common pesticides currently used in the ACF River basin, along with their properties and characteristics. When quantitative data were available, amounts of pesticides used in the ACF River basin were estimated. The pesticides used in agricultural, silvicultural, and urban and suburban areas in the ACF River basin are presented in the following sections of the report.

Agriculture

Information from the U.S. Bureau of Census and the Agricultural Statistics Services for Alabama, Florida, and Georgia were used to estimate pesticide use in a variety of agricultural land-use categories for the counties in the ACF River basin and for the basin as a whole. Amounts of herbicides applied to various crops were estimated from the 1990 Georgia Herbicide Survey Summary (Monks and Brown, 1991). Pesticide data were used to identify types and amounts of high-use pesticides applied and crops treated in the ACF River basin.

Categories of land use on farms in the basin that were inventoried during the agricultural census in 1974, 1978, 1982, and 1987 included total farmland, total pastureland, total woodland, total cropland, and harvested cropland (fig. 4). Total farmland has decreased every agricultural census year from 1974 to 1987 on the basis of agricultural census data. The percentage of county in farmland in the ACF River basin is shown in figure 5 (see Appendix, page 38). In 1987, about 33 percent (4.2 million acres) of the ACF River basin was in farms. Miller, Terrell, Seminole, Mitchell, Crisp, Calhoun, Dooly, and Turner Counties, Ga., had the greatest percentages of the county in total farmland. Figure 6 (see Appendix, page 39) shows the number of irrigated acres per square mile of land in 1987. The distribution of pastureland in the basin, by county, is shown in figure 7 (see Appendix, page 40). Pastureland comprised 28 percent of the total farmland and about 9 percent of all land in the ACF River basin in 1987. Counties having the greatest density of pastureland, in descending order, were Bullock County, Ala., Miller, Forsyth, and Carroll Counties, Ga., and Chambers County, Ala. The distribution of woodland in farms among the counties in 1987 is shown in figure 8 (see Appendix, page 41). Total woodland in farms makes up about 10 percent of the ACF River basin.

Total cropland in the ACF River basin in 1987 represented about 18 percent of the basin and 56 percent of the total farmland. The distribution of cropland in the basin, by county, is shown in figure 9 (see Appendix, page 42). About 55 percent of the total cropland and about 10 percent of the basin is harvested. In 1987, the agricultural counties having the highest total harvested cropland in farms were Jackson County, Fla.; Mitchell County, Ala.; Dooly County, Ga.; Houston County Ala.; and Worth; Colquitt; and Sumter Counties, Ga. The harvested cropland in these counties ranged from 93,400 to 80,700 acres. In 1987, the counties having the highest density of harvested cropland in farms (fig. 10, see Appendix, page 43) were Crisp, Dooly, Seminole, Miller, Mitchell, Peach, Calhoun, and Terrell Counties, Ga.

Harvested acreages of selected crops grown in the ACF River basin in 1974, 1978, 1982, 1987, 1989, and 1990 are shown in figures 11 and 12. U.S. Bureau of Census (1981a,b,c; 1989a,b,c) data were used for 1974, 1978, 1982, and 1987 and State Agricultural Statistics Services data were used for 1989 and 1990. The major crops grown in the ACF River basin in 1990 in the order of acreage harvested were peanuts, soybeans, corn, wheat, hay and cotton. Harvested acreages for these crops ranged from 505,000 acres for peanuts to 144,000 acres for hay. The order of major crop types changes from year to year in response to market conditions, government programs, and the weather. The densities of the major crop types harvested in the ACF River basin, by county, are shown in figures 13-18 (see Appendix, pages 44-49. Acreage planted in orchards for 1974, 1978, 1982, and 1987 is shown in figure 19. In 1987, about 80,000 acres in the ACF River basin were planted in orchards, primarily pecan orchards. Density of orchards in the ACF River basin in 1987 by county is shown in figure 20 (see Appendix, page 50) and the density of pecan trees in counties in the basin is shown in figure 21 (see Appendix, page 51).

Agricultural activity in the ACF River basin is predominately concentrated in that part of the basin in the Coastal Plain physiographic province. Hay is the only crop that is not predominately grown in the Coastal Plain part of the basin, but is predominately grown in that part of the basin in the Piedmont physiographic province north and south of Atlanta. A summary of the counties in the uppermost 10 percent of each category of harvested crops (acres per square mile of county) and pecan trees (number of trees per square mile of county) is listed in table 2.

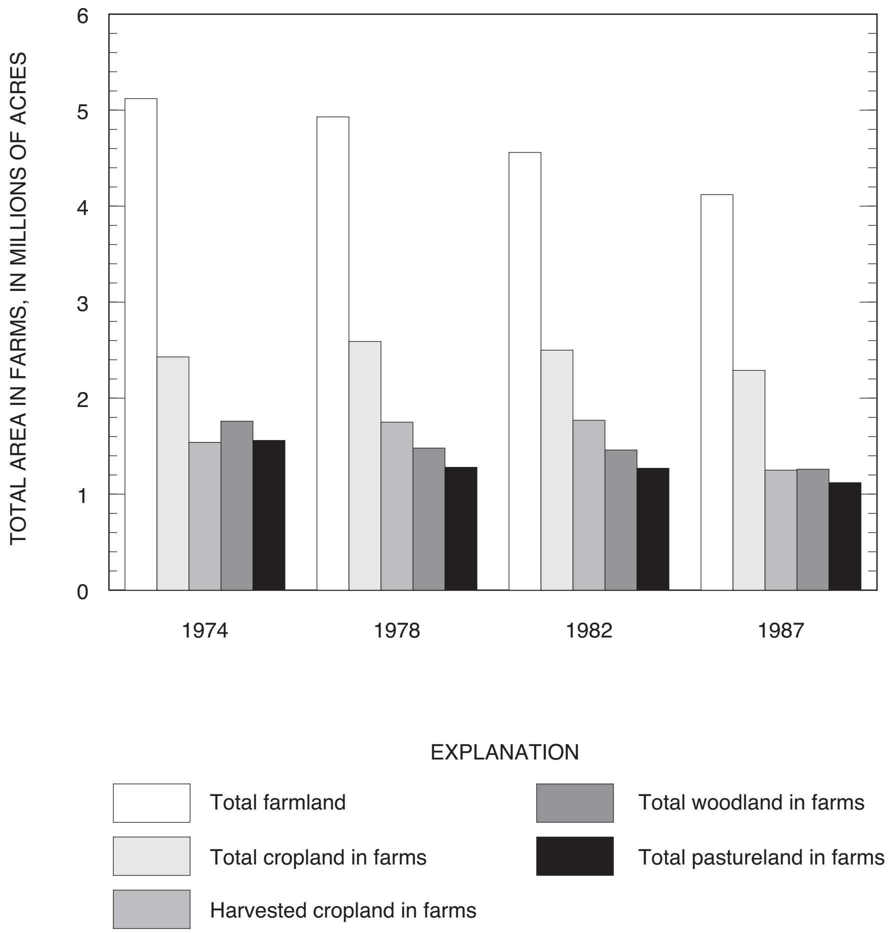

Figure 4. Total areas in farms; and selected categories of cropland, harvested cropland, woodland, and pastureland in farms in the Apalachicola-Chattahoochee-Flint River basin, 1974, 1978, 1982, and 1987.

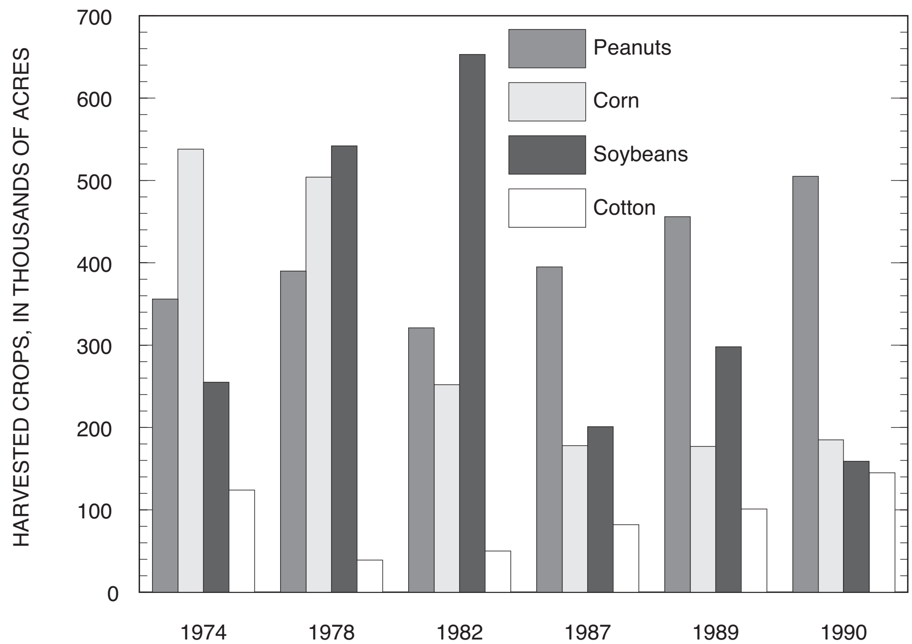

Figure 11. Harvested acres of peanuts, corn, soybeans, and cotton in the Apalachicola-Chattahoochee-Flint River basin, 1974, 1978, 1982, 1987, 1989, and 1990.

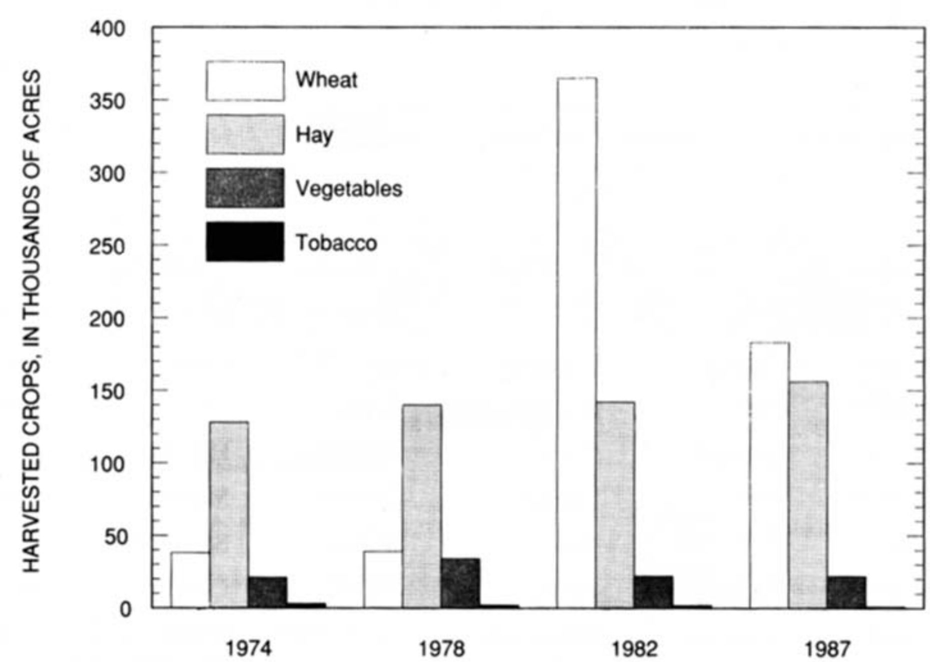

Figure 12. Harvested acres of hay, tobacco, vegetables, and wheat in the Apalachicola-Chattahoochee-Flint River basin, 1974, 1978, 1982, and 1987.

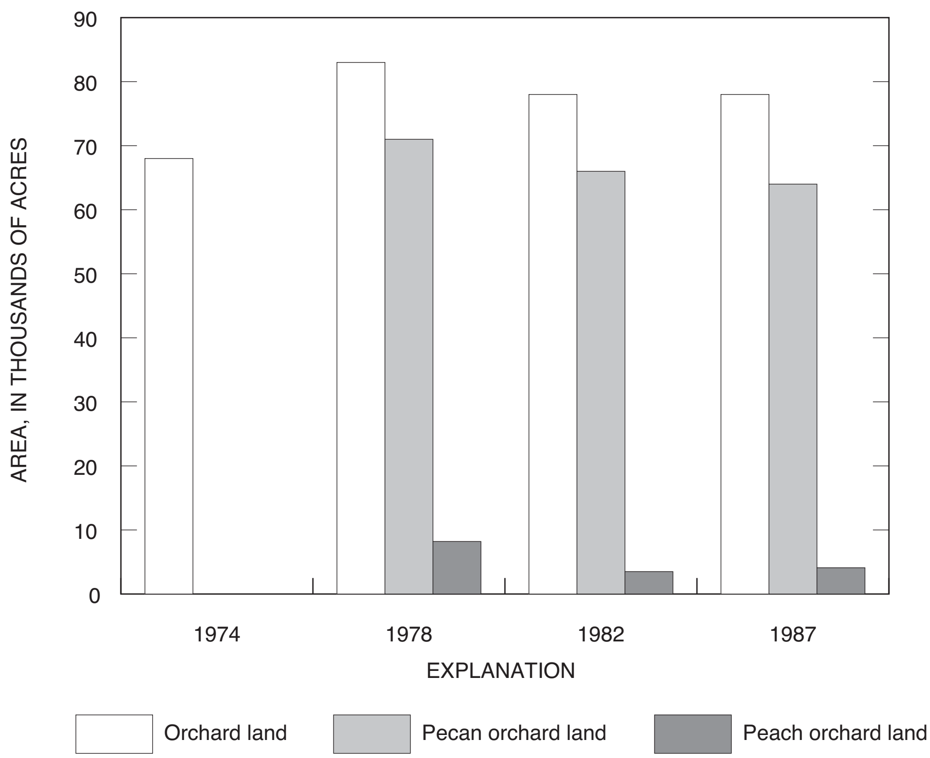

Figure 19. Total acres of orchards, pecan orchards, and peach orchards in the Apalachicola-Chattahoochee-Flint River basin, 1974, 1978, 1982, and 1987.

Table 2. Counties in the uppermost 10 percent of harvested crop density (ranked by acres per square mile of county) for the major crops in the Apalachicola-Chattahoochee-Flint River basin, 1990
[All counties are in Georgia, except where otherwise noted]

Corn	Cotton	Hay	Peanuts	Pecans[1,2]	Soybeans	Wheat[2]
Grady	Dooly	Carroll	Miller	Dougherty	Peach	Peach
Seminole	Colquitt	Fayette	Seminole	Lee	Crisp	Dooly
Miller	Seminole	Henry	Houston, Ala.	Peach	Worth	Terrell
Baker	Calhoun	Forsyth	Crisp	Mitchell	Houston	Crisp
Mitchell	Mitchell	Hall	Turner	Calhoun	Macon	Sumter
Decatur	Crisp	Miller	Worth	Macon	Sumter	Macon
Lee	Baker	Habersham	Dooly	Terrell	Colquitt	Houston
Worth	Turner	Coweta	Henry, Ala.	Crisp	Miller	Calhoun

1. Counties are ranked by number of pecan trees per square mile.
2. Data are from the U.S. Bureau of Census (1989a, 1989b, 1989c).

The times of the year that these crops are planted and harvested are important because many pesticides are applied at specific stages of a crop's growth cycle. Pesticide applications commonly include preplant, preemergent, and one or more postemergent applications. Usual planting and harvesting times for the major crop types in the ACF River basin, compiled from data obtained from the Alabama, Florida, and Georgia Agricultural Statistics Service and the crop specialists at the CES (Rural Development Center, Tifton, Ga., written commun., 1992) are presented in table 3.

Agricultural pesticide-use patterns mimic crop patterns. Most agricultural pesticide use is in the Coastal Plain Province. The acreage treated with various categories of pesticides in the ACF River basin as estimated from crop acreages obtained from the agricultural census data for 1974, 1978, 1982, and 1987 reported by the U.S. Bureau of Census (1981a,b,c: 1989a,b,c) are shown in figure 22. Agricultural pesticide use in the basin appears to have peaked between 1978 and 1987. Almost 2 million acre-treatments were made to agricultural land during 1987. The main categories of pesticides applied were those used to control weeds in crops and pastures (41 percent) and insects on hay and crops (32 percent). Figure 23 (see Appendix, page 52) shows the acre-treatments per square mile for the ACF River basin by county in 1987. Counties in the ACF River basin in the uppermost 10 percent of pesticide use included Seminole, Dooly, Crisp, Calhoun, Mitchell, Miller, Turner, and Peach Counties in Georgia.

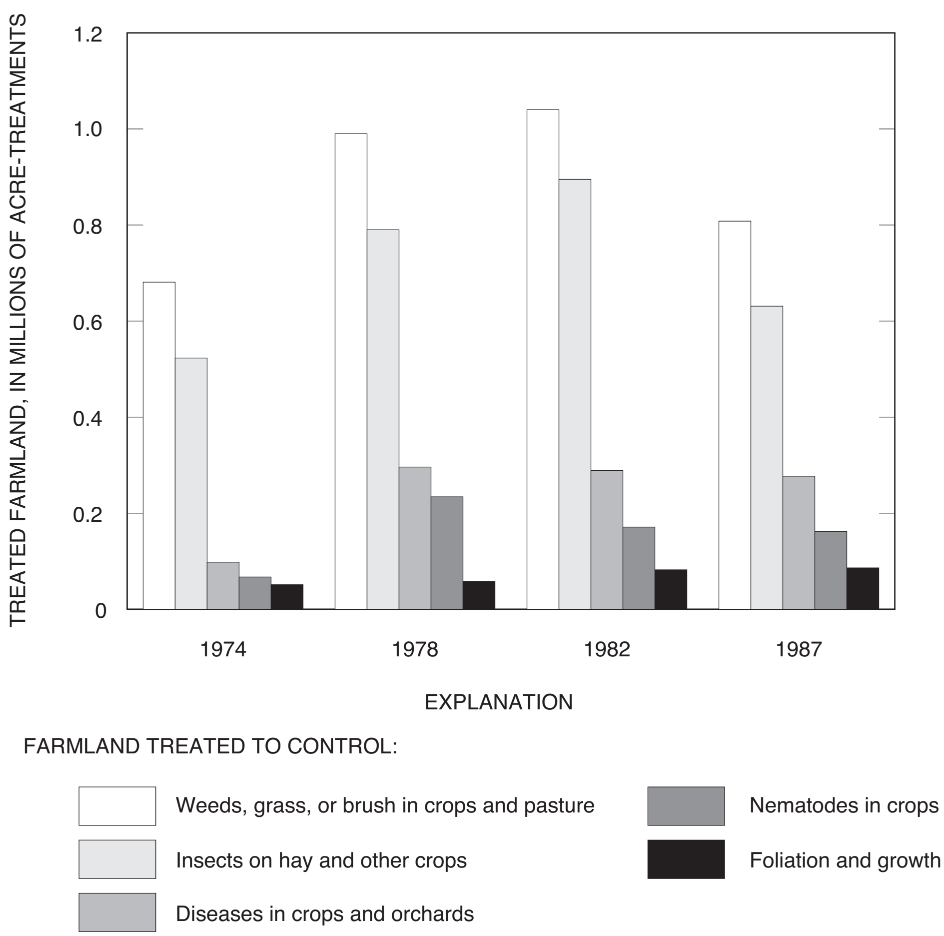

Figure 22. Total farmland treated with pesticides for weed control, insects, plant diseases, nematodes, and defoliants in the Apalachicola-Chattahoochee-Flint River basin, 1974, 1978, 1982, and 1987.

Table 3. Usual planting and harvesting times for the major crop types in the Apalachicola-Chattahoochee-Flint River basin
[Sources: Alabama Agricultural Statistics Service (1990); Florida Agricultural Statistics Service (1990); and Georgia Agricultural Statistics Service (1990)]

Crop type, by state	Usual planting dates	Most active harvesting dates
Corn		
Alabama	March 5 to May 15	August 20 to September 30
Florida	February 15 to April 25	September 1 to October 1
Georgia	February 20 to May 15	August 7 to September 25
Cotton		
Alabama	March 5 to May 25	September 25 to November 20
Florida	April 1 to May 15	October 1 to November 1
Georgia	March 25 to June 3	September 25 to November 25
Hay		
Alabama	not applicable	May 1 to October 1
Florida	not applicable	May 10 to November 20
Georgia	not applicable	May 1 to October 15
Peanuts		
Alabama	April 1 to May 15	September 15 to October 20
Florida	April 1 to May 15	September 15 to October 15
Georgia	March 25 to June 1	September 1 to October 20
Pecans		
Alabama	not applicable	October 20 to November 30
Florida	not applicable	November 15 to December 15
Georgia	not applicable	November 15 to December 15
Soybeans		
Alabama	May 5 to July 15	October 15 to November 15
Florida	May 1 to July 15	November 1 to November 25
Georgia	May 1 to July 10	October 10 to December 3
Wheat		
Alabama	September 15 to December 15	May 15 to June 15
Florida	October 15 to December 1	May 15 to May 31
Georgia	September 25 to December 20	May 15 to June 25

The main herbicides used, pounds of active ingredient used, acres treated, and main crop(s) treated in the Georgia part of the ACF River basin during 1990 are listed in table 4. Data compiled from the Georgia Herbicide Use Survey Summary (Monks and Brown, 1991) indicate that bentazon, paraquat, 2,4-DB, methanearsonates (MSMA/DSMA), alachlor, and pendimethalin were used to treat the largest number of acres (from 307,000 to 205,000 acres); and alachlor, MSMA/DSMA, fluometuron, atrazine, metolachlor, and bentazon were applied in the greatest quantities (from 506,000 to 185,000 pounds of active ingredient) in the Georgia part of the ACF River basin. Since 1990, the use of alachlor in Georgia has decreased dramatically (about 98 percent) in response to market conditions (Steve M. Brown, University of Georgia, CES, personal commun., 1992). Although alachlor use is not banned in Georgia, peanut wholesalers no longer will buy peanuts treated with alachlor. Alachlor is banned for use in Florida. Metolachlor, rather than alachlor, is now being applied to peanuts. Non-herbicide pesticide use was difficult to estimate. Pesticides other than herbicides are used only when necessary to control some type of infestation (nematodes, fungi, insects). A survey of CES and SCS county agents and information from the Georgia Pest Control Handbook (Delaplane, 1991) and Brown and Brown (1992) shows that chlorothalonil, aldicarb, chlorpyrifos, methomyl, thiodicarb, carbaryl, acephate, fonofos, methyl parathion, terbufos, disulfoton, phorate, triphenyltin hydroxide (TPTH), and synthetic pyrethroids/pyrethrins are commonly used.

Application periods of the principal agricultural pesticides span a calender year in the ACF River basin (table 5). However, agricultural pesticides are applied most intensively and on a broader range of crop types from March 1 to September 30 in any given year.

Table 4. Selected herbicides applied to crops in the Georgia part of the Apalachicola-Chattahoochee-Flint River basin, 1990

Common name of herbicide	Active ingredient applied (in pounds per year)	Number of acres treated	Main crop(s) treated
2,4-D	115,000	176,000	Grains, hay
2,4-DB	76,300	286,000	Peanuts
Acifluorfen	10,400	26,100	Peanuts, soybeans
Alachlor	506,000	205,000	Peanuts, corn
Atrazine	224,000	145,000	Corn
Benefin	126,000	95,900	Peanuts
Bentazon	185,000	307,000	Peanuts
Butylate	54,800	18,300	Corn
Chlorimuron	1,360	144,000	Peanuts, soybeans
Cyanazine	75,600	82,100	Cotton
Dicamba	14,500	39,100	Hay
Diuron	30,700	33,400	Cotton, hay
EPTC	26,000	5,210	Corn
Ethalfluralin	98,700	134,000	Peanuts, soybeans
Fenoxaprop-ethyl	1,740	11,600	Peanuts, cotton
Fluazifop-butyl	3,500	22,800	Cotton, soybeans
Fluometuron	229,000	171,000	Cotton
Glyphosate	22,700	13,500	All
Imazaquin	1,340	10,300	Soybeans
Methanearsonate	474,000	232,000	Cotton
Methazole	26,100	31,300	Cotton
Metolachlor	187,000	199,000	Peanuts
Metribuzin	22,400	86,400	Soybeans
Norflurazon	86,600	66,900	Cotton
Paraquat	43,500	286,000	Peanuts
Pendimethalin	173,000	205,000	All
Sethoxydim	27,300	117,000	Peanuts
Trifluralin	92,400	124,000	Cotton, soybeans
Vernolate	117,000	51,200	Peanuts

Table 5. Agricultural pesticide application times, by crop type, in the Apalachicola-Chattahoochee-Flint River basin

Crop and pesticide types	January				February				March				April				May				June				July				August				September				October				November				December			
Corn																																																
Alachlor									■	■	■	■	■	■	■	■																																
Atrazine								■	■	■	■	■	■	■	■	■	■																															
Butylate					■	■	■	■	■	■	■	■	■																																			
Pendimethalin										■	■	■	■	■	■	■	■																															
Terbufos									■	■	■	■	■	■	■	■																																
Parathion-Methyl																				■	■	■	■	■	■	■																						
Cotton																																																
Cyanazine																			■	■	■	■	■	■	■	■	■	■																				
Fluometuron											■	■	■	■	■	■	■	■	■	■	■	■	■	■																								
MSMA, DSMA														■	■	■	■	■	■	■	■	■	■	■	■																							
Norflurazon												■	■	■	■	■	■	■	■	■																												
Pendimethalin									■	■	■	■	■	■	■	■	■	■	■	■																												
Trifluralin									■	■	■	■	■	■	■	■	■	■	■	■																												
Aldicarb												■	■	■	■	■	■	■	■	■	■	■	■	■																								
Chlorpyrifos																	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■																
Cyfluthrin																				■	■	■	■	■	■	■	■	■	■	■	■	■																
Cyhalothrin-lambda																				■	■	■	■	■	■	■	■	■	■	■	■	■																
Cypermethrin																				■	■	■	■	■	■	■	■	■	■	■	■	■																
Esfenvalerate																				■	■	■	■	■	■	■	■	■	■	■	■	■																
Thiodicarb																															■	■	■															
Tralomethrin																				■	■	■	■	■	■	■	■	■	■	■	■	■																
Hay																																																
2,4-D Amine, acid									■	■	■	■	■	■	■	■																																
2,4-D Ester	■	■	■	■	■	■	■	■	■	■	■																														■	■	■	■	■	■	■	■
Dicamba							■	■	■	■	■	■	■	■	■	■	■																															
Paraquat					■	■	■	■	■	■																											■	■	■	■	■	■	■	■				
Triclopyr																	■	■	■	■	■	■	■	■																								

Table 5. Agricultural pesticide application times, by crop type, in the Apalachicola-Chattahoochee-Flint River basin—Continued

Crop and pesticide types	January				February				March				April				May				June				July				August				September				October				November				December			
Carbaryl																																			X	X	X	X	X	X	X	X	X	X				
Peanuts																																																
Acifluorifen																		X	X	X	X	X	X	X																								
Benefin												X	X	X	X	X	X	X	X	X																												
Bentazon																		X	X	X	X	X	X	X																								
Chlorimuron																								X	X	X	X	X	X	X	X																	
2,4-DB																				X	X	X	X	X	X	X	X	X	X	X																		
Ethalfluralin												X	X	X	X	X	X	X	X	X																												
Metolachlor												X	X	X	X	X	X	X	X	X	X																											
Paraquat															X	X	X	X	X	X	X	X	X	X																								
Pendimethalin												X	X	X	X	X	X	X	X	X																												
Sethoydim																					X	X	X	X	X	X	X	X																				
Acephate																			X	X	X	X	X	X																								
Aldicarb													X	X	X	X	X	X	X	X	X	X	X	X																								
Chlorothalonil																					X	X	X	X	X	X	X	X	X	X	X	X																
Chlorpyrifos																			X	X	X	X	X	X																								
Esfenvalerate																											X	X	X	X	X	X	X	X														
Fonofos																			X	X	X	X	X	X																								
Methomyl																											X	X	X	X	X	X	X	X														
Pecans																																																
Diuron										X	X	X	X	X	X	X																																
Glyphosate										X	X	X	X												X	X	X	X					X	X	X	X	X	X	X									
Oryzalin										X	X	X	X	X																																		
Simazine										X	X	X	X	X	X	X																									X	X	X	X	X	X		
Aldicarb																	X	X	X	X	X	X	X	X	X	X																						
Carbaryl																													X	X	X	X	X	X	X	X												
Chlorpyrifos																			X	X	X	X	X	X						X	X	X	X	X														

Table 5. Agricultural pesticide application times, by crop type, in the Apalachicola-Chattahoochee-Flint River basin—Continued

Crop and pesticide types	January				February				March				April				May				June				July				August				September				October				November				December			
Cypermethrin																													■	■	■	■	■	■	■	■												
Dimethoate																■	■	■	■																													
Disulfoton															■	■	■	■	■	■									■	■	■	■	■	■	■	■												
Endosulfan																		■	■	■	■	■	■						■	■	■	■	■	■	■	■												
TPTH											■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■																		
Soybeans																																																
Acifluorfen																			■	■	■	■	■	■	■																							
Bentazon																			■	■	■	■	■	■	■																							
Chlorimuron																	■	■	■	■	■	■	■	■	■	■																						
Ethalfluralin																■	■	■	■	■	■	■	■	■																								
Metribuzin																	■	■	■	■	■	■	■	■	■																							
Paraquat																	■	■	■				■	■	■																							
Pendimethalin																	■	■	■	■	■	■	■	■	■	■																						
Sethoydim																					■	■	■	■	■	■	■	■																				
Trifluralin																	■	■	■	■	■	■	■	■	■	■																						
Acephate																												■	■	■	■	■	■	■	■	■	■											
Parathion-Methyl																												■	■	■	■	■	■	■	■	■	■											
Permethrin																												■	■	■	■	■	■	■	■	■	■											
Thiodicarb																												■	■	■	■	■	■	■	■	■	■											
Tralomethrin																												■	■	■	■	■	■	■	■	■	■											
Wheat																																																
2,4-D	■	■	■	■	■	■	■	■																																	■	■	■	■	■	■	■	■
Propiconazole																																							■	■	■	■	■	■	■	■		
Dimethoate												■	■	■	■	■	■	■																									■	■	■	■		
Disulfoton																																					■	■	■	■	■	■	■	■				
Phorate																																					■	■	■	■	■	■	■	■				
Parathion-Methyl												■	■	■	■	■	■	■																									■	■				

Silviculture

Silviculture refers to the development, cultivation, and care of forests. Qualitative data from the University of Georgia and the U.S. Forest Service were collected to identify high-use, silvicultural pesticides and areas potentially vulnerable to pesticide contamination. Following the procedures summarized in the “Data Sources and Methods of Analysis” section of this report, the ACF River basin was estimated to be about 64 percent forested (includes woodland in farms) in the late 1980’s. Density of forested land in the ACF River basin is shown in figure 24 (see Appendix, page 53). The most densely forested counties, in descending order, are Quitman County, Ga., Liberty and Franklin Counties, Fla., and Stewart and Lumpkin Counties, Ga. Ownership classes of timberland in the ACF River basin are shown in figure 25. About 25 percent of the timberland in the ACF River basin (about 16 percent of the basin) is owned by the forest industry. Much of this land is in pine plantations. Forest-industry owned land is defined as land owned or under long-term lease by companies or individuals operating wood-using plants (Thompson, 1989). Forested land actively managed for silviculture is concentrated in the southern and central part of the ACF River basin. Figure 26 (see Appendix, page 54) shows the density of forest-industry owned land in the ACF River basin on the basis of data collected during 1987, 1989, and 1990. The most significant silvicultural counties in the basin are Franklin County Fla., Stewart County Ga., and Gulf, Calhoun, and Bay Counties, Fla.

In the silviculture industry, pesticides are mainly applied during site preparation after clear-cutting and during the first few years of new forest growth. Site preparation occurs on a 25-year cycle on most pine plantation land. The herbicides dicamba, 2,4-D, 2,4-DP, glyphosate, sulfometuron, hexazinone, imazapyr, triclopyr, and picloram (in combination with other herbicides) are used during site preparation (Delaplane, 1991; and Parshall Bush, University of Georgia, personal commun., 1992). The use of triclopyr and picloram has decreased since the early 1970’s. These herbicides, and atrazine and sethoxydim, are used to control weeds in young pine stands. Insects in pine stands are controlled by chlorpyrifos, diazinon, malathion, acephate, carbaryl, lindane, and dimethoate. Diseases are controlled using chlorothalonil, dichloropropene, and mancozeb. Depending on individual site characteristics, runoff and erosion may be substantial during the period between clear-cutting and the establishment of sufficient new forest growth to stabilize the land surface. This also is the time when pesticide use is the heaviest and water resources may be most vulnerable to contamination.

Urban and Suburban

Pesticides used in urban and suburban areas in the ACF River basin were identified using qualitative data from the lawn-care industry; surveys of products sold at large lawn and garden stores; and data from the National Gardening Association, USEPA, and other sources. About 4 percent of the ACF River basin was in urban and suburban land use in the mid 1970’s, according to the USGS land-use and land-cover classifications reported during that period (1972-78) (E.H. Hopkins, U.S. Geological Survey, written commun., 1995).

The Atlanta Metropolitan Statistical Area (MSA) constituted more than 67 percent of the urban and suburban area in the ACF River basin. Pesticide use in the Atlanta Metropolitan area was surveyed and considered representative of all urban and suburban areas in the basin. In urban and suburban areas, pesticides are applied to lawns and turf, roadsides, and gardens and beds. The herbicides most commonly used by the lawn-care industry are combinations of dicamba, 2,4-D, mecoprop (MCPP), 2,4-DP, and MCPA, or other phenoxy-acid herbicides. An informal survey of lawn-care products available for sale in the Atlanta area indicated that most products available for weed control contain one or more of the following compounds: glyphosate, methyl sulfometuron, benefin (benfluralin), bensulide, acifluorfen, 2,4-D, 2,4-DP, or dicamba. Atrazine also was available for purchase until it was restricted by the State of Georgia on January 1, 1993. The main herbicides used by local and State governments are glyphosate, methyl sulfometuron, MSMA, 2,4-D, 2,4-DP, dicamba, and chlorsulfuron (McCarthy, 1992). Herbicides are used for preemergent control of crabgrass in February and October, and in the summer, for postemergent control of crabgrass. Benefin is commonly used for preemergent control, and the phenoxy-acid herbicides and dicamba are used for post-emergent control. Data from the 1991 Georgia Pest Control Handbook (Delaplane, 1991) and CES and SCS personnel indicate that several insecticides could be considered ubiquitous in use. These insecticides include chlorpyrifos, diazinon, malathion, acephate, carbaryl, lindane, and dimethoate. Chlorothalonil, a fungicide, also is widely used in urban and suburban areas.

In 1991, 63 percent of southern households in the United States participated in do-it-yourself lawncare, according to the National Gardening Association (1992). Nine to 15 percent of households are estimated to use a professional lawn-care company (Research Triangle Institute, 1992; National Gardening Association, 1992). Vegetable gardening and shrub-care activities were performed by 28 percent, and insect control by 36 percent of households (National Gardening Association, 1992). The average garden in the South is 500 ft^2, which is twice the National average.

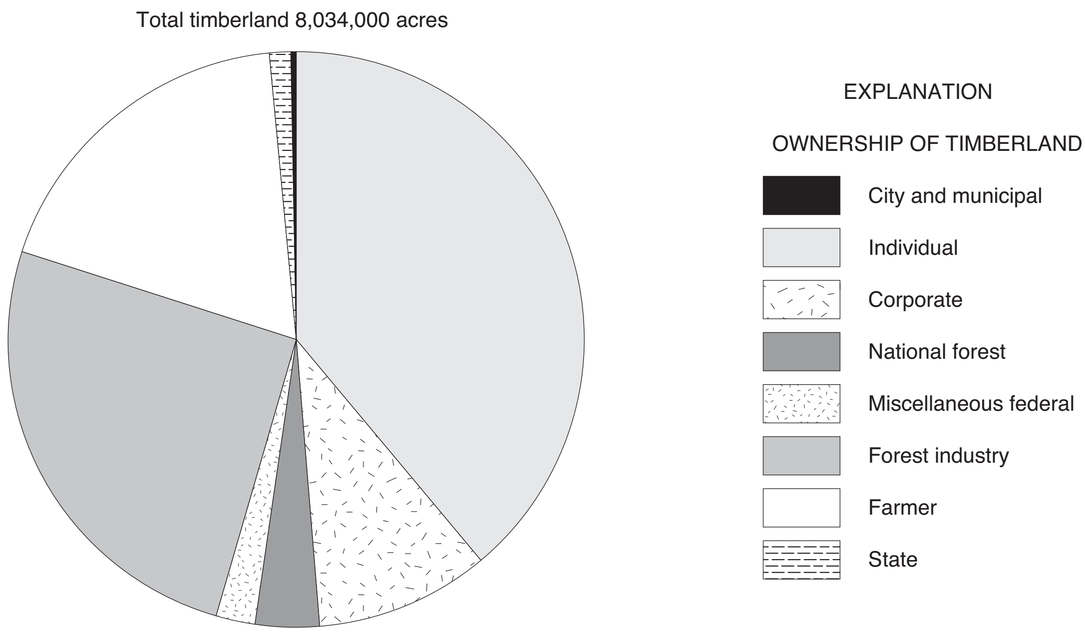

Figure 25. Ownership of timberland in the Apalachicola-Chattahoochee-Flint River basin, 1987, 1989, and 1990.

The most common insecticides purchased for outdoor use in urban and suburban areas are ready-to-use products that are mainly formulations containing chlorpyrifos (Bruce W. Butterfield, National Gardening Association, personal commun., 1992). Other commonly purchased insecticides include concentrated forms of water-soluble liquid and dry-chemical insecticides (mainly carbaryl) that must be mixed with water before they are applied. Herbicides bought in formulations sold as weed and feed products also contain fertilizers.

The average-size lawn for detached houses nationally is about 15,000 ft^2 (Bruce W. Butterfield, National Gardening Association, personal commun., 1992). Estimates of the total amount of lawn for detached houses in the Atlanta MSA in the ACF River basin are on the basis of the national average and are listed in table 6. There are about 190 mi^2 of lawns in the Atlanta MSA part of the ACF River basin. It is estimated that home owners in this area apply pesticides to about 120 mi^2 and the lawn-care industry applies pesticides to about 23 mi^2. The remainder of lawns are untreated (47 mi^2). Fulton, Cobb, and DeKalb Counties, Ga., have the most treated lawns (66 percent of the total). Lawn-care companies in the Atlanta MSA treat about the same amount of residential and commercial land area, according to a study by Hubbard and others (1990). Therefore, about another 23 mi^2 of commercial area in the Atlanta MSA in the ACF River basin is treated by lawn-care companies.

The other types of areas treated with pesticides were not estimated in the urban and suburban land-use class. Other types of areas include golf courses, roadsides, local government land, parks, industrial land, schools, and forests. Tetra Tech, Inc., (1991, p. 41) reported that residential land was the single largest contributor of nitrogen (82 percent) and phosphorus (52 percent) in Cobb County, Ga., and accounted for 60 percent of the fertilized land in the County. Because this estimate is on the basis of the amount of lawn and shrub area, this type of area also could be a major contributor of pesticides in the urban and suburban class.

Table 6. Estimates of lawn acreage treated with pesticides in the Apalachicola-Chattahoochee-Flint River basin part of the Atlanta Metropolitan Statistical Area (MSA), Georgia, by county, 1990

[Estimates on the basis of surveys of southern households by the National Gardening Association (1992) and data reported by Research Triangle Institute (1992)]

County	Part of county in study area, in percent	Households in study area	Lawn area, in acres[1]	Lawn area treated by lawn-care companies, in acres[2]	Lawn area treated by homeowners, in acres[3]	Lawn area not treated, in acres[4]
Cherokee	4.0	100	36	4	23	9
Clayton	58	25,000	8,600	1,000	5,400	2,100
Cobb	68	79,000	27,000	3,300	17,000	6,800
Coweta	100	15,000	5,300	630	3,300	1,300
DeKalb	31	40,000	14,000	1,700	8,700	3,500
Douglas	100	19,000	6,700	800	4,200	1,700
Fayette	100	18,000	6,300	800	4,000	1,600
Forsyth	76	10,000	3,500	420	2,200	860
Fulton	86	118,000	41,000	4,900	26,000	10,000
Gwinnett	26	24,000	8,100	980	5,100	2,000
Henry	7.0	1,000	380	45	240	94
Paulding	29	3,500	1,200	140	760	300
Spalding	56	7,900	2,700	330	1,700	680
Total area, in acres			**120,000**	**15,000**	**79,000**	**31,000**
Total area, in square miles			**190**	**23**	**120**	**47**

1. Average-sized lawn assumed to be 15,000 ft^2 (approximately 1/3 acre).
2. An estimated 12 percent of the lawn area is assumed treated by lawn-care companies.
3. An estimated 63 percent of the lawn area is assumed treated by homeowners
4. An estimated 25 percent of the lawn area is assumed untreated.

PESTICIDE-CONCENTRATION DATA

Pesticide-concentration data for surface and ground water, bottom sediment, and aquatic biota in the U.S. Geological Survey's National Water Information System (NWIS) and the U.S. Environmental Protection Agency's Storage and Retrieval System (STORET) computerized databases were evaluated to define the spatial and temporal occurrence and distribution of pesticides in the ACF River basin. The NWIS and STORET databases contain about 19,600 individual analyses of pesticides in the ACF River basin. Surface-water samples constitute 16 percent of the total analyses; ground-water samples are 49 percent; bottom-sediment samples, 24 percent; and aquatic biota, 11 percent. About 4.6 percent of the total number of pesticide analyses had concentrations that exceeded a minimum reporting level. Of the pesticide concentrations that exceeded minimum reporting levels, 39 percent were for samples of bottom sediments, 37 were for aquatic biota, 22 percent were for surface water, and 2 percent were for ground water.

National Water Information System (NWIS)

NWIS contains about 4,400 individual analyses of pesticide concentrations in samples collected in the ACF River basin, of which, 7.2 percent have concentrations above minimum reporting levels. The analyses were made during the period from 1971 through 1989. The database included pesticide analyses of bottom sediments, 65 percent; surface-water samples, 32 percent; and ground-water samples, 3 percent. There were no sample records for pesticide analyses in aquatic biota in the NWIS database. Pesticides detected at concentrations above minimum reporting levels in at least one sample are summarized in table 7. Only five of the principal pesticides (2,4-D, alachlor, lindane, diazinon, and atrazine) currently used in the ACF River basin were detected at concentrations exceeding minimum reporting levels. Pesticides that were analyzed for, but had reported concentrations below minimum reporting levels in all samples, are summarized in table 8. Endrin, methoxychlor, mirex, phosphorothioates (parathion, for example), and phosphorodithioates (malathion, for example) constitute about 69 percent of these analyses.

Storage and Retrieval System (STORET)

STORET contains about 15,200 individual analyses of pesticide concentrations in the ACF River basin, of which 3.8 percent have concentrations above minimum reporting levels. The analyses were made during the period from 1960 through 1991. The database included pesticide analyses of ground-water samples, 55 percent; bottom-sediment samples, 23 percent; surface-water samples, 8 percent; and aquatic biota, 14 percent. The principal aquatic biota analyzed were fish species, including white sucker, carp, channel catfish, and large mouth bass. Pesticides detected at concentrations above minimum reporting levels in at least one sample are summarized in table 9. Only four of the pesticides (2,4-D, lindane, chlorpyrifos, and malathion) currently used in the ACF River basin were detected at or above minimum reporting levels. Pesticides that were analyzed for, but had concentrations below minimum reporting levels in samples from all media are summarized in table 10. Pesticide analyses below minimum reporting levels are distributed over a wide variety of compounds. Most of the analyses without detectable pesticide concentrations are ground-water samples (86 percent).

Distribution of Analyses in the NWIS and STORET Databases

Most of the pesticide analyses having concentrations above minimum reporting levels in NWIS and STORET are of environmentally persistent organochlorine insecticides that are now banned for use in the United States by USEPA. About 76 percent of the analyses that contained reportable concentrations were from bottom sediments and aquatic biota reflecting the persistent, hydrophobic nature of these compounds. Most analyses in NWIS and STORET are samples collected five or more years before this study (1991). Most samples were collected as part of monitoring programs in the Atlanta Metropolitan area and along the mainstems of major rivers, and are not well-distributed spatially throughout the ACF River basin.

Distribution of analyses among pesticides

Distribution of all analyses among the principal pesticides in the NWIS and STORET databases, and the relative number of analyses having concentrations at or above minimum reporting levels, are shown in figure 27. Nearly 56 percent of the analyses having concentrations above minimum reporting levels in the NWIS database were for two pesticide groups—DDT and chlordane. Pesticide analyses for the dieldrin, phenoxy-acid, and heptachlor groups, and diazinon, accounted for an additional 37 percent of the analyses having detectable concentrations. Within this group, dieldrin comprised almost 93 percent of the detectable concentrations. Collectively, these five pesticide groups and diazinon accounted for about 93 percent of the analyses having concentrations above minimum reporting levels and analyses for these pesticides accounted for about 60 percent of all analyses in the NWIS database for the ACF River basin. With the exception of 2,4-D, 2,4-DP, and diazinon, all other pesticides in these groups are now banned by USEPA for use in the United States.

Table 7. Summary of pesticides having concentrations at or above the minimum reporting levels from 1970-91 in the National Water Information System (NWIS) for the Apalachicola-Chattahoochee-Flint River basin [Water, in micrograms per liter; sediment, in micrograms per kilogram; --, not applicable]

Pesticide	Total numbe of analyses	Surface water			Ground water			Bottom sediment			Minimum reporting levels
		Number of analyses	Number of detections	Detections, in percent	Number of analyses	Number of detections	Detections, in percent	Number of analyses	Number of detections	Detections, in percent	Water, Sediment
Phenoxy-Acid Group											
2,4-D	120	59	12	22	29	0	0	32	0	0	0.01-water .1-sediment
2,4,5-T	115	60	8	13	23	0	0	32	0	0	.01-water .1-sediment
Silvex	121	60	7	12	29	0	0	32	0	0	.01-water .1-sediment
Dieldrin Group											
Aldrin	241	119	1	1	59	0	0	63	3	5	.01-water .1-sediment
Dieldrin	241	119	9	8	59	0	0	63	38	60	.01-water .1-sediment
Lindane Group											
Lindane	241	119	8	7	59	0	0	63	0	0	.01-water .1-sediment
Chlordane Group											
Chlordane	241	119	27	23	59	0	0	63	44	74	.1-water 1.0-sediment
Heptachlor	241	119	7	6	59	0	0	63	15	24	.01-water .1-sediment
Heptachlor epoxide	241	119	3	3	59	0	0	63	3	4	.01-water .1-sediment
DDT Group											
DDD	237	119	3	3	59	2	3	59	31	53	.01-water .1-sediment
p,p'-DDD	3	0	--	--	0	--	--	3	3	100	.1-sediment
DDE	237	119	1	1	59	0	0	59	26	44	.01-water .1-sediment
p,p'-DDE	4	0	--	--	0	--	--	4	4	100	.1-sediment
DDT	237	119	6	5	59	4	7	59	23	39	.01-water .1-sediment
p,p'-DDT	4	0	--	--	0	--	--	4	4	100	.1-sediment
Other Pesticides											
Alachlor	12	1	1	100	11	0	0	0	--	--	.1-water
Toxaphene	248	119	0	0	65	2	3	64	1	2	1.0-water 10.-sediment
Fenthion	2	2	2	100	0	0	--	0	--	--	.01-water
Diazinon.	89	39	14	36	10	0	0	40	0	0	.01-water
Simetryne	15	3	0	0	12	1	8	0	--	--	.1-water
Simazine	27	8	0	0	16	1	6	3	0	0	.1-water
Prometone	15	3	1	33	12	0	0	0	--	--	.1-water
Atrazine	30	11	2	18	16	0	0	3	0	0	.1-water

Table 8. Summary of pesticides having concentrations below the minimum reporting levels for all sample records from 1970 through 1991 in the National Water Information System (NWIS) for the Apalachicola-Chattahoochee-Flint River basin

[water, reporting level in micrograms per liter; sediment, reporting level in micrograms per kilogram; --, no data]

Pesticide	Number of samples having concentrations below the minimum reporting level by sample media			Minimum reporting level(s)
	Surface water	Ground water	Bottom sediment	
Dacthal	--	4	--	0.01--water
2,4-DP	5	5	--	.01--water
Metolachlor	1	9	--	.1--water
Trifluralin	1	9	--	.1--water
Propham	1	11	--	.5--water
Carbaryl	2	15	--	.5--water
Methomyl	2	13	--	.5--water
Aldicarb	--	4	--	.5--water
Metribuzin	1	13	--	.1--water
Dichloroethane	1	20	--	.2 to 3--water
Hexachlorocyclopentadiene	--	3	--	.01 to 5--water
Bromomethane	1	13	--	.2 to 3--water
Chloromethane	1	7	--	.2 to 3--water
Dichlorobenzene	2	16	--	.2 to 5--water
Dichloropropane	1	20	--	.2 to 3--water
Dichloropropene	3	32	--	.2 to 3--water
Perthane	6	34	7	.1--water, 1--sediment
Endosulfan	7	37	17	.01--water, .1--sediment
Endrin	116	65	63	.01--water, .1--sediment
Isodrin	--	5	--	.01--water
Methoxychlor	25	23	42	.01--water, .1--sediment
Hexachlorobenzene	--	3	--	.01 to 5--water
Hexachlorobutadiene	--	3	--	5 --water
Mirex	69	51	17	.01--water, .1--sediment
Dicofol	--	6	--	.01--water
Pentachlorophenol	--	5	--	30--water
4,6-Dinitro-o-cresol	--	5	--	30--water
Phosdrin	--	4	--	.01--water
Azodrin	--	4	--	.1--water
Disulfoton	1	--	--	.01--water
Phorate	1	4	--	.01--water
Ethion	39	6	40	.01--water
Malathion	39	10	40	.01--water, .1--sediment
Ethyl-Parathion	39	10	37	.01--water, .1--sediment
Demeton	--	4	--	.01--water
Guthion	--	4	--	.1--water
Ethy-Parathionl	39	10	40	.01--water, .1--sediment
Trithion	39	6	37	.01--water. .1--sediment
Methyltrithion	39	6	40	.01--water, .1--sediment
Terbufos	--	4	--	.1--water
Propazine	3	10	--	.1--water
Prometryne	3	12	--	.1--water
Cyanazine	3	14	--	.1--water
Ametryne	3	10	--	.1--water
Atratone	--	1	--	.1--water
Cyprazine	--	1	--	.1--water
Simetone	--	1	--	.1--water

Table 9. Summary of pesticides having concentrations at or above minimum reporting levels from 1960 through 1991 in Storage and Retrieval System (STORET) for the Apalachicola-Chattahoochee-Flint River basin

[G, grab sample; T, temporal sample; --, not applicable. A grab sample is a discrete sample that represents one point in time. A temporal sample is a number of samples taken over a period of time and composited into one sample prior to analyses]

Compound	Surface water			Ground water			Aquatic biota			Bottom sediment		
	Number of analyses	Number of detections	Detections, in percent	Number of analyses	Number of detections	Detections in percent	Number of analyses	Number of detections	Detections, in percent	Number of analyses	Number of detections	Detections, in percent
Phenoxy-Acid Group												
2,4-D	6 2	0 0	0.0-G 0-T	248	0	0	17	0	0	58	4	7
Silvex	6 2	1 2	16.7G 100-T	248	0	0	17	0	0	23	0	0
Lindane Group												
Alpha-BHC	34	0	0.0-G	0	--	--	93	4	4	178	2	1
Lindane (-BHC)	57	4	6.8-G	249	0	0	95	8	8	82	1	1
Dieldrin Group												
Aldrin	58 2	1 0	1.7-G 0-T	0	--	--	95	0	0	214	0	0
Dieldrin	58 2	23 2	40-G 100-T	1	1	100	129	22	17	207	6	3
Endrin	58 2	2 0	3-G 0-T	249	0	0	80	0	0	178	0	0
Endrin aldehyde	23	0	0-G	0	--	--	38	1	3	65	0	0
Chlordane Group												
Chlordane, (*cis*- + *trans*-)	10	6	60-G	0	--	--	24	18	75	122	4	3
Chlordane technical mix	49 2	1 0	2-G 0-T	2	1	50	109	43	39	189	27	14.3
cis-Nonachlor	0	--	--	0	--	--	0	--	--	3	3	100
trans-Nonachlor	0	--	--	0	--	--	9	9	100	0	--	--
Oxychlordane	0	--	--	0	--	--	2	2	100	0	--	--
1-OH-chlordene	5	1	20	0	--	--	0	--	--	2	0	0
Heptachlor	60 2	0 0	0-G 0-T	0	--	--	45	0	0	98	1	1
Heptachlor epoxide	54 2	2 0	4-G 0-T	0	--	--	48	0	0	120	0	0

Table 9. Summary of pesticides having concentrations at or above minimum reporting levels from 1960 through 1991 in Storage and Retrieval System (STORET) for the Apalachicola-Chattahoochee-Flint River basin—Continued

[G, grab sample; T, temporal sample; --, not applicable. A grab sample is a discrete sample that represents one point in time. A temporal sample is a number of samples taken over a period of time and composited into one sample prior to analyses]

Compound	Surface water			Ground water			Aquatic biota			Bottom sediment		
	Number of analyses	Number of detections	Detections, in percent	Number of analyses	Number of detections	Detections in percent	Number of analyses	Number of detections	Detections, in percent	Number of analyses	Number of detections	Detections, in percent
DDT Group												
DDD	32	16	50-G	0	--	--	88	10	11	32	10	31
o,p'-DDD	0	--	--	0	--	--	1	0	0	20	2	10
p,p'-DDD	30	0	0-G	0	--	--	121	38	31	92	7	9
DDE	34	4	12	0	--	--	108	77	71	36	12	33
DDE, Sus	4	1	25-G	0	--	--	0	--	--	0	--	--
p,p'-DDE	28	0	0-G	0	--	--	133	41	31	91	21	23
DDT	35 2	13 0	37-G 0-T	0	--	--	82	1	1	81	15	19
p,p'-DDT	28	0	0-G	0	--	--	119	15	13	91	6	7
DDT+DDE+ DDD	15	0	0-G	0	--	--	34	29	85	79	12	15
Other Pesticides												
Dicofol	0	--	--	249	1	.4	0	--	--	0	--	--
Toxaphene	33 2	0 0	0-G 0-T	249	0	0	58	1	2	212	1	0.9
1,2-Dichloroethane,	18	1	6-G	154	0	0	0	--	--	18	1	13
B-Endosulfan	28	3	11-G	0	--	--	38	0	0	32	0	0
Endosulfan sulfate	29	0	0-G	0	--	--	45	1	2	32	0	0
Dichlorobenzene	43	1	2-G	10	0	0	26	0	0	22	0	0
Hexachloro-benzene	16	0	0-G	5	0	0	58	2	3	124	0	0
1,2-Dichloropropane	17	0	0-G	154	4	3	0	--	--	8	0	0
Methoxychlor	20 2	0 0	0-G 0-T	249	0	0	61	2	3	171	0	0
Mirex	19	0	0-G	0	--	--	62	12	19	140	0	0
Pentachlorophenol	47	0	0-G	27	0	0	76	3	4.0	142	8	6.0
Chlorpyrifos	0	--	--	0	--	--	6	6	100	0	--	--
Malathion	16	1	6-G	126	0	0	0	--	--	20	0	0

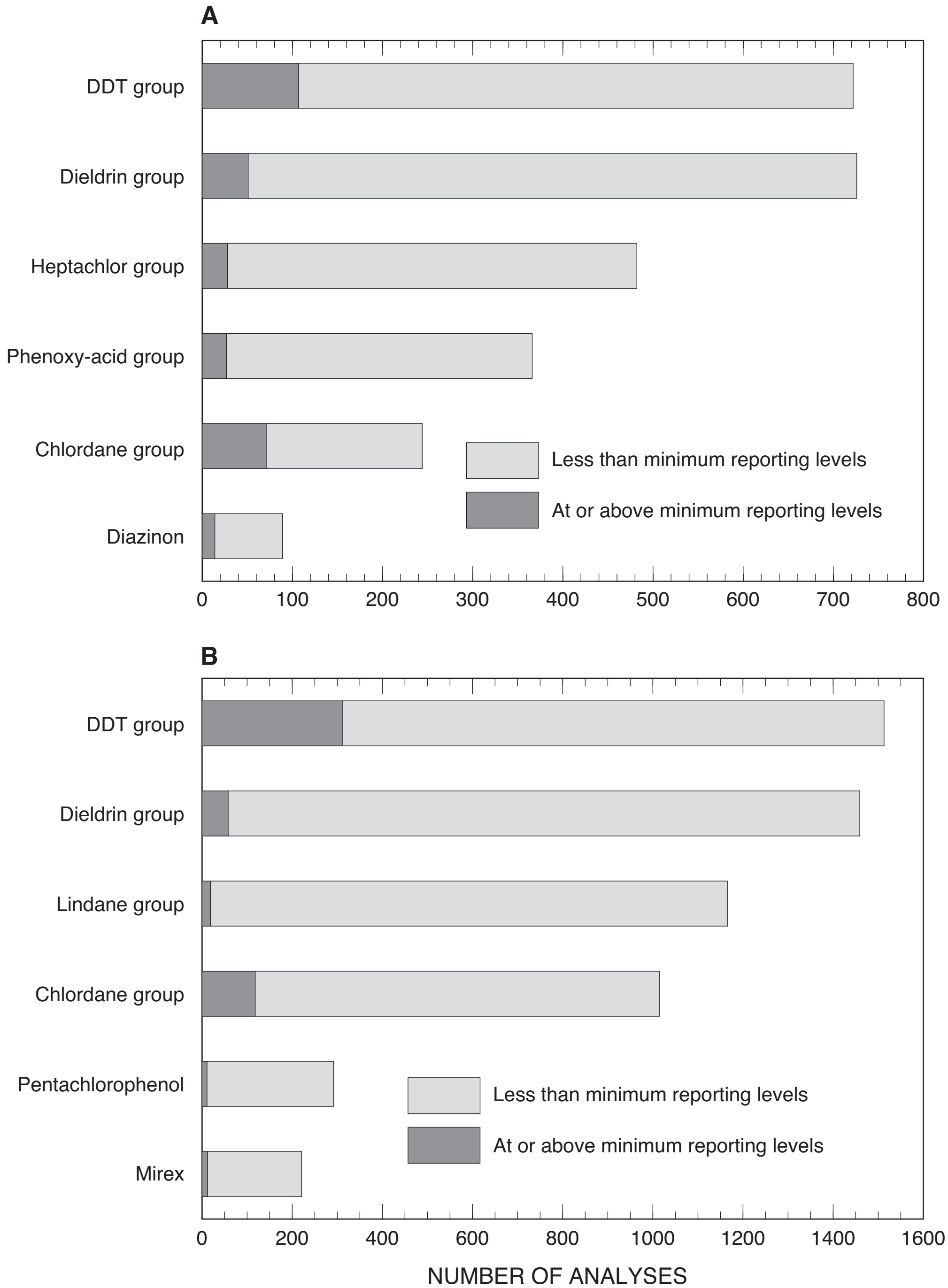

Figure 27. Distribution of analyses among the pesticide groups in the NWIS (A) and STORET (B) for Apalachicola-Chattahoochee-Flint River basin.

Table 10. Summary of pesticides having concentrations below the minimum reporting levels from 1960-91 in all media in Storage and Retrieval System (STORET) in the Apalachicola-Chattahoochee-Flint River basin
[G, grab sample; T, temporal composite; --, not applicable; MRL, minimum reporting levels
]

Compound	Surface and ground water: Number of surface-water analyses	Surface and ground water: Number of ground-water analyses	Surface and ground water: Minimum reporting level(s): Most common MRL, in micrograms per liter	Surface and ground water: Minimum reporting level(s): Analyses having most common MRL, in percent	Surface and ground water: Range of MRLs, in micrograms per liter	Aquatic biota: Number of analyses	Aquatic biota: Minimum reporting level(s): Most common MRL, in micrograms per liter	Aquatic biota: Minimum reporting level(s): Analyses having most common MRL, in percent	Aquatic biota: Range of MRLS, in micrograms per liter	Bottom sediments: Number of analyses	Bottom sediments: Minimum reporting level(s): Most common MRL, in micrograms per liter	Bottom sediments: Minimum reporting level(s): Analyses having most common MRLs, in percent	Bottom sediments: Range of MRLs, in micrograms per liter	Total number of analyses in all media
Dacthal	0	126	0.01	99	0.01 and 99	5	0.1	40	0.01 to 8.0	0	--	--	--	131
Amiben	0	248	0.2	98	0.2 and 1.0	0	--	--	--	0	--	--	--	248
Metolachlor	G-4	0	0.1	75	0.1 and 1.0	0	--	--	--	128	2.0	98	2; 4; 10; and 100	132
Alachlor	G-4	126	3.0	97	0.1 to 3.0	0	--	--	--	2	10, 100	50, 50	10 and 100	132
N,N-diethyl-2-(1-naphthyoxy)-pro-pionamine	0	125	.81	100	--	0	--	--	--	0	--	--	--	125
Isopropalin	0	126	2.0	100	--	0	--	--	--	0	--	--	--	126
Profluralin	0	126	2.0	100	--	0	--	--	--	0	--	--	--	126
Benefin	G-4	0	0.1	75	0.1 and 1.0	0	--	--	--	0	--	--	--	4
Pendimethalin	0	125	1.8	100	--	0	--	--	--	0	--	--	--	125
Fluchloralin	0	125	15	100	--	0	--	--	--	0	--	--	--	125
Trifluralin	0	126	2.0	100	--	0	--	--	--	0	--	--	--	126
Carbaryl	0	125	10	100	--	0	--	--	--	0	--	--	--	125
Carbofuran	0	92	2.0	99	0.02 and 2.0	0	--	--	--	0	--	--	--	92
Methomyl	0	90	3.0	77	0.03 to 5.0	0	--	--	--	0	--	--	--	90
Aldicarb	0	38	0.2	66	0 to 10	0	--	--	--	0	--	--	--	38
Butylate	0	126	1.25	100	--	0	--	--	--	0	--	--	--	126
EPTC	0	126	1.7	100	--	0	--	--	--	0	--	--	--	126
Vernolate	0	126	0.56	100	--	0	--	--	--	0	--	--	--	126
Pebulate	0	125	1.81	100	--	0	--	--	--	0	--	--	--	125
Metribuzin	0	126	1.25	100	--	0	--	--	--	0	--	--	--	126
-BHC	34	0	0.01	79	.01 to 3	88	0.01,0.02	37, 31	0.0002 to 0.5	156	1.0	53	0.1 to 20 in 99.4, 1,000 in 0.6 percent	278
-BHC	G-28	0	0.01	82	0.01 to 0.1	39				32	3.0,2.0, 1.0	47, 19, 16	1 to 1,000	99
Bromomethane	G-17	20	10	87	5 and 10	0	--	--	--	8	10	75	5 and 10	45
Chloromethane	G-37	20	10	67	1 to 10	3	0.03	100	--	22	10	77	1 to 10	82
Dichloropropene	G-29	309	1.0	99	1 and 5	0	--	--	--	8	1.0	75	1 and 5	346
Dibromochloropropane	0	7	1.0	100	--	0	--	--	--	0	--	--	--	7
cis-Chlordane + Nonachlor, bed	0	0	--	--	--	0	--	--	--	18	4.0	83	2 and 4	18
trans-Chlordane + Nonachlor, bed	0	0	--	--	--	0	--	--	--	18	4.0	83	2 and 4	18
Hexachloro-cyclopentadiene	G-11	5	100	64		0	--	--	--	6	400 2,000	83 17	400 and 2,000	22

More than half of the pesticide analyses having concentrations above minimum reporting levels in the STORET database were for pesticides in the DDT group (about 57 percent of the total), and about 20 percent were for pesticides in the chlordane group. Pesticide analyses from the dieldrin and lindane groups, pentachlorophenol, and mirex accounted for an additional 17 percent of analyses having detectable concentrations. Dieldrin again accounted for about 93 percent of the detectable concentrations within the dieldrin group. Collectively, the four pesticide groups, and pentachlorophenol and mirex, accounted for about 94 percent of the analyses having pesticide concentrations above minimum reporting levels, and analyses for these pesticides accounted for about 34 percent of all analyses present in the STORET database for the ACF River basin. All pesticides in these groups, except for lindane, are now banned by USEPA for use in the United States.

Distribution of analyses among sample media

Distribution of all pesticide analyses and pesticide analyses having concentrations above minimum reporting levels among media in the NWIS and STORET databases are shown in figure 28. The NWIS database has a substantially larger number of pesticide analyses of surface water than does the STORET database (about 1,930 and 1,220, respectively), but contains no data for tissue of aquatic biota.

Pesticide concentrations were above minimum reporting levels in 7.2 percent of the analyses in the NWIS database. Almost 100 percent of the pesticides detected in bottom sediment and about 50 percent of the pesticides detected in surface water are of the DDT, chlordane, dieldrin, and heptachlor groups. Most of the pesticides detected in surface water are of the phenoxy-acid and lindane groups and diazinon (table 7).

Pesticide concentrations were above minimum reporting levels in about four percent of the analyses in STORET. Nearly 95 percent of the pesticides detected in bottom sediment are from the DDT, chlordane, dieldrin, and lindane groups and pentachlorophenol. About 95 percent of the pesticides detected in aquatic biota are from the DDT, chlordane, dieldrin, and lindane groups and mirex. About 67 percent of the pesticides detected in surface water are from the DDT, dieldrin, and chlordane groups. The high percentage of analyses with detectable concentrations of pesticides for tissue of aquatic biota reflects the hydrophobic nature and the environmental persistence of these pesticides.

Spatial and Temporal Distribution of Pesticides

Geographic patterns in the occurrence and distribution of the commonly used organochlorine compounds, phenoxy-acid herbicides, and organophosphate insecticides are somewhat defined by pesticide uses associated with various land uses. The locations of all sites where surface-water, sediment, or aquatic biota were sampled for selected pesticides are shown in figures 29-38 (see Appendix, pages 56-65). The subset of sites showing measurable quantities of pesticides are also shown. Data presented in these figures represent the composite effort of several USGS monitoring programs (NWIS database) and those of the other Federal and State agencies reporting data to the USEPA (STORET database) over a 32-year period from 1960 to 1991.

Most organochlorine compounds were banned by the USEPA during the 1970's and 1980's because they were shown to cause cancer, induce tumors, cause birth defects, be hazardous to wildlife, or toxic to aquatic life (USEPA, 1990). DDT, DDD, and DDE were detected in wide distribution in the sediments and aquatic biota of primarily mainstem and reservoir sites in the Chattahoochee, Flint, and Apalachicola drainages (fig. 29). DDT was used through 1973 as an insecticide on cotton, fruits, and vegetables, and for mosquito control (Smith and others, 1988), so its widespread occurrence in both urban and agricultural settings is consistent with its use. Surface-water sampling for DDT was limited primarily to the Atlanta Metropolitan area; however, it was found at many sampling sites. Chlordane, heptachlor, dieldrin, and related compounds were used agriculturally through 1974, but predominantly as termiticides through the late 1980's (Buell and Couch, 1995). Compounds in these groups have been found in the sediments and aquatic biota of tributary streams draining the Atlanta Metropolitan area and mainstem reaches and reservoirs of the Chattahoochee River downstream from the Atlanta and Columbus, Ga., Metropolitan areas (figs. 30-32). Various chlordane compounds and dieldrin have also been found in the Chattahoochee River just downstream from West Point Reservoir and in the Apalachicola River just downstream from Lake Seminole (figs. 30, 32). Lindane (-BHC) has restricted use (since 1985), mostly on pecan orchards, but also on truck-garden vegetables. Lindane has been found at scattered locations throughout the ACF River basin in surface water, sediment, and aquatic biota; however, sampling locations where data were collected are sparse and patchy (fig. 33). Mirex was extensively used for fire-ant control throughout the southeastern United States until 1976 when its use was banned by the USEPA (1990). Aquatic tissues were analyzed for mirex at only a few sites along the Chattahoochee, Flint, and Chipola Rivers and Spring Creek (inflow to Lake Seminole), but some measurable concentration was detected in all samples (fig. 34).

Phenoxy-acid herbicides are widely used in residential, commercial/industrial, agricultural, and silvicultural areas of the ACF River basin. All surface-water sampling for 2,4-D (fig. 35), 2,4,5-T and silvex (fig. 36), with the exception of one site on Spring Creek for 2,4-D, was done in the Atlanta Metropolitan area. Most of these sites had detectable concentrations of these herbicides. Sediment samples collected in the lower Coastal Plain reach of the Chattahoochee River and Lake Seminole had detectable concentrations of 2,4-D (fig. 35), but sampling throughout the rest of the basin was sparse.

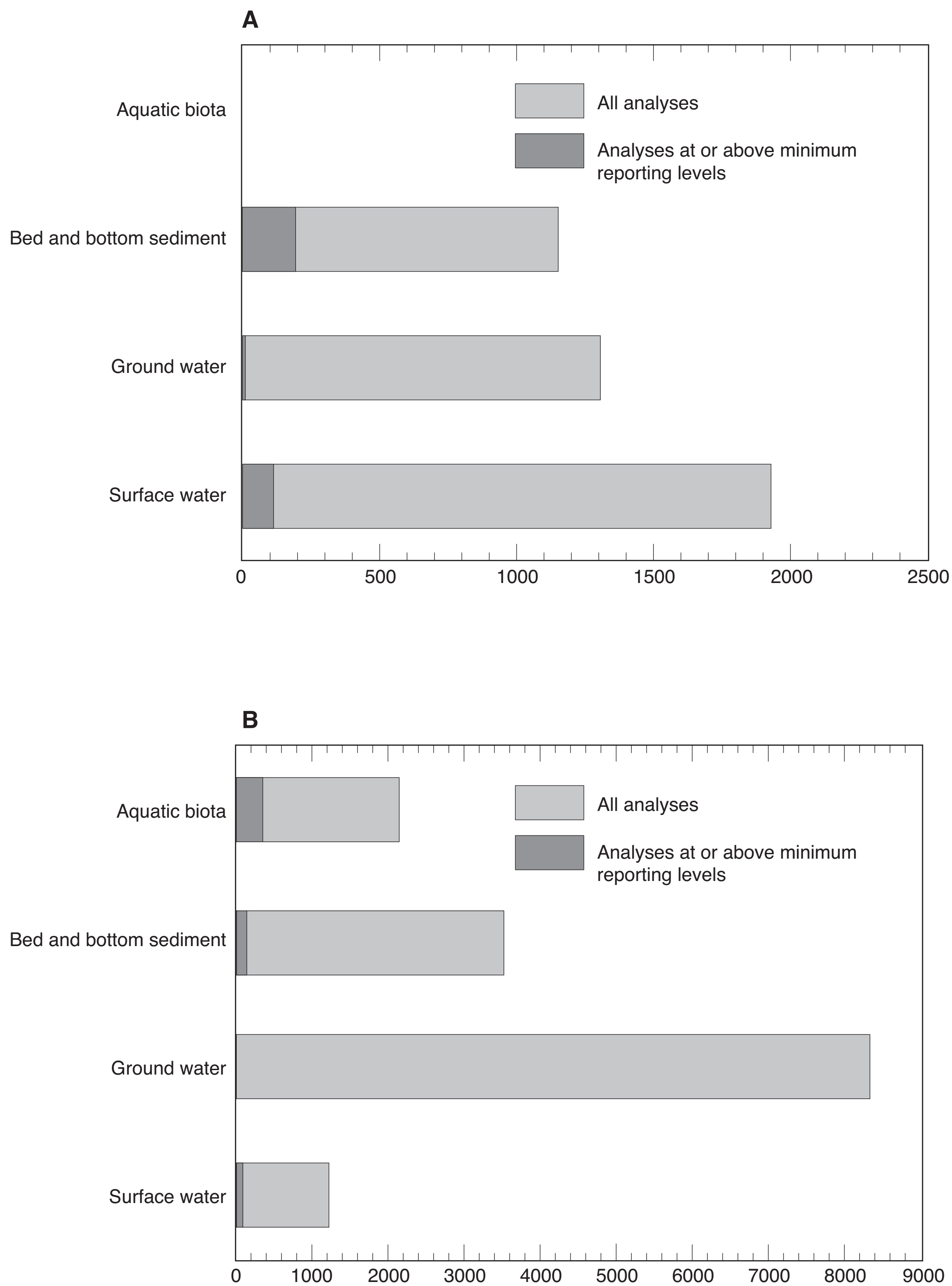

Figure 28. Distribution of all pesticide analyses, and the pesticide analyses having concentrations at or above minimum reporting levels among media in the NWIS (A) and STORET (B) for the Apalachicola-Chattahoochee-Flint River basin.

Organophosphate insecticides in current use (such as diazinon and chlorpyrifos) have largely replaced the organochlorine insecticides. Diazinon has been detected in frequent occurrence in surface waters of the Atlanta Metropolitan area, and at one site each in the Chipola River and Spring Creek drainages (fig. 37). Diazinon is widely used in both urban and agricultural settings so this spatial picture most likely under-represents occurrence in the basin. Chlorpyrifos has replaced chlordane and dieldrin as a residential and commercial termiticide since 1988, but scant data are available on its occurrence and distribution in the ACF River basin. Limited sampling of aquatic tissues has been done at three sites in the reach of the Chattahoochee River downstream from Atlanta (fig. 38). Chlorpyrifos was detected at all three sites.

Temporal distributions of pesticide analyses in various media are presented for the NWIS database (table 11) and for the STORET database in table 12 (in pocket in back of report). Much of the environmental monitoring for pesticide occurrence by Federal and State agencies has been targeted to known sources and areas of contamination—an approach consistent with regulatory requirements focused on human health. Many efforts, such as the USEPA's National Study of Chemical Residues in Fish (USEPA, 1992) or USF&W's National Contaminant Biomonitoring Program (NCBP; Jacknow and others, 1986; Schmitt and others, 1990), either were synoptic in nature or conducted during a limited period of time. Thus, the composite temporal picture represented by these sampling efforts is inherently patchy. It is unfortunate that only limited inference can be drawn on temporal patterns.

In USGS monitoring programs represented by the NWIS data (table 11), surface waters and sediments were sampled most frequently during the late 1970's; ground waters were sampled most frequently during the early 1980's; and little, if any, data were collected during the late 1980's. In other Federal and State monitoring programs represented by the STORET data (table 12), surface waters were sampled most frequently during the 1960's, with more limited sampling conducted during the late 1970's, the 1980's, and the early 1990's. Most of the ground-water sampling was conducted during the late 1980's and early 1990's as part of a regional ground-water monitoring program conducted by the State of Georgia, Department of Natural Resources, Georgia Geologic Survey. Sediments were sampled most frequently during the late 1970's and early 1980's, with some sampling being done both prior to and after this time period. Aquatic tissues were sampled somewhat consistently from the late 1970's through the early 1990's for a number of the organochlorine compounds. Intensive sampling of tissues for DDD, DDE, DDT, and dieldrin was conducted during the 1960's.

SUMMARY AND CONCLUSIONS

The Apalachicola-Chattahoochee-Flint (ACF) River basin was one of the first 20 study units selected by the U.S. Geological Survey (USGS) in 1991 as part of its National Water-Quality Assessment (NAWQA) program. A major emphasis of the NAWQA program is to examine the occurrence and distribution of pesticides in the Nation's surface- and ground-water resources. This report summarizes existing information on land use and pesticide use, identifies the principal pesticides in current use; and evaluates previously-collected concentration data to identify the occurrence and distribution of pesticides that have been detected in the ACF River basin of Georgia, Florida, and Alabama.

Areas that may be most vulnerable to pesticide contamination in the ACF River basin are agricultural, silvicultural, urban, and suburban areas where pesticide use is greatest. About 33 percent of the ACF River basin is used for agriculture and 16 percent is used for silviculture. About 5 percent of the basin is in urban and suburban settings.

In agriculture, pesticides are used most intensely from March 1 to October 1 during any given year in the ACF River basin. In 1990, the herbicides bentazon, paraquat, 2,4-DB, methanearsonate (MSMA/DSMA), alachlor, and pendimethalin were applied to agricultural areas ranging from 307,000 to 204,000 acres in the Georgia part (73 percent) of the ACF River basin. Alachlor, MSMA/DSMA, fluometuron, atrazine, metolachlor, and bentazon were applied in quantities that ranged from 506,000 to 185,000 pounds of active ingredient.

In silvicultural areas, pesticides have been applied mainly during site preparation for reforestation after clear cutting and during the first few years of new forest growth. The herbicides typically used have been imazapyr, dicamba, 2,4-D, 2,4-DP, glyphosate, sulfometuron, hexazinone, triclopyr, picloram, atrazine, and sethoxydim. Insects in pine stands have been controlled with dimethoate, malathion, acephate, carbaryl, lindane, and chlorpyrifos. Diseases commonly have been controlled with chlorothalonil, dichloropropene, and mancozeb.

In urban and suburban areas, pesticides have been applied to turf, lawns, roadsides, and bedding plants. Homeowners mainly apply the herbicides glyphosate, sulfometuron, benefin (benfluralin), bensulide, acifluorfen, 2,4-D, 2,4-DP, and dicamba, for weed control. Atrazine was used by homeowners until 1993 when its use was restricted by the U.S. Environmental Protection Agency (USEPA). Herbicides most commonly applied by the lawn-care industry have been combinations of dicamba, 2,4-D, mecoprop (MCPP), 2,4-DP.

Table 11. Summary of pesticide analyses having concentrations above the minimum reporting levels from 1971-89 in the National Water Information System (NWIS) for the Apalachicola-Chattahoochee-Flint (ACF) River basin
[--, not applicable; MRL, minimum reporting level]

Compound	Minimum reporting level	Time period 1971-74			Time period 1975-79			Time period 1980-84			Time period 1985-89		
		Number of analyses	Number at or above MRL	Maximum concentration	Number of analyses	Number at or above MRL	Maximum concentration	Number of analyses	Number at or above MRL	Maximum concentration	Number of analyses	Number at or above MRL	Maximum concentration
Pesticides detected in surface water, in micrograms per liter													
DDD	0.01	18	0	<0.01	94	3	0.40	4	0	<0.01	3	0	<0.01
DDE	.01	18	0	<.01	94	1	.01	4	0	<.01	3	0	<.01
DDT	.01	18	0	<.01	94	6	.12	4	0	<.01	3	0	<.01
Chlordane technical mixture	.1	18	5	.80	94	22	1.5	4	0	<.10	3	0	<.10
Heptachlor	.01	18	0	<.01	94	7	.07	4	0	<.01	3	0	<.01
Heptachlor epoxide	.01	18	1	.01	94	2	.04	4	0	<.01	3	0	<.01
Dieldrin	.01	18	5	.01	94	4	.05	4	0	<.01	3	0	<.01
Lindane	.01	18	0	<.01	94	8	.40	4	0	<.01	3	0	.01
Diazinon	.01	17	12	.20	15	0	<.01	4	1	.01	3	1	.01
2,4-D	.01	17	10	.28	37	3	.10	2	0	<.01	3	0	<.01
2,4,5-T	.01	17	8	.20	38	0	<.01	2	0	<.01	3	0	<.01
Silvex	.01	17	7	.04	38	0	<.01	2	0	<.01	3	0	<.01
Atrazine	.01	0	--	--	8	0	<.01	8	0	<.01	3	2	.01
Pesticides detected in ground water, in micrograms per liter													
DDD	.01	1	0	<.01	20	0	<.01	35	2	.01	1	0	<.01
DDT	.01	1	0	--	20	0	<.01	35	4	.03	1	0	<.01
Toxaphene	.1	1	0	<.1	22	0	<.1	35	2	8.0	7	0	<.10
Pesticides detected in bed and bottom sediment, in micrograms per kilogram, dry weight													
p,p'-DDD	.1	0	--	--	3	3	5.7	0	--	--	0	--	--
p,p'-DDE	.1	0	--	--	4	4	2.7	0	--	--	0	--	--
p,p'-DDT	.1	0	--	--	4	4	.84	0	--	--	0	--	--
DDD	.1	17	8	4.2	30	14	29	12	9	25	0	--	--
DDE	.1	18	5	1.5	29	10	14	12	11	3.3	0	--	--
DDT	.1	18	11	16	29	8	4.5	12	4	.7	0	--	--
Aldrin	.1	18	2	1.0	33	0	<.1	12	1	.3	0	--	--
Chlordane technical mixture	1.0	18	18	170	33	22	210	12	4	4.0	0	--	--
Dieldrin	.1	18	16	2.1	33	16	3.2	12	6	.3	0	--	--
Heptachlor	.1	18	14	6.0	33	1	.1	12	0	<.1	0	--	--
Heptachlor epoxide	.1	18	2	.3	33	1	.4	12	0	<.1	0	--	--

Several insecticides are ubiquitous in use throughout the ACF River basin. These include chlorpyrifos, diazinon, malathion, acephate, carbaryl, and dimethoate. Aldicarb, parathion-methyl, methomyl, and phorate also are used extensively in agricultural areas, as are the fungicide, chlorothalonil, and the nematocide, fenamiphos.

The pesticide data used in this retrospective analysis were obtained from the U.S. Geological Survey's (USGS's) National Water Information System (NWIS) (1971-89) and U.S. Environmental Protection Agency's (USEPA's) Water Storage and Retrieval System (STORET) (1960-91) water-quality databases. These data collectively represent the efforts of many Federal and State programs designed to 1) describe synoptic patterns in the occurrence and distribution of pesticides over large areas, 2) provide long-term monitoring of pesticides, or 3) provide case-specific data on local pesticide contamination. Synoptic programs represented in the data include the USGS's Upper Chattahoochee and Apalachicola River Quality Assessments, the USEPA's National Study of Chemical Residues in Fish, and the U.S. Army Corps of Engineer's reservoir and navigation-channel sampling program. Long-term monitoring programs include the USGS/USEPA's joint Pesticide Monitoring Network and the State of Georgia's surface-water and ground-water ambient-monitoring networks. Local issues related to pesticide contamination in the Apalachicola-Chattahoochee-Flint (ACF) basin include the effects of intensive row-crop agriculture on the surface- and ground-water quality of the Coastal Plain physiographic province and the effects of point and nonpoint urban runoff on surface-water quality in the Atlanta Metropolitan area.

The geographic patterns in the occurrence and distribution of the commonly used organochlorine compounds, phenoxy-acid herbicides, and organophosphate insecticides are somewhat defined by pesticide uses associated with various land uses. Most of the organochlorine compounds were banned by the USEPA during the 1970's and 1980's because they were shown to cause cancer, induce tumors, or cause birth defects or were found to be hazardous to wildlife or toxic to aquatic life. DDT (together with DDD and DDE) was detected in wide distribution in the sediments and aquatic tissues of primarily mainstem and reservoir sites in the Chattahoochee, Flint, and Apalachicola drainages. Chlordane, heptachlor, dieldrin, and related compounds were used agriculturally through 1974, but predominantly as termiticides through the late 1980's. Compounds in these groups have been found in sediments and aquatic tissues of tributary streams draining the Atlanta Metropolitan area and in mainstem reaches and reservoirs of the Chattahoochee River downstream from the metropolitan areas of Atlanta and Columbus, Ga. Mirex was extensively used for fire-ant control throughout the southeastern United States until 1976 when its use was banned by the USEPA. Aquatic tissues were analyzed for mirex at only a few sites along the Chattahoochee, Flint, and Chipola Rivers and Spring Creek (inflow to Lake Seminole), but some measurable concentration was detected in all samples.

The phenoxy-acid herbicides are widely used in residential, commercial/industrial, agricultural, and silvicultural areas of the ACF River basin. Most of the surface-water sites sampled in the Atlanta Metropolitan area had detectable concentrations of these herbicides.

The organophosphate insecticides in current use (such as diazinon and chlorpyrifos) have largely replaced the organochlorine insecticides. Diazinon has been frequently detected in surface waters of the Atlanta Metropolitan area. Diazinon is widely used in both urban and agricultural settings, but has not been analyzed for throughout the basin, so this spatial picture most likely under-represents occurrence in the basin. Chlorpyrifos has replaced chlordane and dieldrin as a residential and commercial termiticide since 1988, but few data are available on its occurrence and distribution in the ACF River basin.

Much of environmental monitoring for pesticide occurrence by Federal and State agencies has been targeted to known sources and areas of contamination—an approach consistent with regulatory requirements focused on human health. Many efforts either were synoptic in nature or were conducted during a limited period of time. Thus, the composite temporal picture represented by these sampling efforts is inherently patchy. Unfortunately, only limited inference can be drawn on temporal patterns in pesticide occurrence.

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APPENDIX

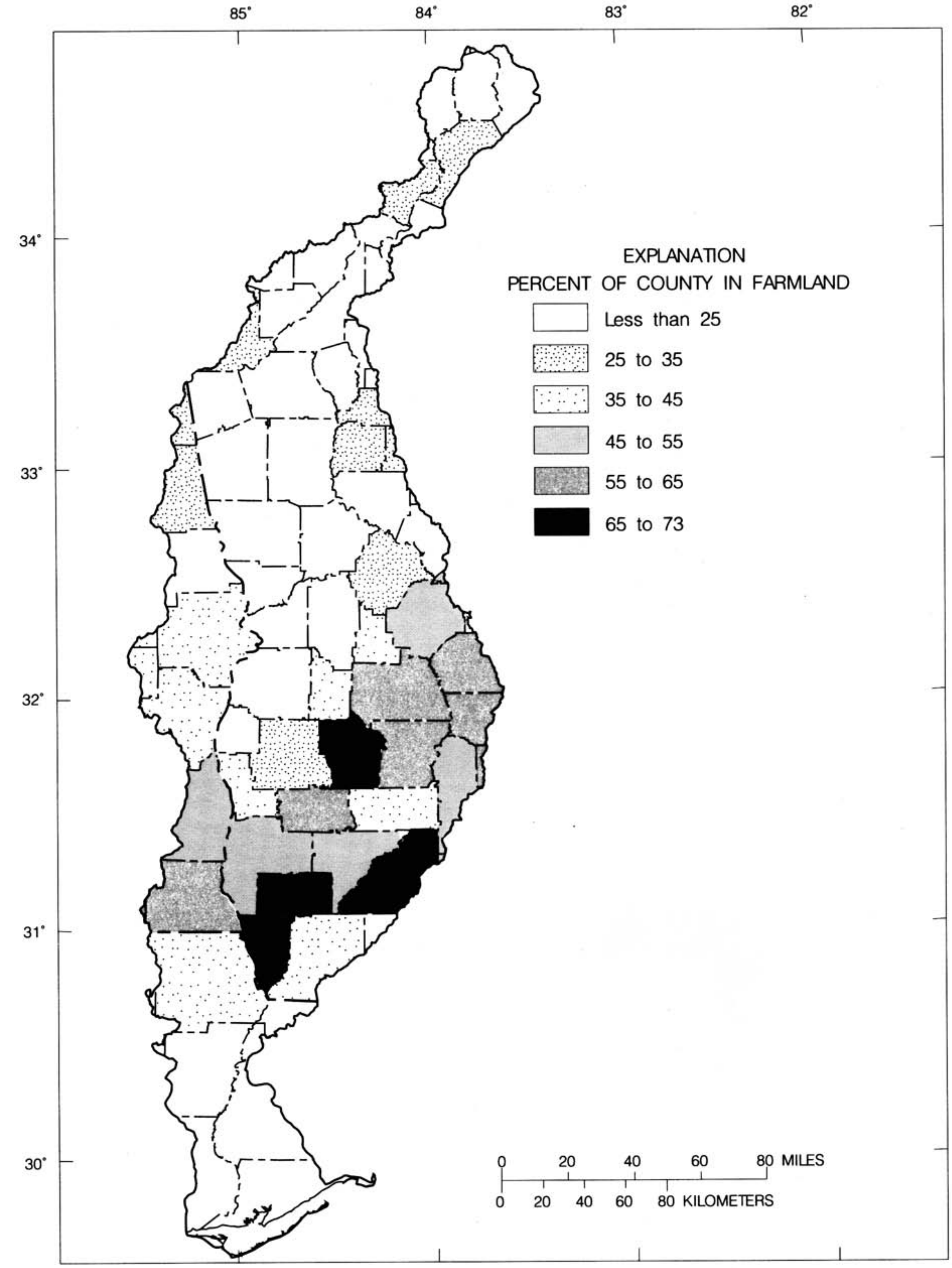


Figure 5. Percent of county in farmland in the Apalachicola-Chattahoochee-Flint River basin, 1987.

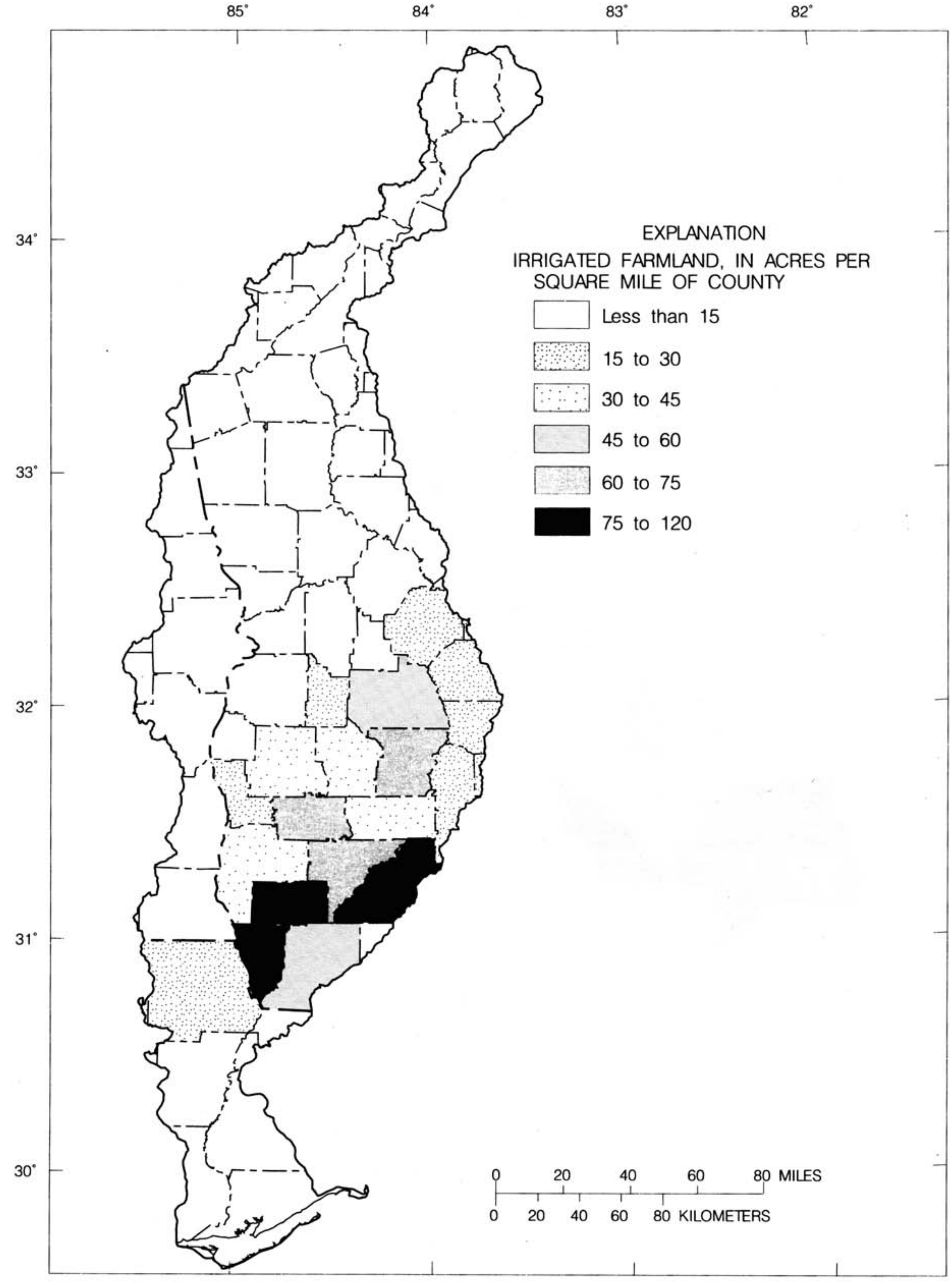


Figure 6. Irrigated farmland in the Apalachicola-Chattahoochee-Flint River basin, 1987.

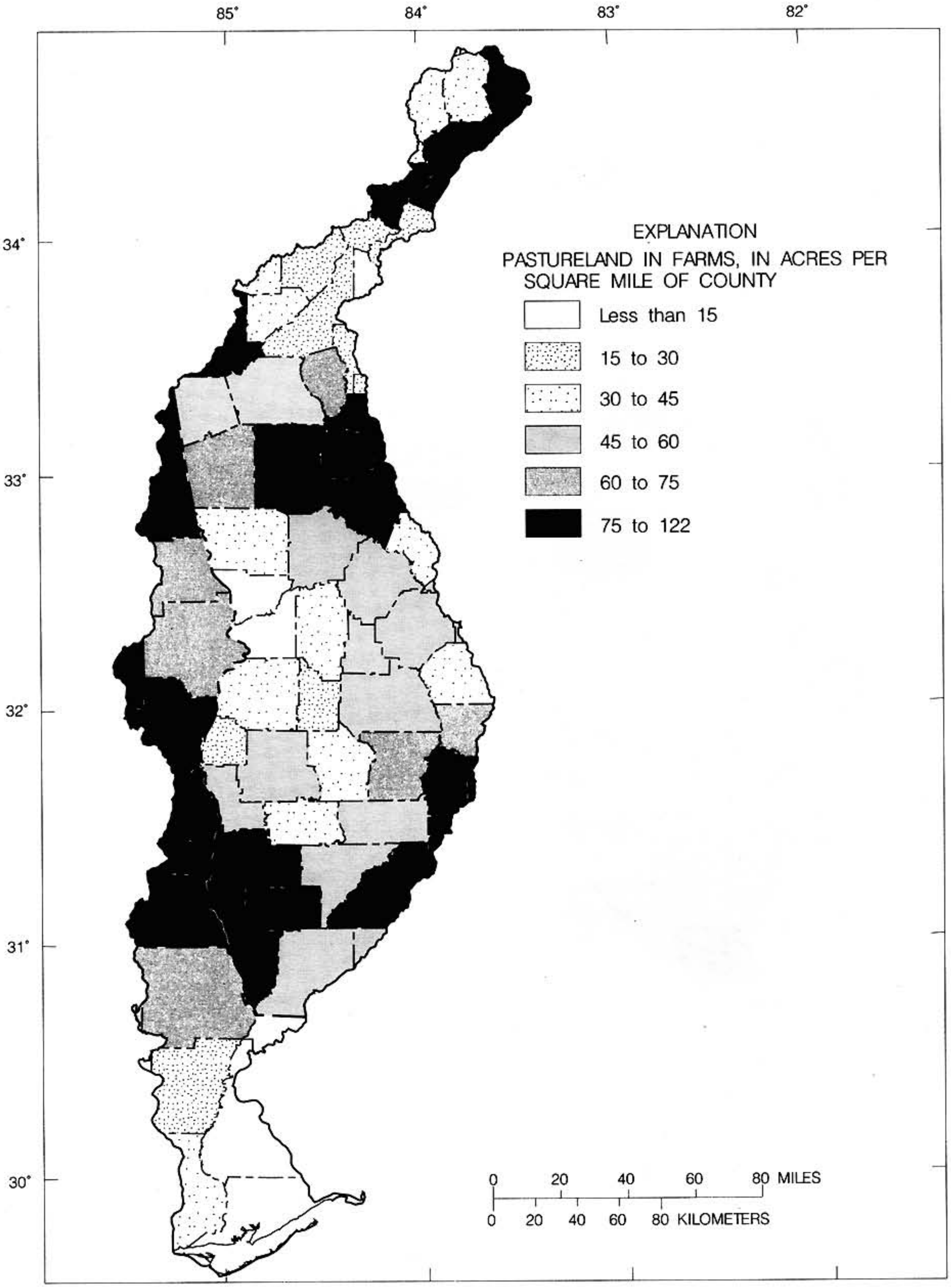


Figure 7. Pastureland in farms in the Apalachicola-Chattahoochee-Flint River basin, 1987.

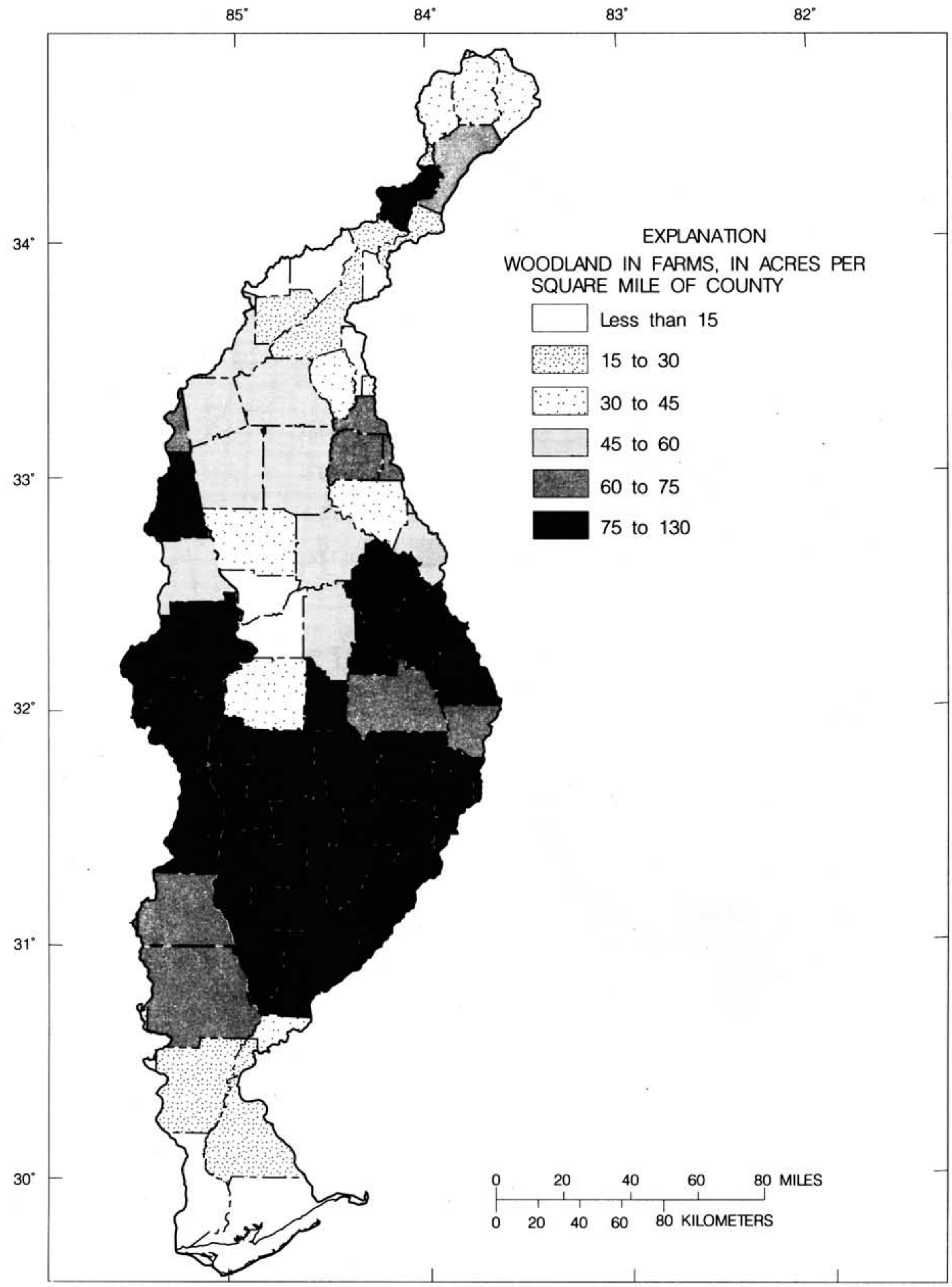


Figure 8. Woodland in farms in the Apalachicola-Chattahoochee-Flint River basin, 1987.

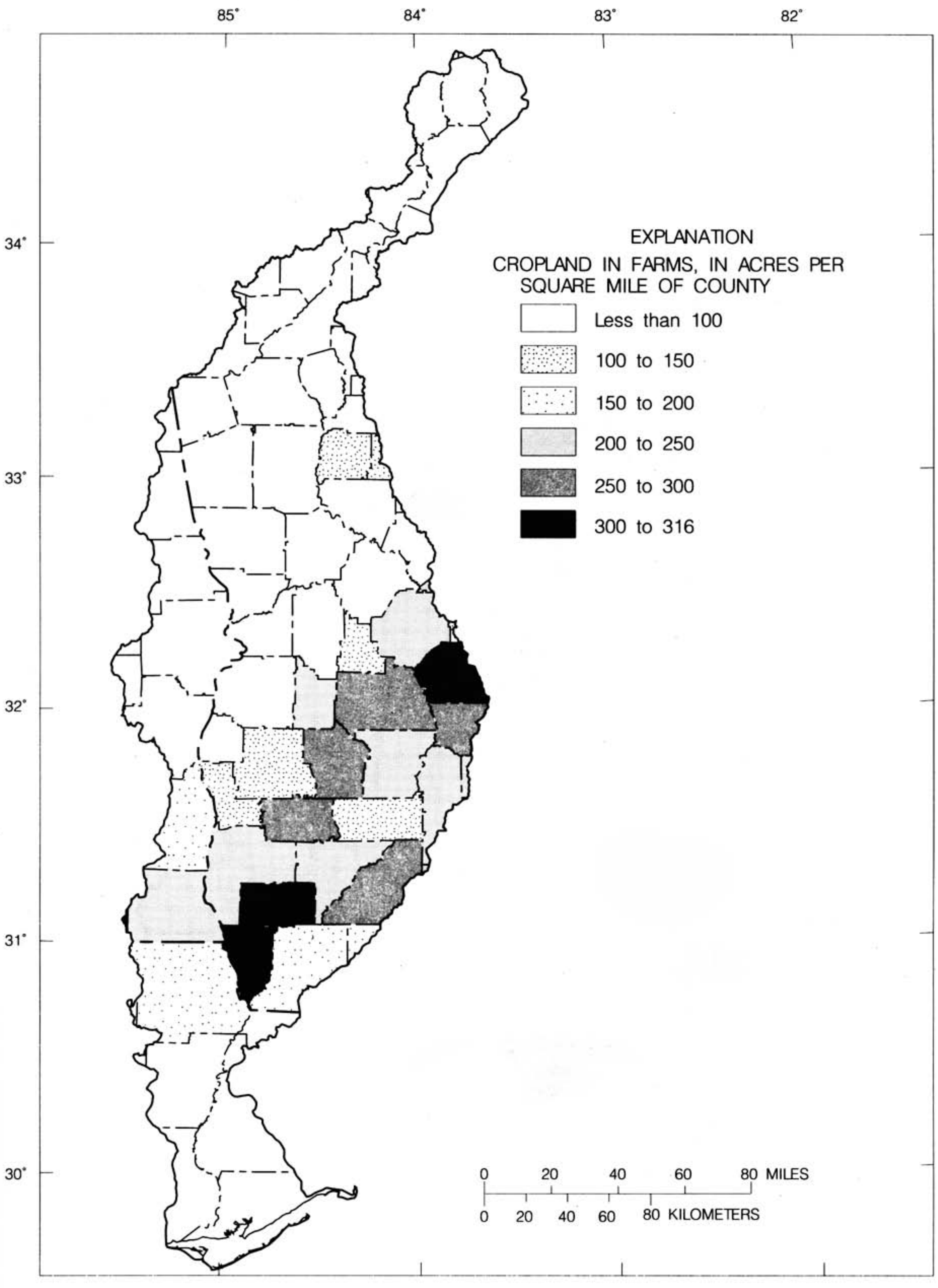


Figure 9. Total cropland in farms in the Apalachicola-Chattahoochee-Flint River basin, 1987.

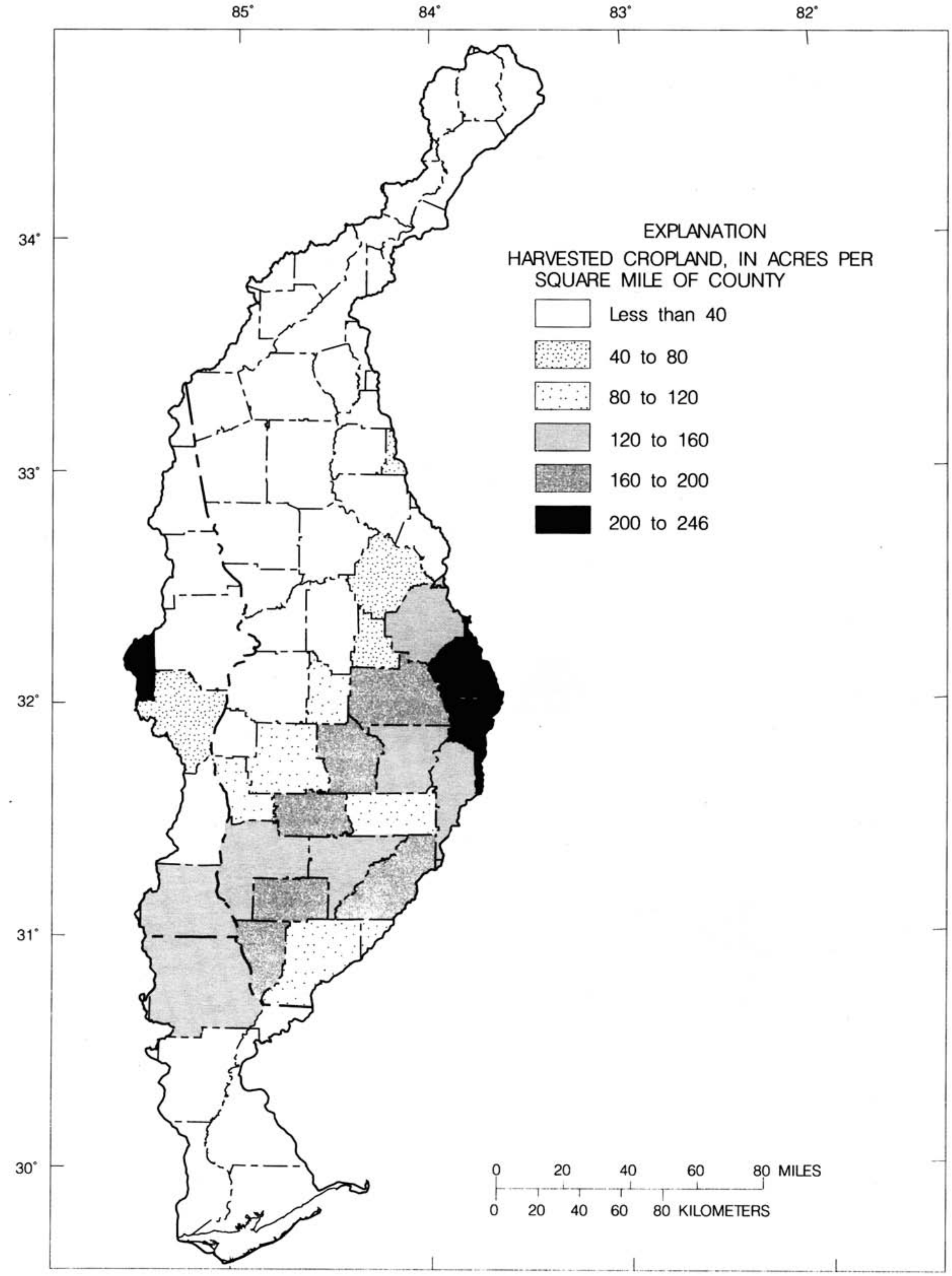


Figure 10. Harvested cropland in farms in the Apalachicola-Chattahoochee-Flint River basin, 1987.

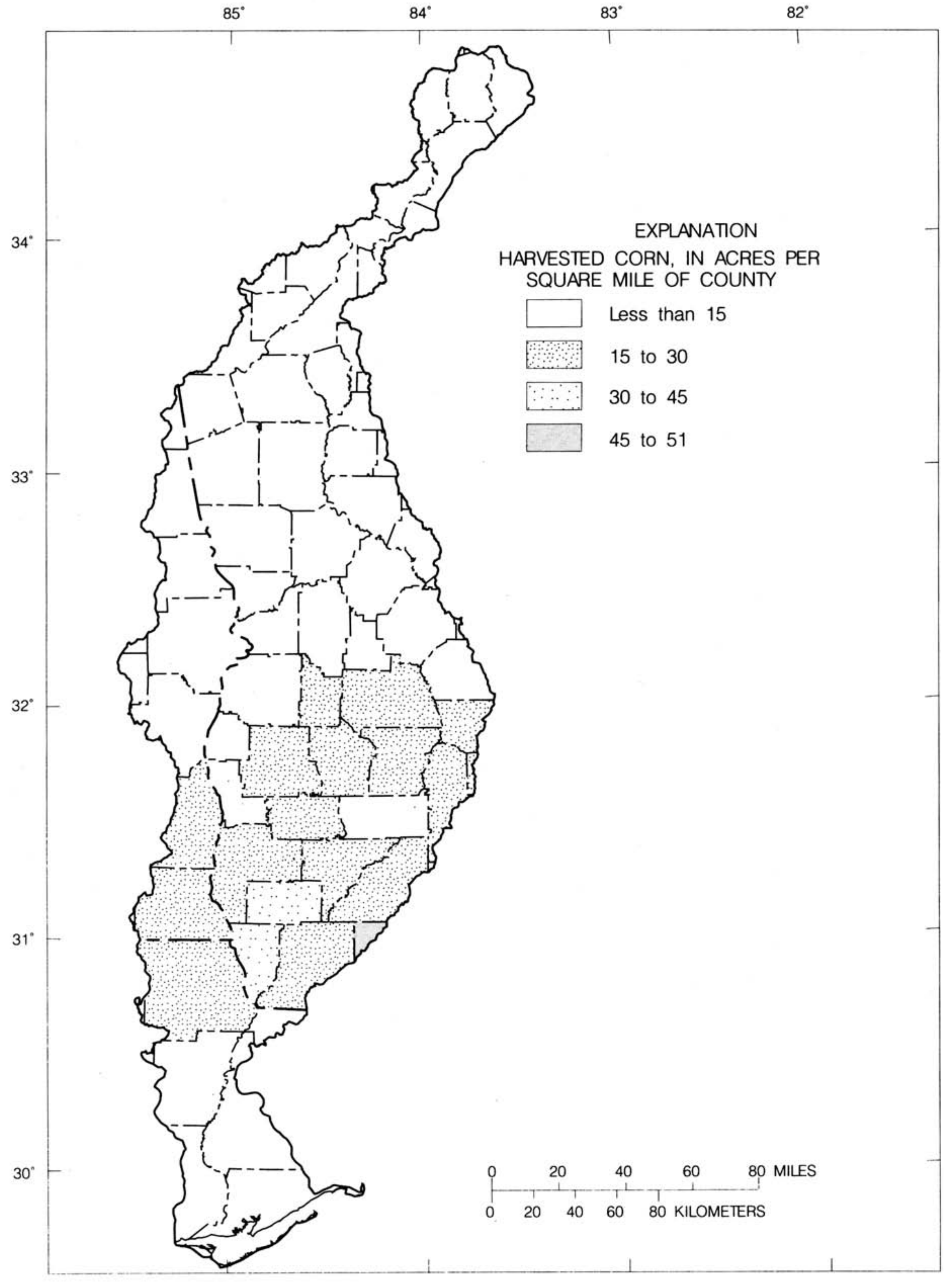


Figure 13. Harvested acres of corn in the Apalachicola-Chattahoochee-Flint River basin, 1990.

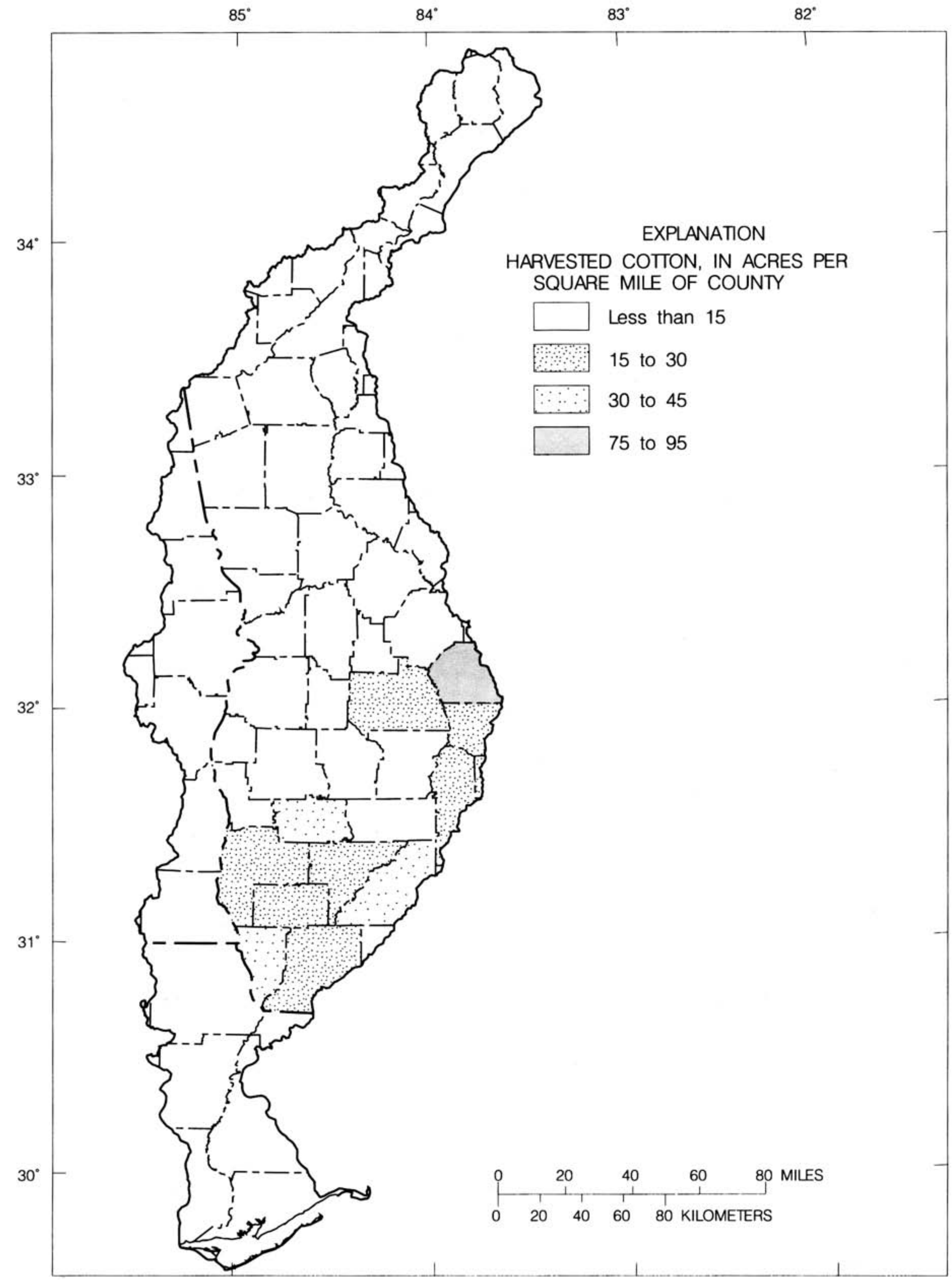


Figure 14. Harvested acres of cotton in the Apalachicola-Chattahoochee-Flint River basin, 1990.

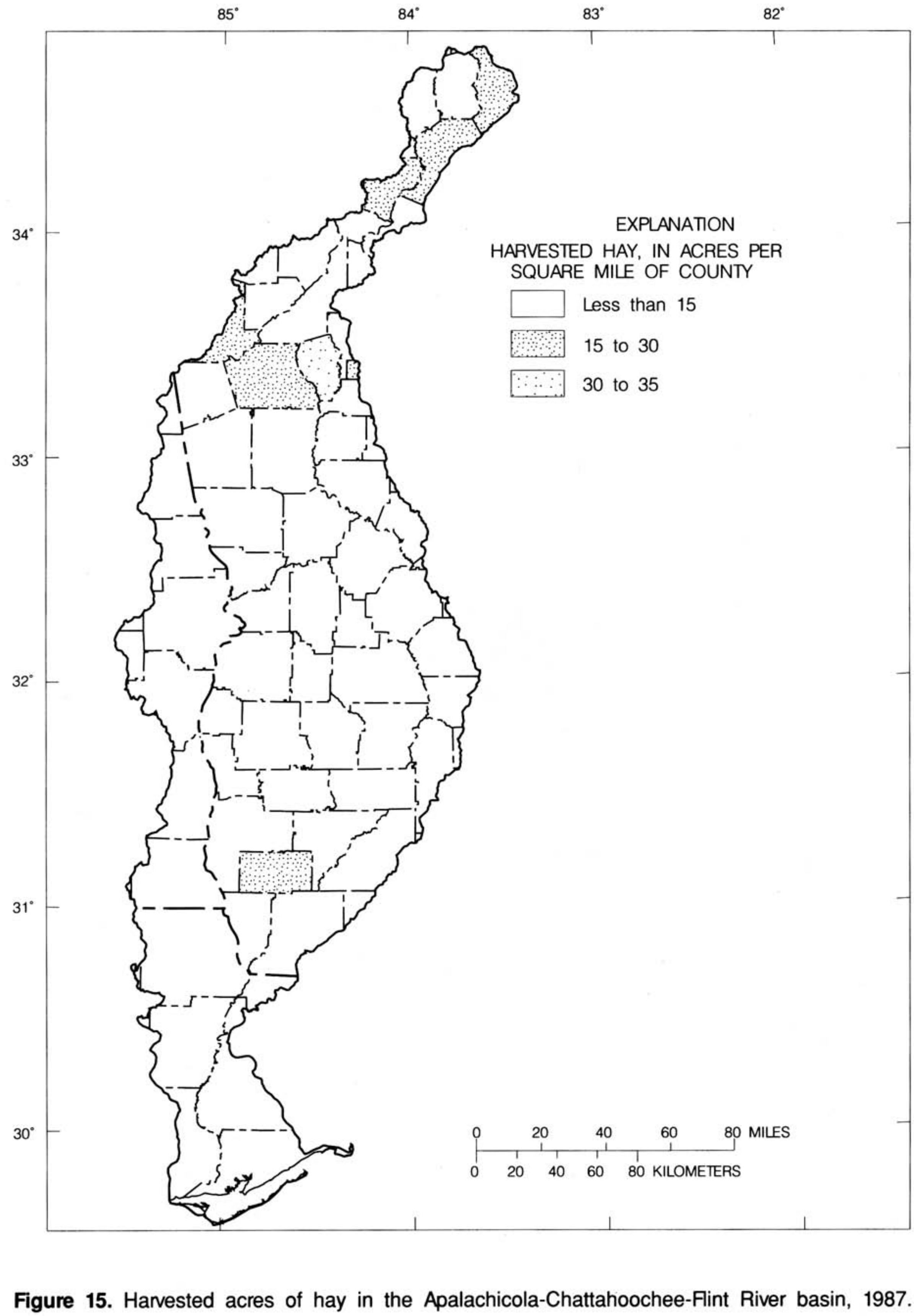


Figure 15. Harvested acres of hay in the Apalachicola-Chattahoochee-Flint River basin, 1987.

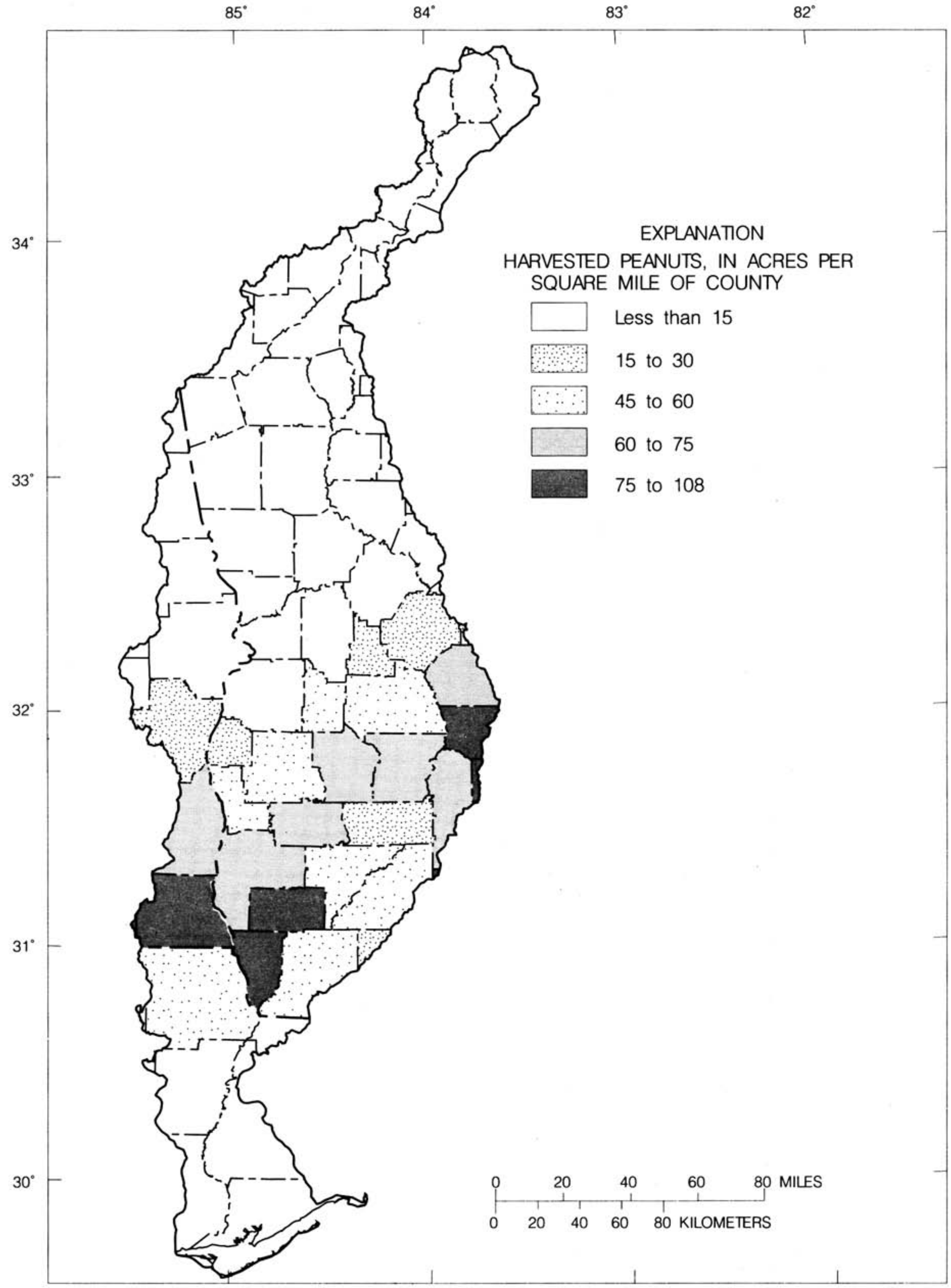


Figure 16. Harvested acres of peanuts in the Apalachicola-Chattahoochee-Flint River basin, 1990.

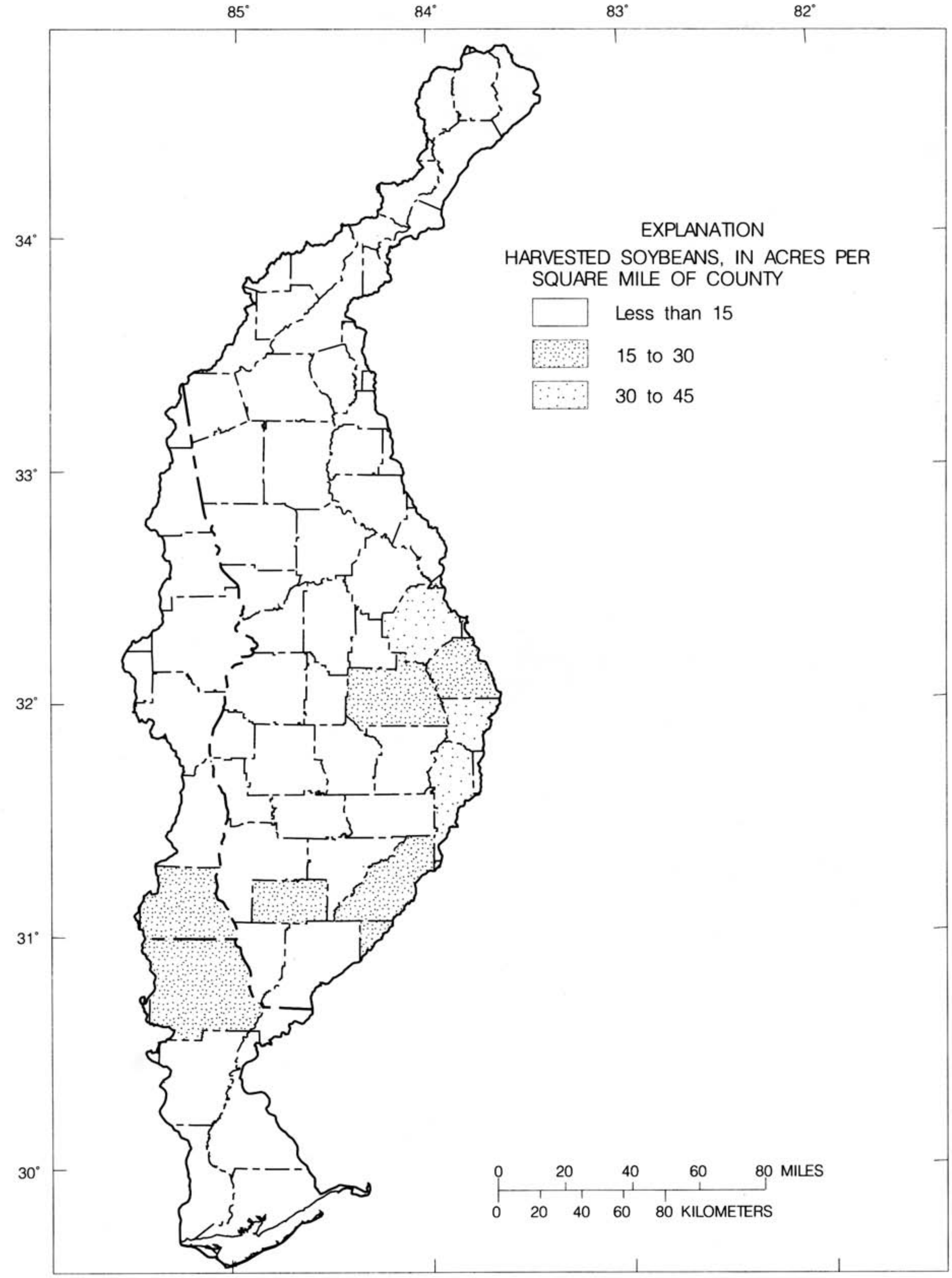


Figure 17. Harvested acres of soybeans in the Apalachicola-Chattahoochee-Flint River basin, 1990.

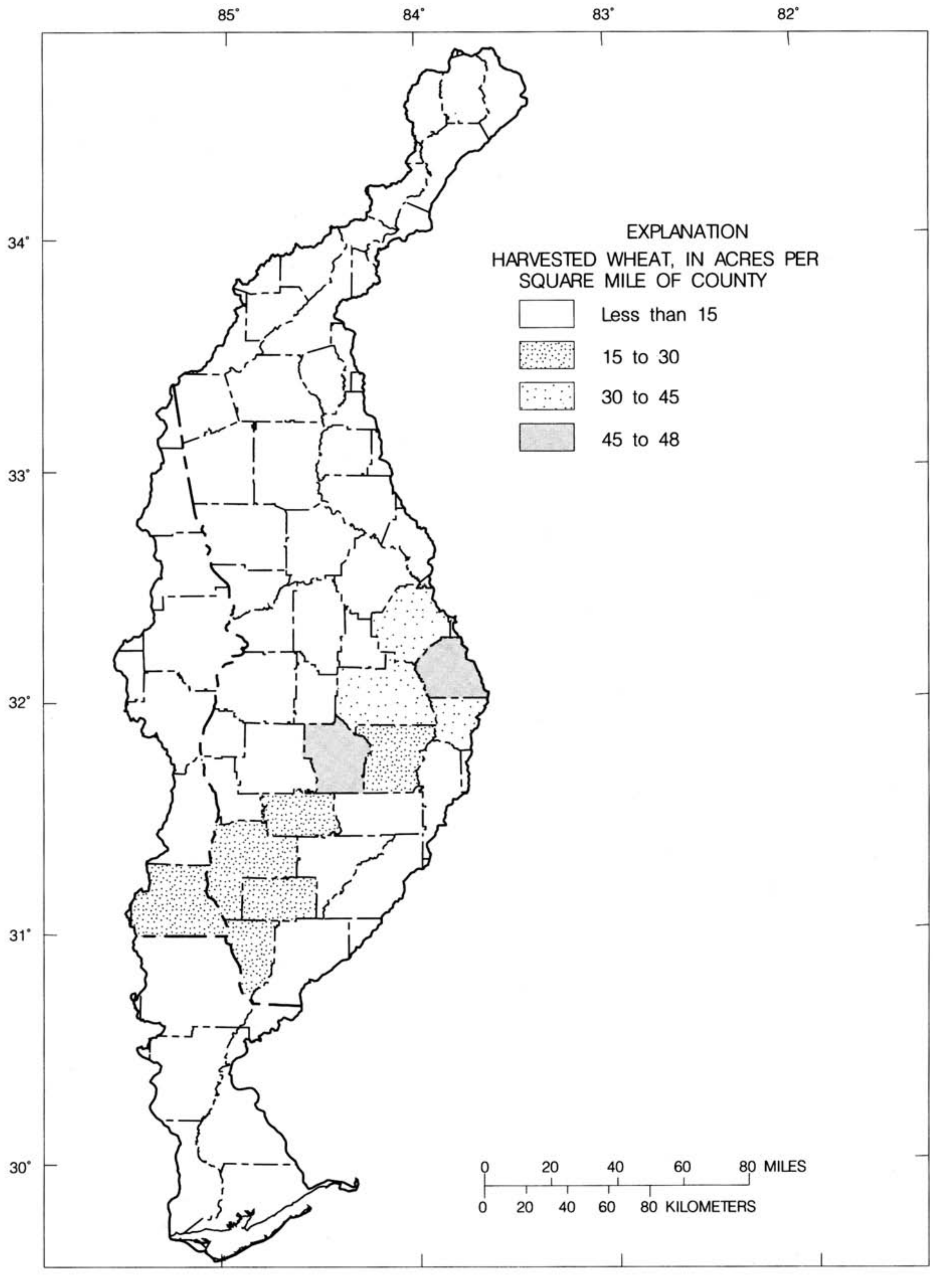


Figure 18. Harvested acres of wheat in the Apalachicola-Chattahoochee-Flint River basin, 1987.

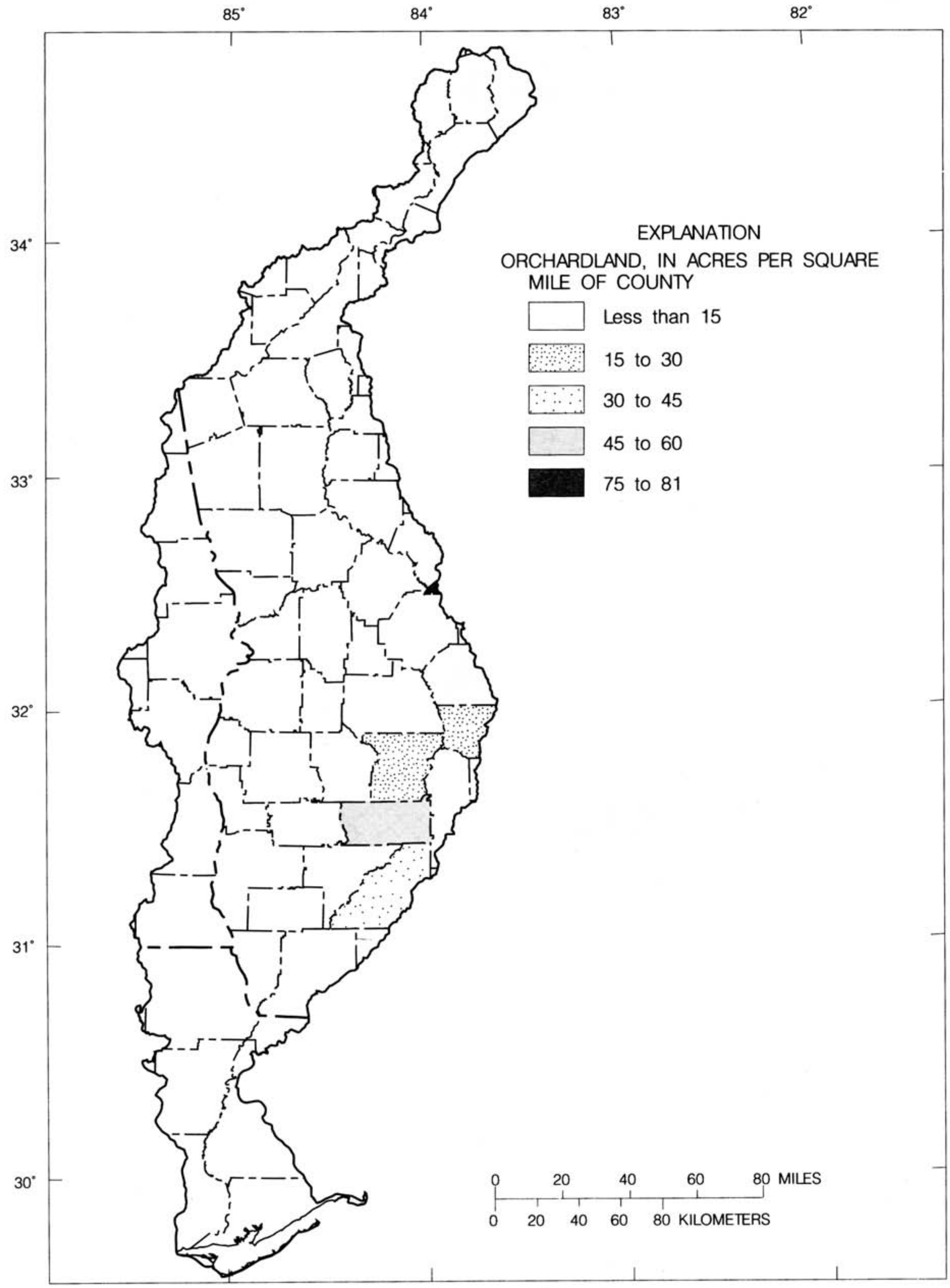


Figure 20. Orchardland in the Apalachicola-Chattahoochee-Flint River basin, 1987.

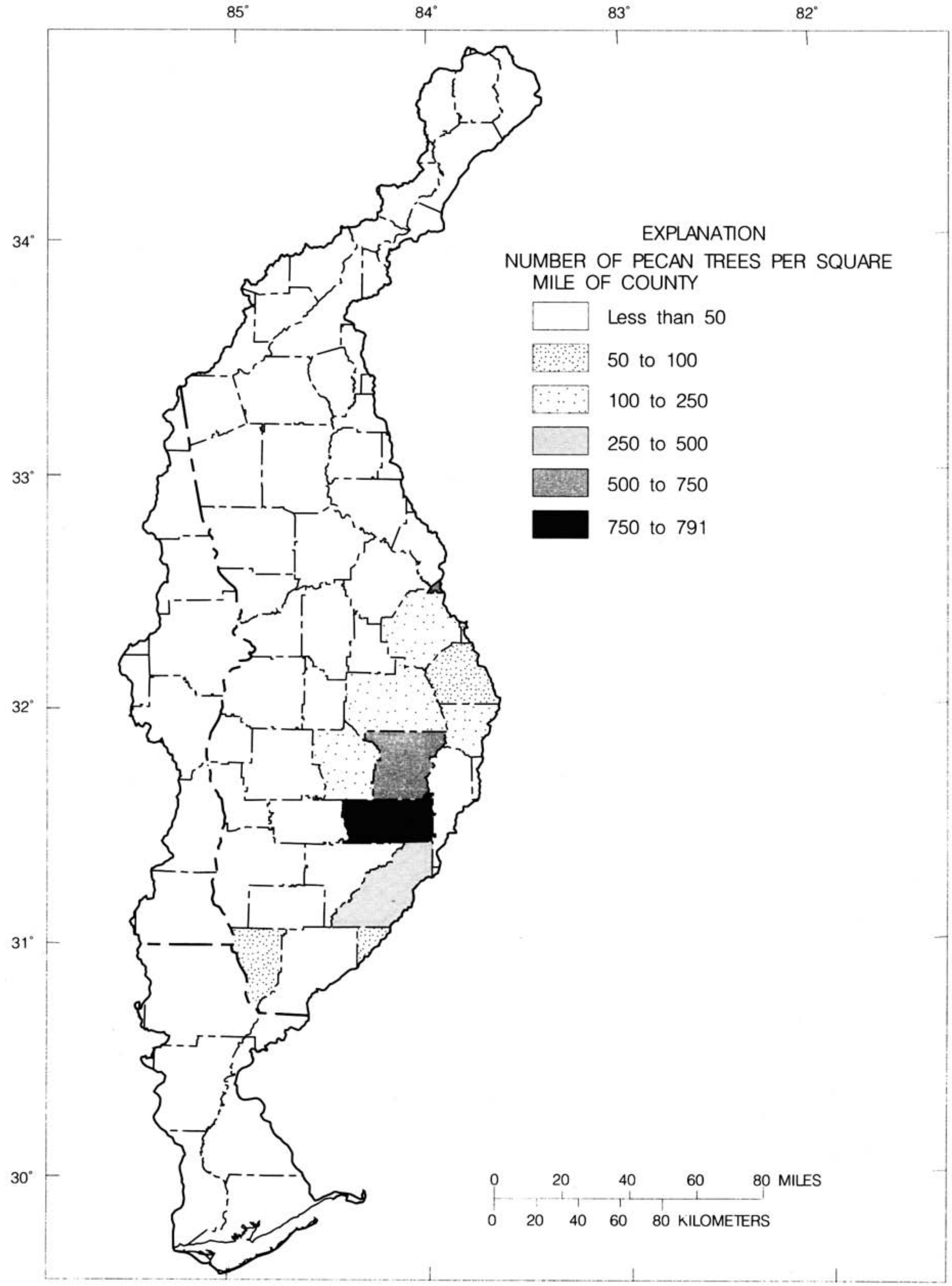


Figure 21. Number of pecan trees in the Apalachicola-Chattahoochee-Flint River basin, 1987.

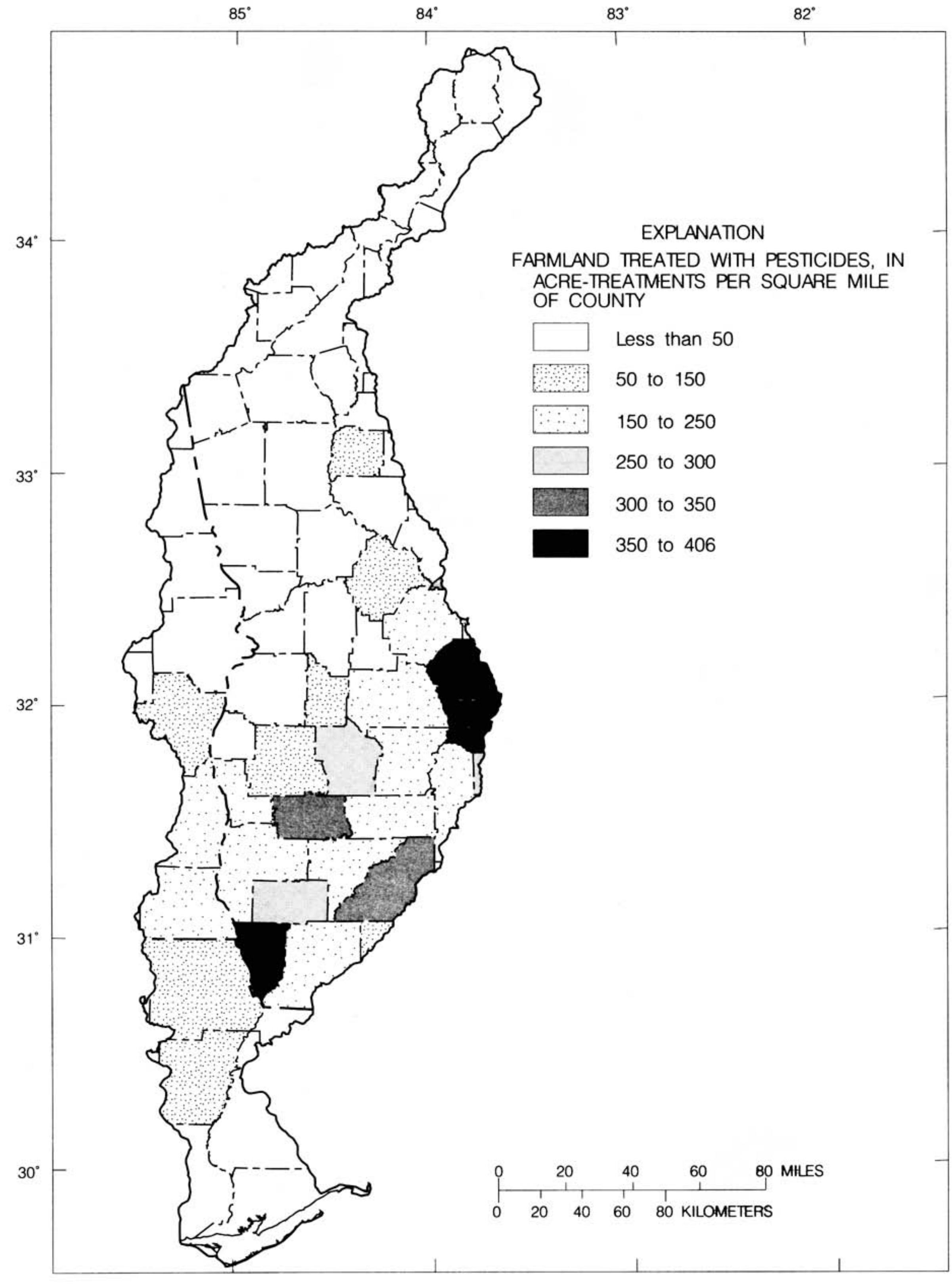


Figure 23. Farmland treated with all categories of pesticides in the Apalachicola-Chattahoochee-Flint River basin, 1987.

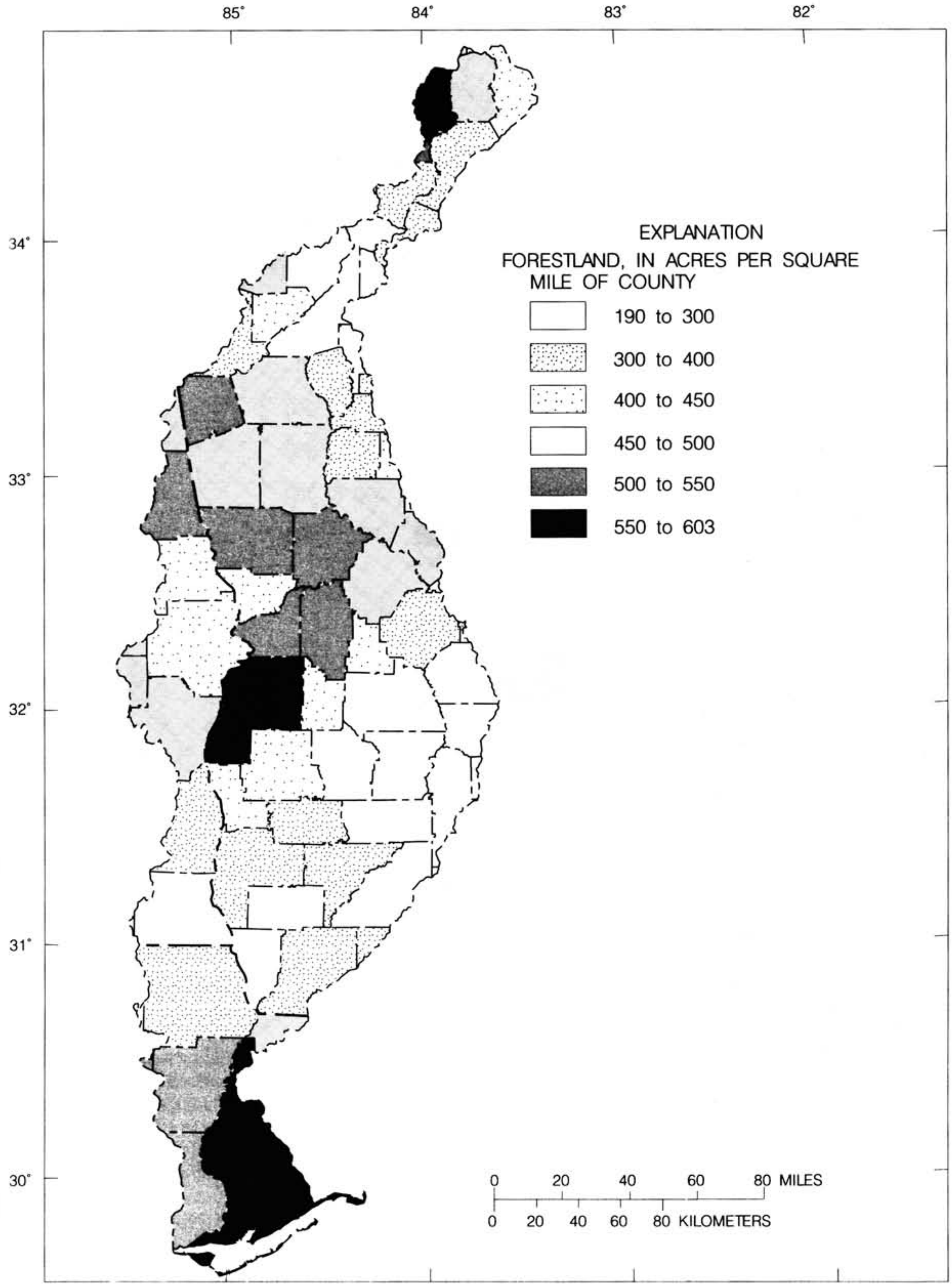


Figure 24. Forest land in the Apalachicola-Chattahoochee-Flint River basin, 1987, 1989, and 1990.

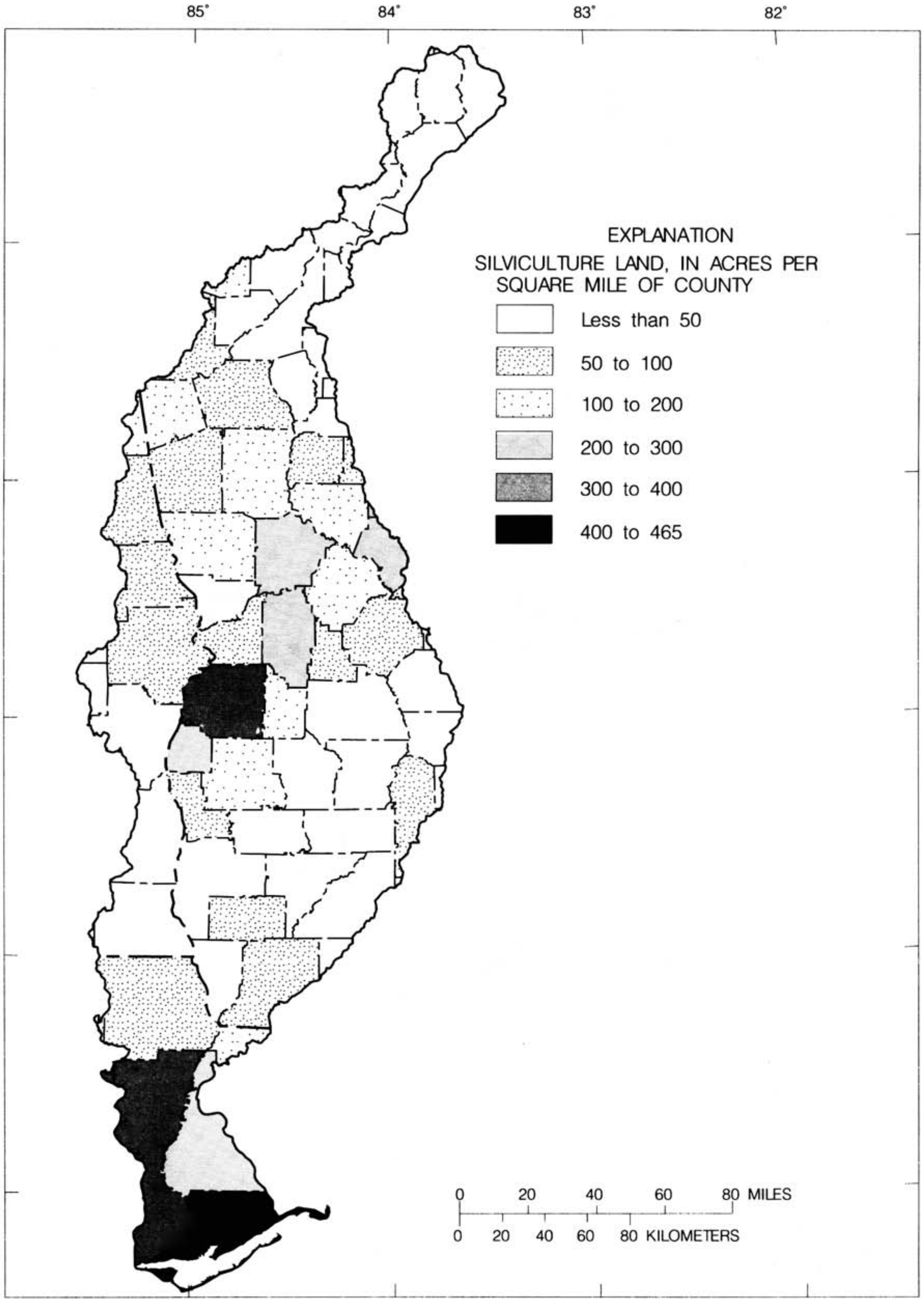


Figure 26. Silviculture land in the Apalachicola-Chattahoochee-Flint River basin, 1987, 1989, and 1990.

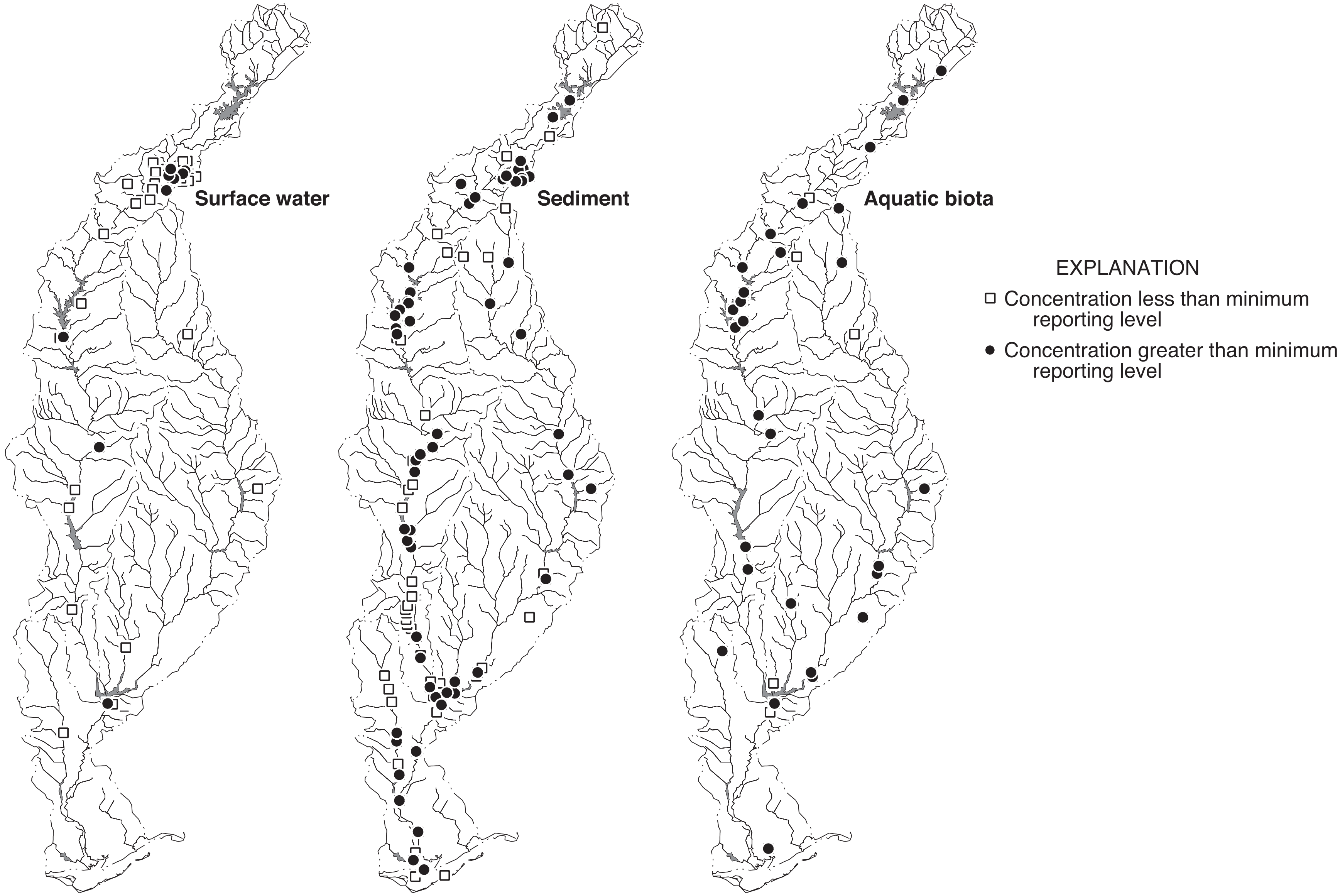


Figure 29. Sites sampled for compounds in the DDT group in surface water, sediment, and aquatic biota in the Apalachicola-Chattahoochee-Flint River basin.

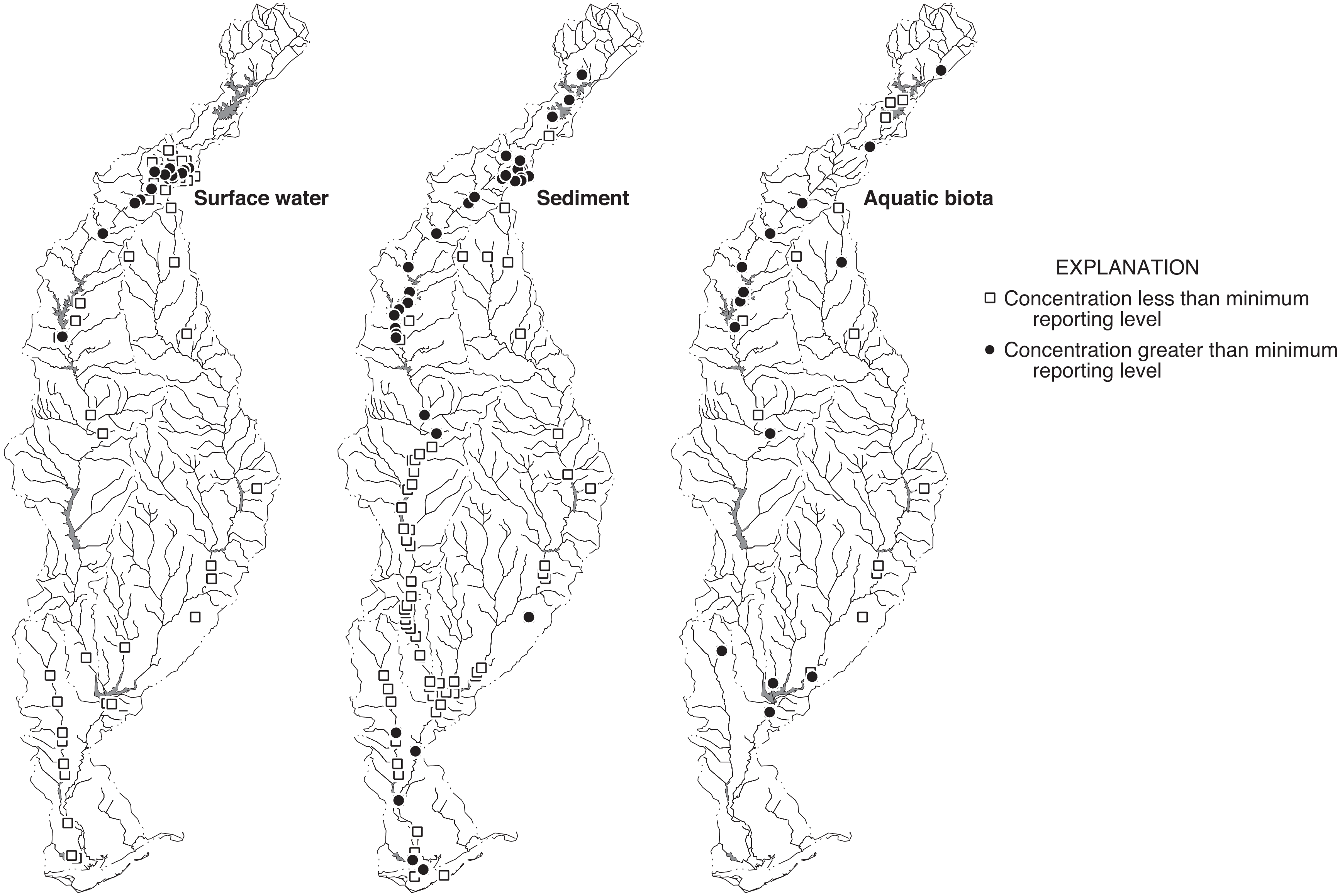


Figure 30. Sites sampled for componds in the chlordane group in surface water, sediment, and aquatic biota in the Apalachicola-Chattahoochee-Flint River basin.

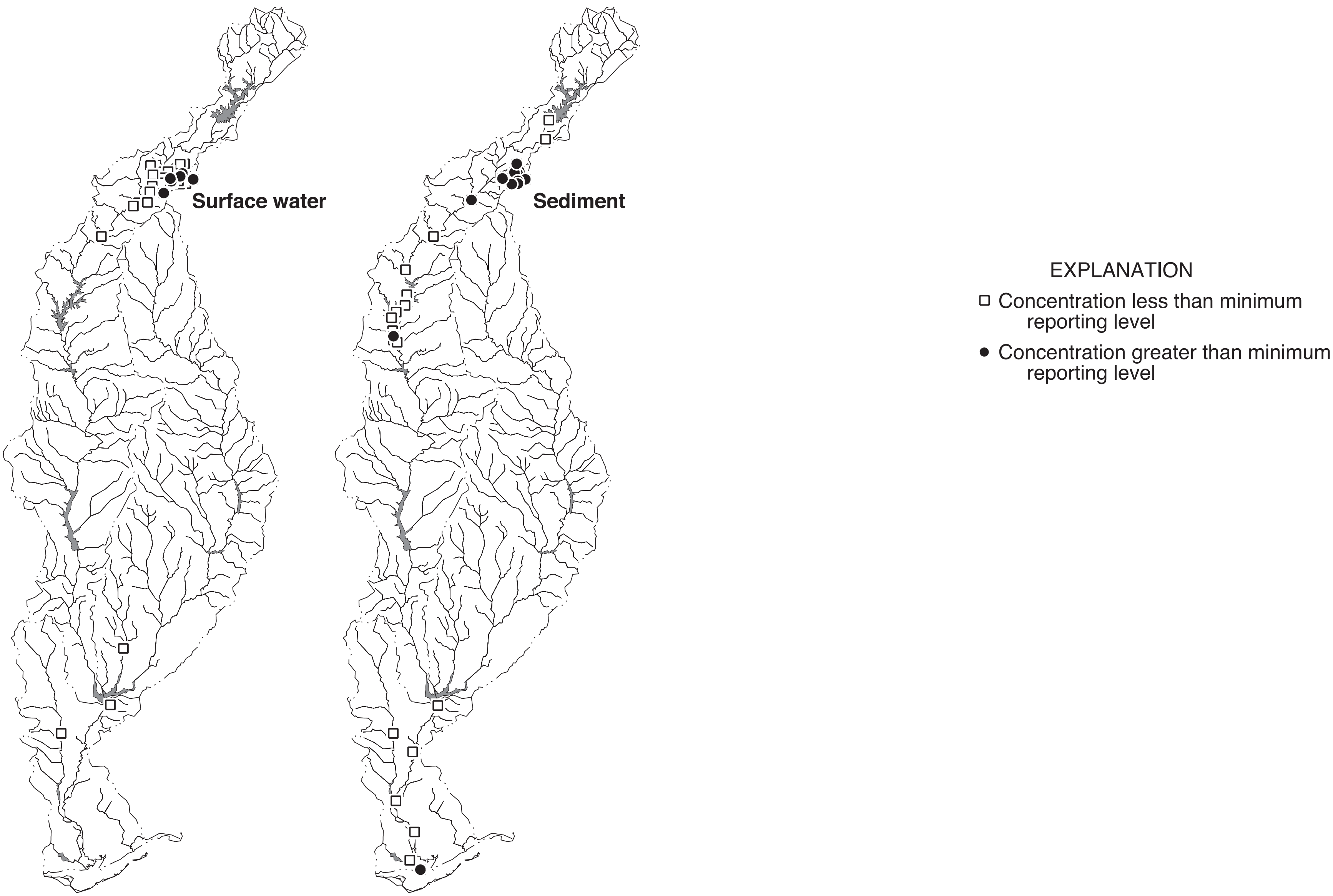


Figure 31. Sites sampled for heptachlor and heptachlor epoxide in surface water and sediment in the Apalachicola-Chattahoochee-Flint River basin.

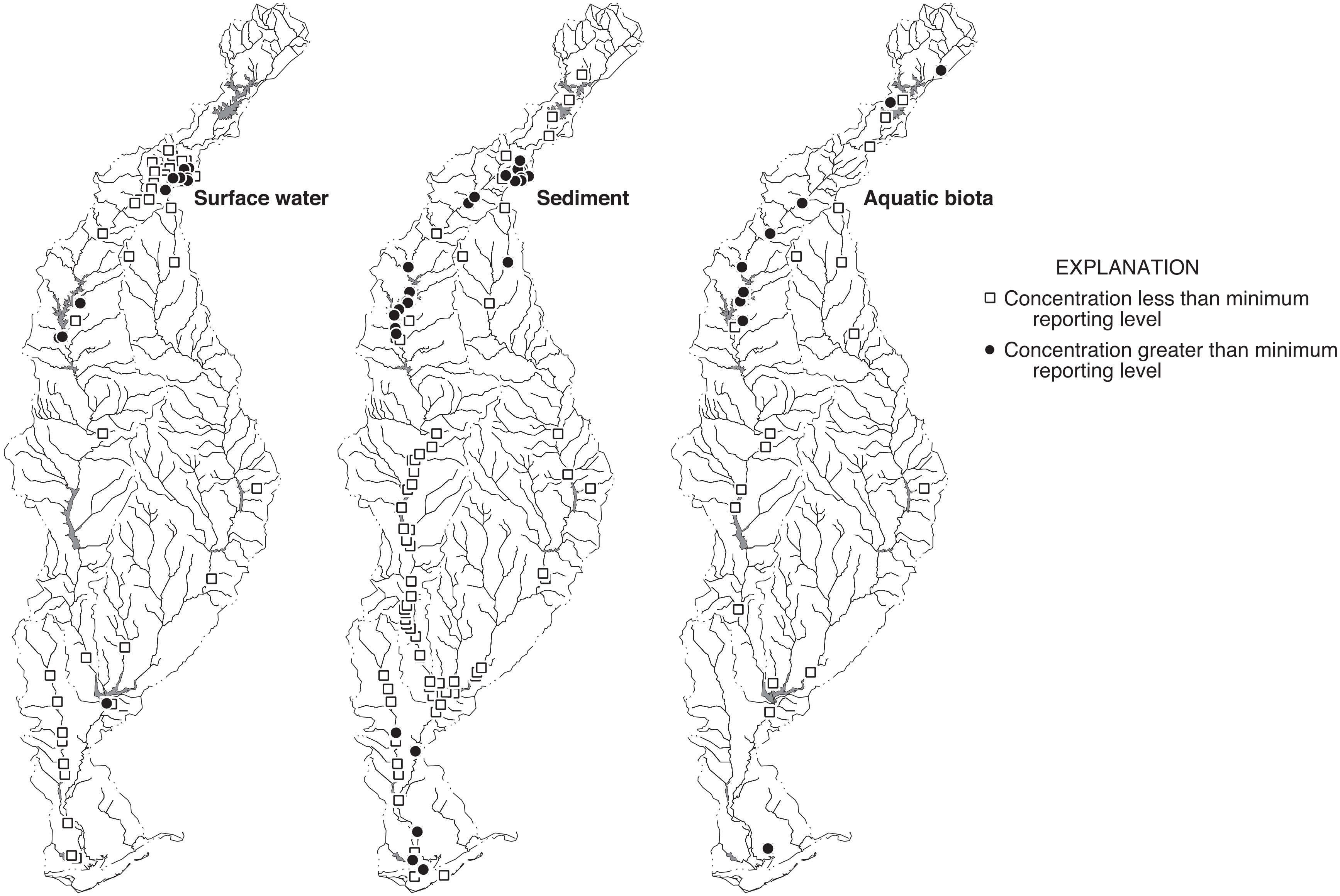


Figure 32. Sites sampled for compounds in the dieldrin group in surface water, sediment, and aquatic biota in the Apalachicola-Chattahoochee-Flint River basin.

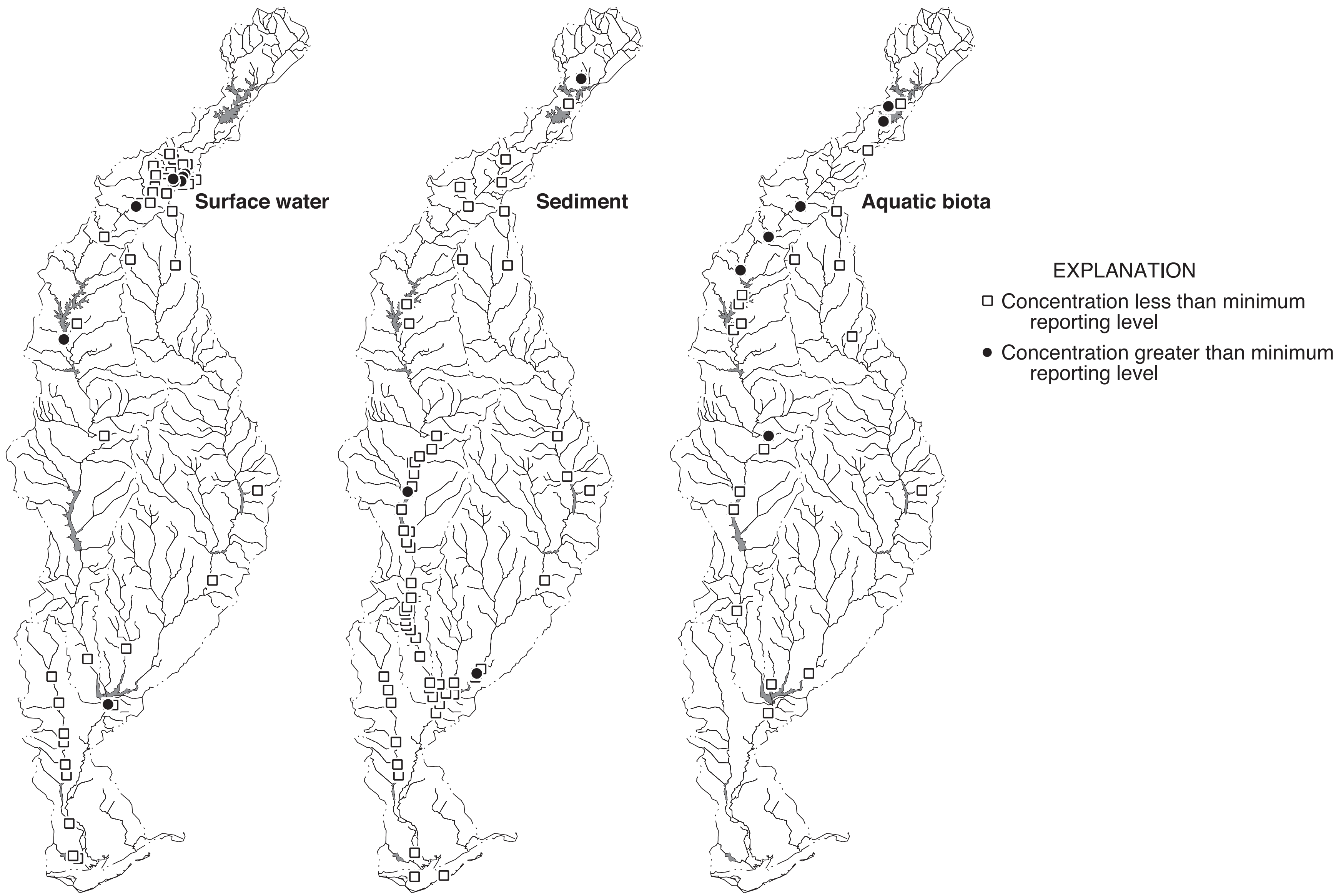


Figure 33. Sites sampled for componds in the lindane group in surface water, sediment, and aquatic biota in the Apalachicola-Chattahoochee-Flint River basin.

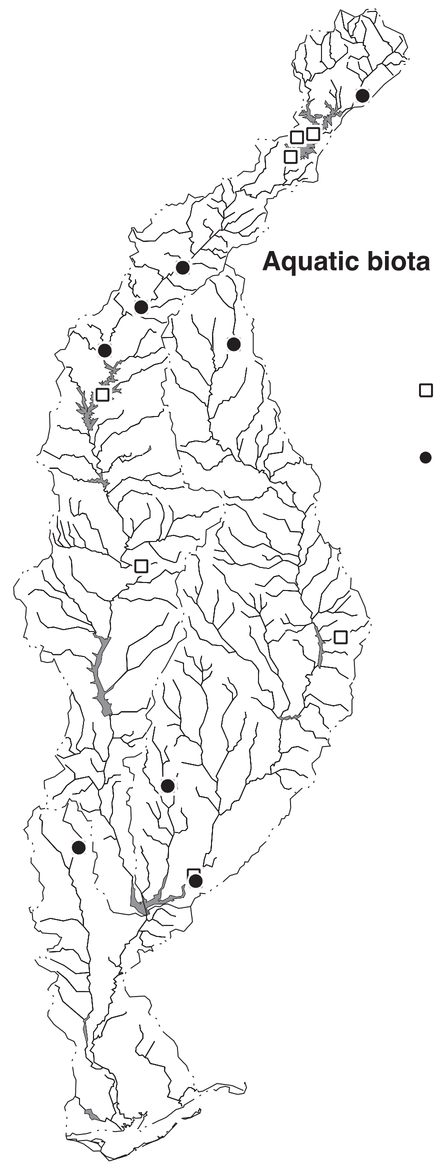


Figure 34. Sites sampled for mirex in aquatic biota in the Apalachicola-Chattahoochee-Flint River basin.

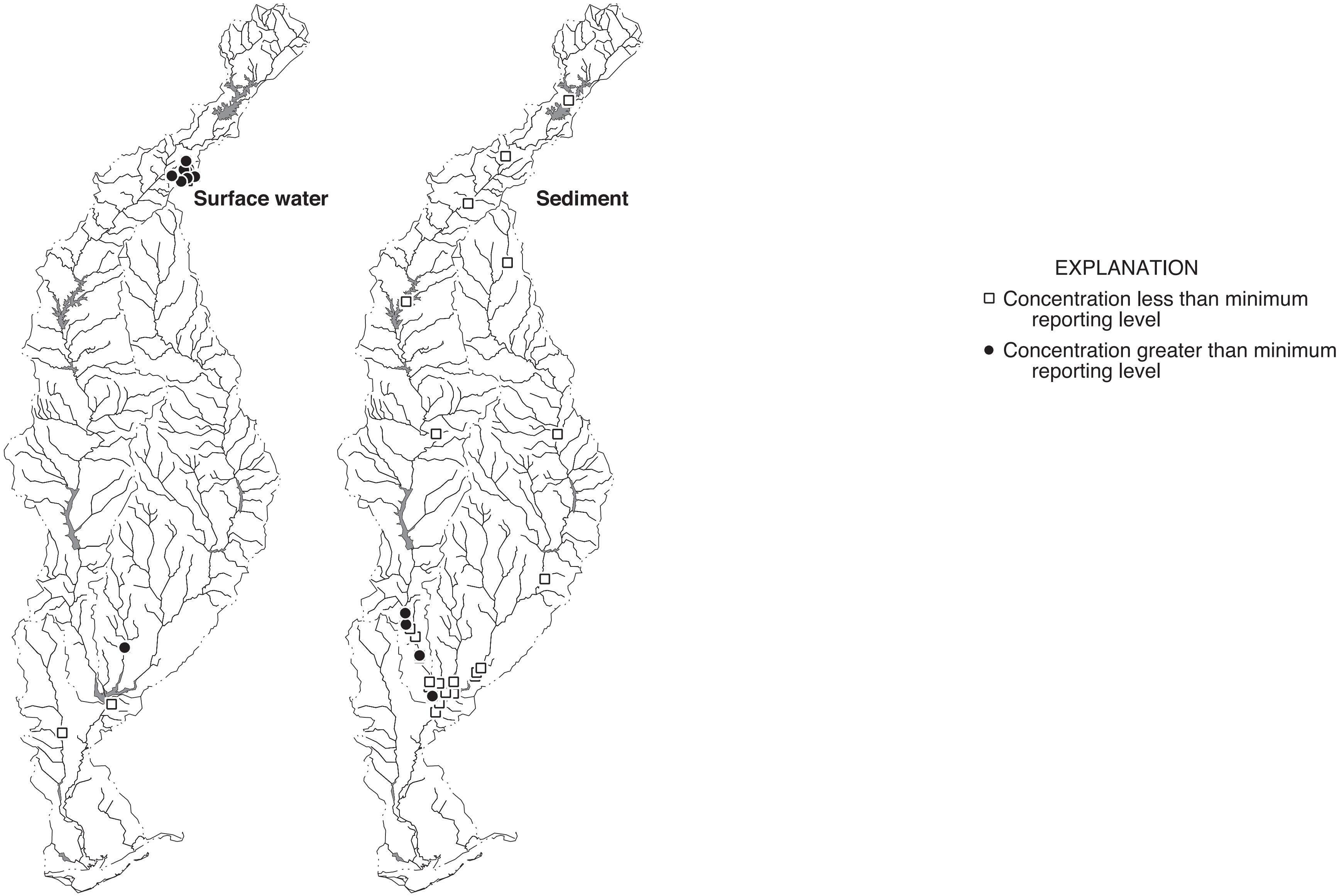
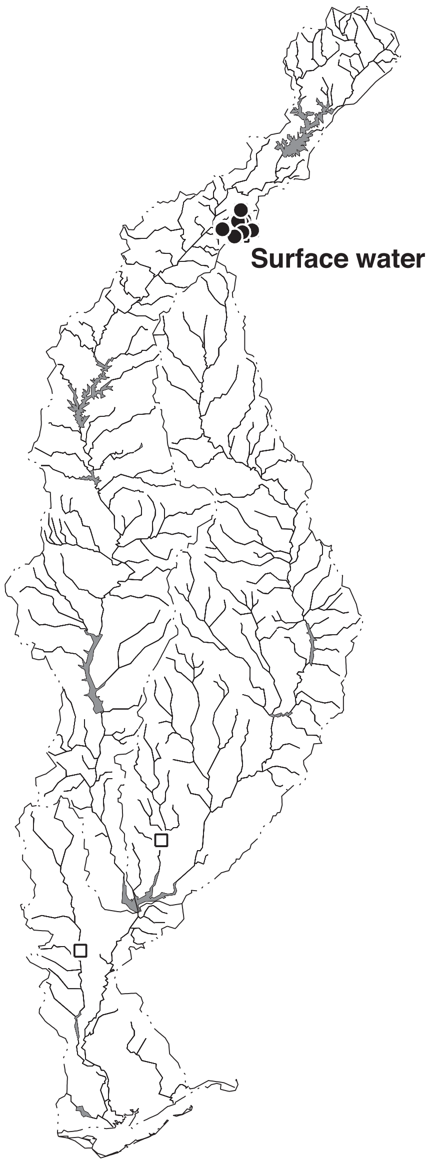


Figure 35. Sites sampled for 2,4-D in surface-water and sediment in the Apalachicola-Chattahoochee-Flint River basin.

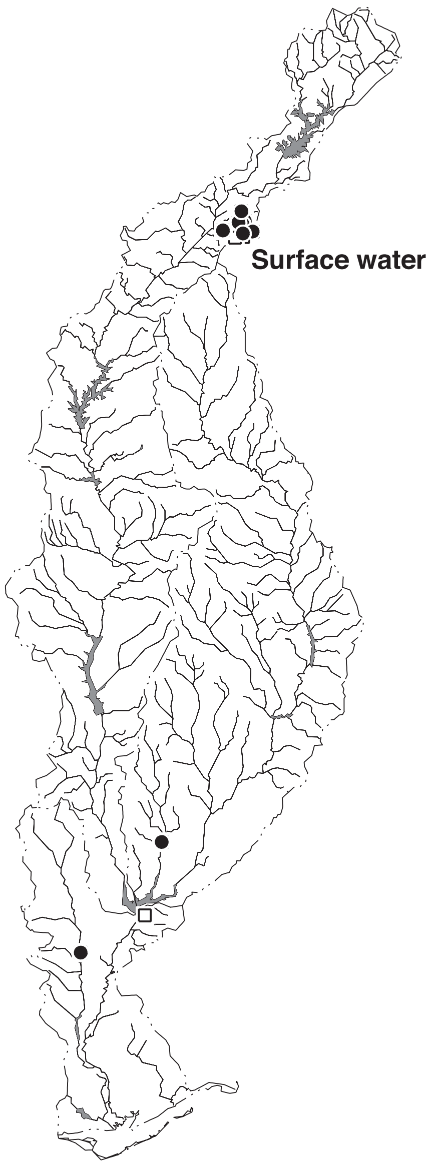


EXPLANATION

□ Concentration less than minimum reporting level

● Concentration greater than minimum reporting level

Figure 36. Sites sampled for 2, 4, 5-T and/or silvex in surface water in the Apalachicola-Chattahoochee-Flint River basin.



EXPLANATION

□ Concentration less than minimum reporting level

● Concentration greater than minimum reporting level

Figure 37. Sites sampled for diazinon in surface water in the Apalachicola-Chattahoochee-Flint River basin.

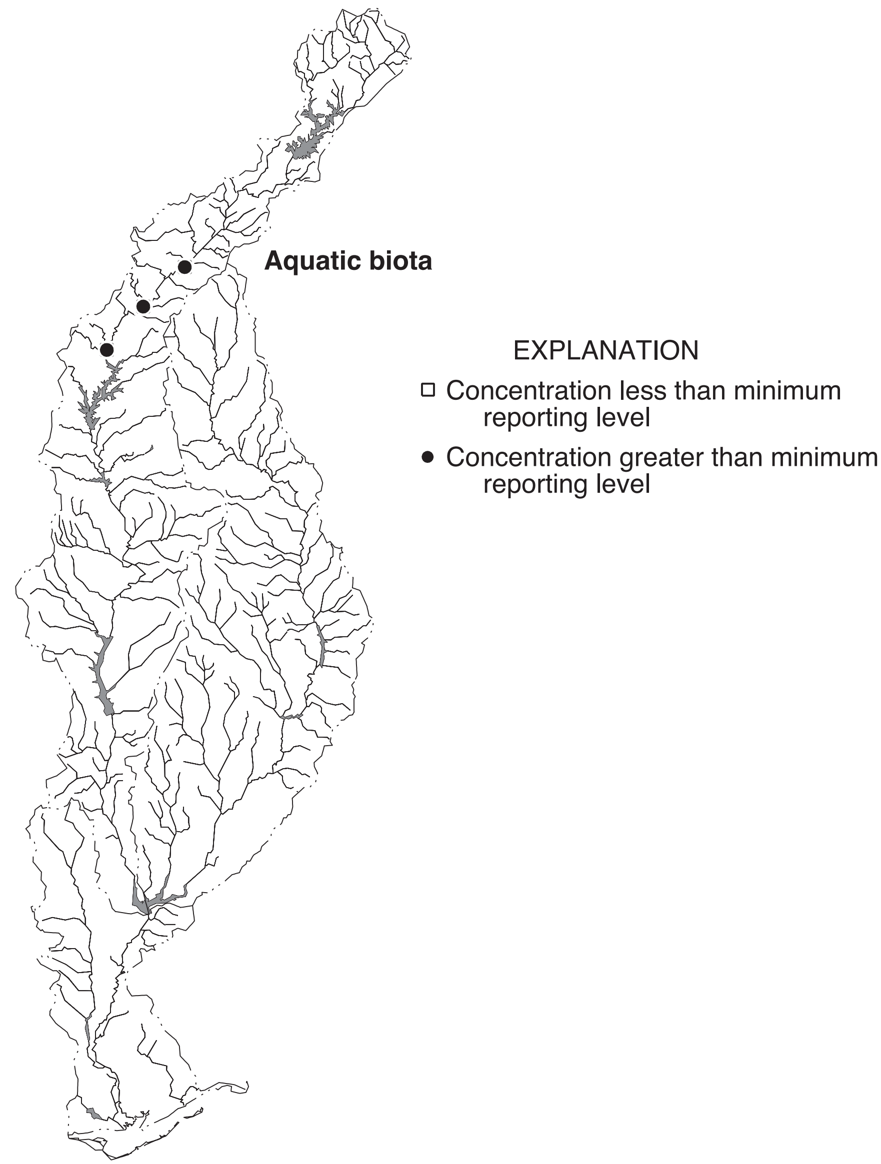


Figure 38. Sites sampled for chlorpyrifos in aquatic biota in the Apalachicola-Chattahoochee-Flint River basin.

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