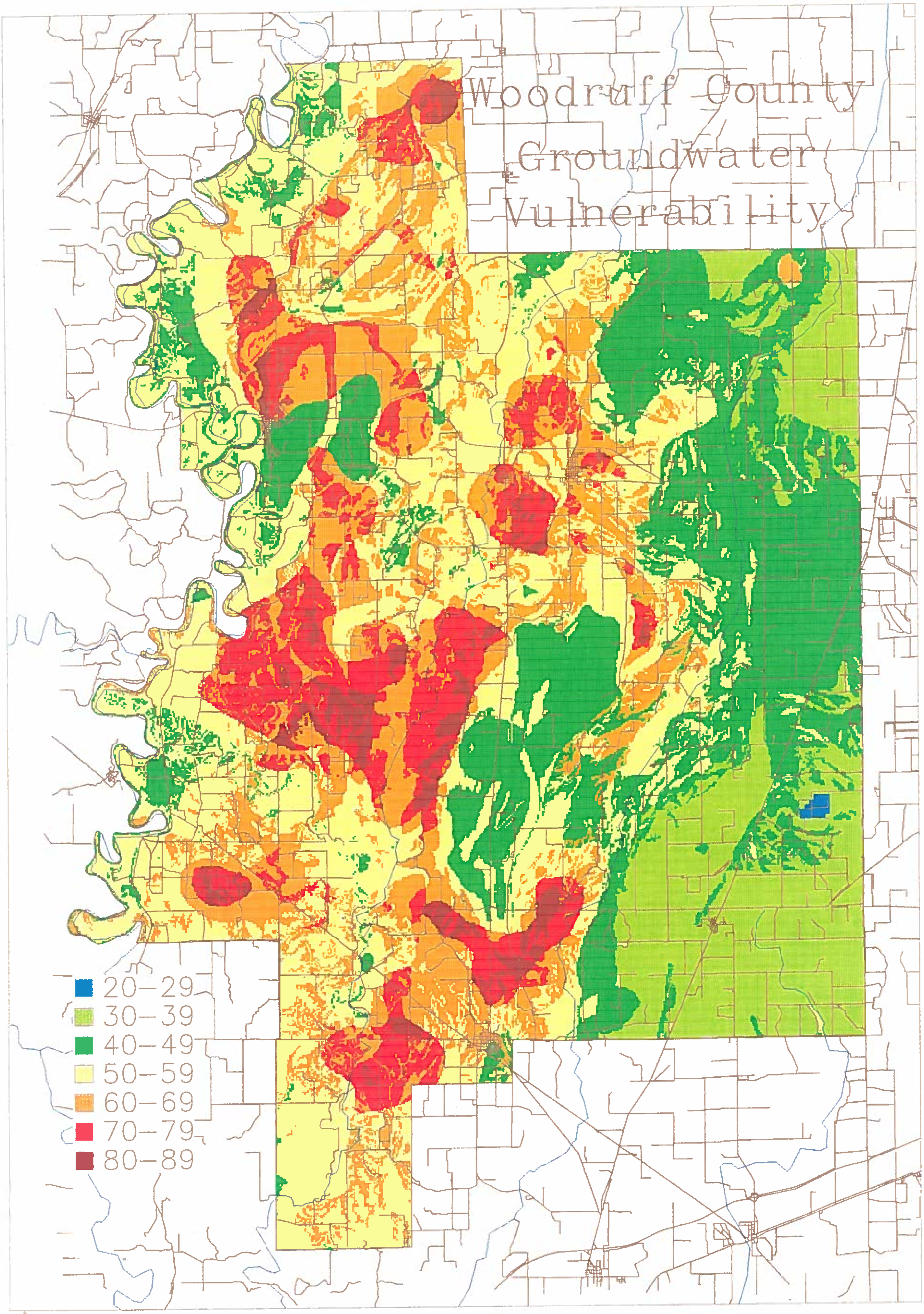
Woodruff County
Groundwater
Vulnerability
20-29
30-39
40-49
50-59
60-69
70-79
80-89

INTRODUCTION

There is much unknown about the extent of pesticide contamination of groundwater in Arkansas. In recent years, several research studies have been conducted where wells for irrigation and domestic uses have been sampled and analyzed for pesticides (Lavy, 1988; USGS,1993; Nichols, et al., 1993). For state and federal regulatory agencies, evaluation of the potential ground water contamination begins with considering those areas in Arkansas where pesticides are used and where the ground water is vulnerable to contamination. With a relatively large area of crops grown in Arkansas and only limited financial resources available for chemical analyses by state and federal agencies, the question of where these agencies should begin to sample the ground water for pesticides is pertinent. Therefore, there is a need for the development of a scheme that can be used to optimize the available resources.

OBJECTIVE

The objective of this work was to estimate areas in Woodruff county where the ground water is vulnerable to pesticide contamination. This study used a combination of geographic information systems (GIS) techniques and satellite remote sensing to estimate the areas of potential pesticide contamination of the ground water.

METHODS

Location of the Study

Woodruff county lies in the Mississippi alluvial valley in eastern Arkansas (Figure 1). It has an area of about 378,000 acres of which 71% is in farmland and 53% is in harvested cropland (Table 1). The 1992 statistical reports on agricultural landuse documented the diversity of agronomic crops grown and harvested in Woodruff County. The farmers in the county were quite productive with the largest agricultural landuse planted in soybeans, followed by rice and wheat, grain sorghum, corn and cotton, etc. Approximately 53% of the cropland in Woodruff County is irrigated with 1,108 irrigation wells registered by the Soil and Water Conservation Commission (Figure 2). Livestock does not appear to be a major factor in the overall agricultural productivity of the county.

Determination of the Areas of Vulnerable Groundwater

The areas in Woodruff county where the ground water is highly vulnerable to pesticide contamination were determined by using a ground water vulnerability model along with GIS techniques.

Table 1. Summary of the 1992 agricultural statistics of Woodruff county, Arkansas.

Characteristic		acres
Approximate land area		378,758
Land in farms		269,601
Average size of farms		872
Cropland harvested		201,173
Irrigated land		106,324
Soybeans		
	total	139,000
	irrigated	43,000
Rice		
	harvested	55,500
Wheat		
	harvested	34,000
Grain Sorghum		
	harvested	23,500
Corn		
	harvested	9,700
Cotton		
	total	5,500
	irrigated	2,700

*Source 1992 Agricultural statistics, AES Report Series 325.

The ground water vulnerability model used in this study considered the soil and hydrogeological characteristics that are considered important in the transport of pesticides to ground water in Arkansas. The factors included depth to ground water, recharge of ground water, aquifer media, soil, topography, impact of the vadose zone and hydraulic conductivity of the aquifer. These factors were incorporated into a ranking procedure which uses sets of weights, rates and ranges to produce a relative numerical index. Each factor was weighted for its influence within the model and its importance to movement of pesticides to the groundwater. Ranges within each factor were given rates which varied from 1 to 10. The rate for a given factor was then multiplied by the appropriate weight and the product summed for all seven factors. Factors used in the model with their associated weight and maximum rate are presented in Table 2.

Table 2. Factors of the groundwater vulnerability model, weights and maximum rates.

Model factor	Weight	Maximum rate
Depth to groundwater	5	10
Recharge	4	9
Aquifer media	2	10
Soil	5	10
Topography	3	10
Impact of vadose zone media	7	10
Conductivity of the aquifer	2	10

The GIS used the ground water vulnerability model information to manipulate database layers existing within the computer (Table 3). Depth to ground water was interpreted by subtracting potentiometric surface values from the elevation data layer. Recharge rates were evaluated from a USGS 1 x 1 mile grid. The surface geology data layer was utilized in the interpretation of aquifer media and hydraulic conductivity of the aquifer. The soils data layer was a detailed 1:24,000 scale based on the recent mapping of Woodruff County by the Soil Conservation Service. Topography (slope) was produced by the GIS from the elevation data layer. The clay confining unit was used to represent the impact of vadose zone media.

Individual data layers representing each of the factors were re-classed to the given rates for each of the prescribed ranges within a factor. The data layer values were then multiplied by the appropriate weight for the given factor. The resulting data layers were then summed to produce a map of relative indices for groundwater vulnerability to pesticides (GVIP) for Woodruff County. The values of GVIP for Woodruff County ranged from 61 to 246. The indices were then multiplied by 100 and divided by the maximum index possible (276) to obtain a comparable scale of 1 to 100 for the final map. These final indices were designated as RGVIP. This scale would allow for comparison of the results of this ground water vulnerability model with those of other models. In this study, RGVIP indices ranged from 22 to 89 with the higher the indicae the more vulnerable the ground water to pesticide contamination. Particular attention was given to the characteristics and landuse of those areas with RGVIP>70 and RGVIP>80.

Table 3. Base data layers used in GIS analyses.

Base Data Layer	Source	Scale/ Resolution	Type	Factor Interpreted
Surface Geology	CAST	1:500,000	Vector Polygons	Aquifer Media
				Aquifer Hydraulic Conductivity
Soil	SCS	1:24,000	Vector Polygons	Soil
Elevation	USGS	80 m	Raster	Depth to Groundwater
				Topography
Potentiometric	USGS	Base Map 1:500,000	Vector Contours	Depth to Groundwater
Recharge	USGS	1x1 mile grid	Site	Recharge
Clay Confining Unit	USGS	Base Map 1:500,000	Vector Contours	Impact of Vadose Zone

Use of Satellite Imagery for Crop Identification

Satellite imagery of the Mississippi Delta Region of Arkansas from Landsat 5 was obtained from EOSAT. The date of the scene was June 22, 1992. The image was geo-referenced and trimmed from its original size to only the Arkansas portion of scene number 23/35. The image coordinates were calculated from the original values and applied to the new image with GEOSET. In order to compensate for haze across the image, a bitmap of clear water areas was constructed for a scatter plot linear regression equation. In these equations, channel 4 (0.76 - 0.90 um) was used as the independent variable because the longer infrared wavelengths experience little degradation due to atmospheric effects when compared with the visible bands. Radiometric correction was accomplished using a scatterplot linear regression equation. As a result, the model was constructed to examine the linear relationship between an infrared channel and the channels over water.

The 1992 crop data in Woodruff County were manually collected from the ASCS office in Augusta. Farm folders were selected based upon field size, type of crop and location with a 7.5 minute USGS quadrangle. A representative sample from each part of the quad was outlined and labeled according to crop planted. The field was then transferred to the computer and outlined on the black and white (Band 4) image map of the county.

It appeared that soil water status was an important factor in the spectral variability across the image. Therefore, in order to develop a more statistically robust classification, the 1:250,000 state soil association map was overlaid on the satellite image. The spectrally homogeneous areas were digitized, each individual class of modified soil polygons was masked and an unsupervised classification procedure run under each mask. The ground truth crop data were attributed to the different classes generated from the satellite imagery. Some of the crops were collated into a single class. The results of the classification procedures were patched and a color table developed. The accuracy of the satellite imagery was then compared to the 1992 Arkansas Annual Agricultural Report.

RESULTS

Areas Vulnerable to Pesticide Contamination

The pesticide ground water vulnerability model was used to determine the areas in Woodruff County having the highest relative vulnerability to pesticides. The spatial distribution of the RGVIP overlaid with the roads and streams is presented in Figure 3. For communication purposes, the RGVIP at a location was arbitrarily divided into classes each consisting of 10 indicae.

Values of RGVIP in Woodruff County ranged from 22 to 89. The highest RGVIP tends to occur in the western half and in particular between the Cache and White Rivers in west central portion of the county. The lowest RGVIP tends to be in the eastern portion of the county. The two highest classes of RGVIP were 80 to 89 and 70 to 79 and represented 2.2 and 8.9% of the total area in the county, respectively. Therefore, a total of 11.1% of Woodruff County had a RGVIP greater than 70. The locations in the county of areas having the more vulnerable groundwater are shown in Figure 4. This map reemphasizes that the area around the Cache River and east of the White River tends to have the highest RGVIP.

The inherent potential of an aquifer to be contaminated is also shown in Figures 3 and 4. A high RGVIP indicates the capacity of the hydrogeologic environment and the landscape factors to readily move water borne pesticides into the groundwater. Low RGVIP values indicate areas where the ground water is better protected from pesticide leaching by the natural environment. The ground water vulnerability map represents a potential for contamination based upon the availability of pesticides.

The probability of a given RGVIP in Woodruff County was determined by calculating the %area of each RGVIP and cumulating these percentages from lowest to highest RGVIP. The cumulative area was plotted versus RGVIP to give the cumulative probability diagram (data not shown). Unexpectantly, we found that the frequency distribution of the RGVIP was approximately normally distributed with a graphically estimated mean of 53.5 and standard deviation of 41.5. This indicated that the nature of the distribution of RGVIP was Gaussian and not greatly skewed at the tails, i.e. at very low and high values of RGVIP. From a practical view, this means that in Woodruff County the probability of an area having a given RGVIP can be calculated with the Gaussian equation and that the probability of having a RGVIP greater or smaller than this value can also be calculated. The mean RGVIP for the county is considered to be relatively low but the coefficient of variation of 77% is high indicating high variability of these indicaes in the county. The sources of this variability may be attributed to the correlation structure of the various databases and/or to the variations within the databases.

The wells in the most vulnerable areas are shown in Figure 5. There are 103 wells in areas with RGVIP > 70 and 28 wells in areas with RGVIP > 80. With respect to the latter category, 15 wells were located in an area with a RGVIP of 81 and 8 wells were located in an area with a RGVIP of 83. The highest RGVIP was 86 with two wells located in the southcentral portion of the county.

Crops in the Vulnerable Areas

Satellite imagery was used to determine the landuse of Woodruff County on June 22, 1992, and therefore, the potential application of certain pesticides within a given area and year. The general landuse of the county was divided into 5 broad classifications (Figure 6). Of the 379,934 acres, this GIS analysis showed: 70.5% of the area was in cropland; 7.5% was in grass; 20.1% was in forest and 1.7% was in water sources. These percentages were close to those of the Agricultural Statistics presented in Table 1. Of particular interest is that the forested areas tended to be concentrated along the White and Cache Rivers and Bayou Deview.

The detailed cropping patterns in the county are shown in Figure 7. At this time during the growing season, we were unable to adequately distinguish the reflectances of corn from grain sorghum. As a result, these areas were combined into one classification.

The areal extent of the crops using the remote sensing techniques varied with the crop. The cropping landuse for Woodruff County is presented in Table 4. The largest landuse was in soybean (28.2% of areal coverage) which was followed by forest (20.1%), rice (15.7%), wheat-double cropped soybeans (9.6%), layout (8.2%), corn/grain sorghum (7.7%), grass (7.5%) and cotton (1.2%). Interestingly, if the soybeans and the double-cropped soybeans acreage were combined, the resulting total was 143,544 acres which is close to the 139,000 acres harvested (Table 1). The same result was found with corn and grain sorghum. The extent of rice, however, was slightly over predicted as compared with the data given in Table 1. When USGS topographic quads were examined for these locations, it was noted that these areas also included cypress brakes and swampy areas which could easily be misclassified as flooded rice. The extent of cotton was under predicted. Even though our estimates are reasonably close in most cases, these results show that additional research is needed to refine our ability to distinguish the cropping patterns in real time.

The spatial distribution of crops grown in the areas having a RGVIP greater than 70 is shown in Figure 8. The total area in this category was 42,243 acres. A list of the areal extent of the crops grown in these areas is given in Table 4. As expected, the results show that soybeans were grown in the largest extent in the most vulnerable areas. This was followed by forest and rice with small acreage of cotton.

Table 4. Aerial extent of crops grown in Woodruff County and in the areas of RGVIP greater than 70 and for RGVIP greater than 80.

Crop	County acres	%	RGVIP > 70 acres	%	RGVIP > 80 acres	%
Corn/grain sorghum	29334	7.7	822	9.1	712	8.6
Cotton	4485	1.2	563	1.3	82	1.0
Grass	28490	7.5	3485	8.3	922	11.1
Layout	30988	8.2	3313	7.8	909	11.0
Rice	59580	15.7	7363	17.4	1363	16.4
Soybean	107114	28.2	11407	27.0	2482	29.9
Soybean/wheat	36430	9.6	3343	7.9	852	10.3
Forest	76199	20.1	8605	20.4	862	10.4
Water	6406	1.7	342	0.8	120	1.5
Total	379935		42243		8304	

The spatial distribution of the crops grown in the areas having a RGVIP greater than 80 is shown in Figure 9. The total area of this, the highest vulnerability classification, was 8,304 acres. A list of the extent of each of the crops is given in Table 4. In this area soybeans were grown in the largest extent and was followed by rice and a diverse distribution of grass, layout, soybean/wheat and forest.

Soils in the Vulnerable Areas

Eight soil series were identified in the most vulnerable areas, i.e. RGVIP>80. The identification of these soils, textural class and areal extent in Woodruff county are presented in Table 5. The total areal extent of these soils in Woodruff county was greater than 11,700 acres. The fact that there was a larger areal extent of these soils than vulnerable areas as predicted by the ground water vulnerability model with RGVIP > 80 indicated that some areas where these soils are located was not considered to be highly vulnerable to pesticide contamination. Thus, factors other than soils are also important in determining the vulnerability of an area to pesticide contamination.

Selected physical and chemical profile characteristics of these eight soil series are presented in Table 6. These data were obtained from the SCS blue sheets as well as predictions from Cassel et al. (1983). The soils tended to be coarse textured throughout the profile with sand contents ranging from between 10 to 15% in the Commerce and Arrington soils to 81% in the Bulltown soils. Clay contents ranged from about 4% in the Wiville soils to 39% in the Commerce soils. Organic carbon ranged from about 1.7 in the surface of the Arrington soils to 0.15% in the Dundee subsoils. As expected the organic carbon was higher near the surface than in the subsoils. Values of pH mostly tended to be between 5 and 6 with the exception of the Commerce and Arrington soils which had pH values greater than 7.0.

Table 5. Soils at the sites considered highly vulnerable to pesticide leaching and their areal extent in Woodruff County, AR.

Soil series	Textural class	Area
		acres
Arrington	sil	5
Askew	fsl	30
Bosket	fsl	2547
Bulltown	lfs	2753
Commerce	sicl	425
Dubbs	sil	967
Dundee	sil	16
Wiville	fsl	1566

Table 6. Physical and chemical characteristics of the eight soil series where the groundwater is vulnerable to pesticide contamination.

Soil series	Depth interval	sand	clay	OC	DUL	DLL	B D	pH
				Soil property				
	cm			%			g/cm^3	
Askew	0-20	67.5	15.0	1.16	18.9	5.9	1.35	5.2
	20-30	65.0	18.5	0.44	16.5	4.9	1.48	5.2
	30-80	77.5	24.0	0.29	29.0	14.7	1.48	5.2
	80-130	60.0	20.0	0.29	23.7	10.5	1.48	5.2
	130-180	77.5	10.0	0.29	11.8	3.8	1.5	5.2
Bosket fsl	0-50	68.1	10.1	0.73	18.9	5.9	1.40	5.8
	50-90	74.2	18.0	0.29	18.9	5.9	1.40	5.5
	90-120	67.4	21.5	0.29	29.0	18.0	1.38	5.8
	120-150	61.6	10.2	0.29	18.9	5.9	1.40	5.4
Dundee sil	0-13	30.0	19.8	0.44	29.0	18.7	1.40	5.2
	13-74	32.6	19.4	0.15	28.4	15.1	1.45	5.2
	74-152	43.2	25.1	0.15	25.0	11.4	1.50	5.9
Dubbs sil	0-13	25.0	11.5	0.73	23.0	11.4	1.45	5.3
	13-58	15.0	27.5	0.50	29.0	13.5	1.50	5.2
	58-127	27.0	17.5	0.50	22.5	12.3	1.45	5.2
Bulltown lfs								
	0-20	80.0	7.0	0.73	18.8	6.3	1.55	5.5
	20-66	81.0	7.0	0.44	18.9	6.5	1.55	5.5
	66-130	57.5	19.5	0.44	20.4	19.5	1.48	5.5
	130-175	65.0	14.0	0.44	19.6	17.6	1.55	5.5
	175-203	80.0	6.0	0.44	17.5	5.9	1.55	5.5
Commerce sicl								
	0-25	10.0	33.0	1.31	33.4	20.3	1.35	7.1
	25-91	15.0	39.0	0.44	31.8	24.2	1.50	7.2
	91-183	24.5	35.0	0.44	30.6	21.1	1.50	7.5
Wiville fsl								
	0-28	52.5	7.4	0.73	24.1	9.6	1.50	6.2
	28-46	67.5	15.3	0.44	20.5	8.8	1.50	6.2
	46-142	52.4	19.0	0.44	21.2	10.4	1.53	6.2
	142-163	67.4	15.0	0.44	23.3	9.1	1.53	6.2
	163-203	55.0	6.3	0.44	19.8	7.3	1.55	6.2
Arrington sil								
	0-66	15.4	26.4	1.74	27.5	13.9	1.38	7.7
	66-127	15.5	26.6	0.58	28.8	14.5	1.38	7.7
	127-183	25.5	32.5	0.58	32.2	19.6	1.38	7.7

Extensive use of 26 pesticides have been identified in Arkansas that have been classified as having either high or moderate mobility. These pesticides are listed in Table 7 along with estimates on the half life, partition coefficient and relative leaching potential. The half lives range from 4 days for oxamyl to 110 days for propiconazole. Soil partition coefficients ranged from 20 in the case of imazaquin to 1000 for diazinon. A total of 10 pesticides were classified as moderate in leaching potential.

Another important factor is the application rate of each of the pesticides. The estimated annual application rates are functions of crop and pesticide and are presented in Table 8. The application rates ranged from 0.009 kg a.i./ha for chlorimuron in soybeans to 3.92 kg a.i./ha for alachlor in soybeans.

Characteristics of the Area Surrounding the USGS Sampled Wells

Since the various databases in the computer were geo-referenced, we determined the characteristics of the area surrounding the nine wells sampled for pesticides by the USGS. The results are presented in Table 9 and the locations of the nine wells are shown in Figure 10. These results show that there was a good relationship between the USGS results and our model predictions. Only wells 7, 8 and 9 were found by USGS to contain pesticides, although at extremely low concentrations in wells 7 and 9. We would conclude with our techniques that the probability of pesticides being found in these two wells would be low. Well number 8, however, initially contained metolachlor at a concentration of 25 ppb, and the RGVIP at this location was high. The well was surrounded by grass, soybeans and forest. Metolachlor is a herbicide that is used extensively in soybean production, and therefore, our techniques indicate that the groundwater at this site would be vulnerable to pesticide contamination.

The cell weighted-average RGVIP was computed for each well sampled by USGS for pesticides. Wells numbered 2, 7 and 9 had average RGVIP values of 52, 54 and 57, wells 1 and 3 had average values of 65 and 64, wells numbered 4, 5, and 6 had average RGVIP values of 76, 75 and 70, and well 8 had the highest average RGVIP of 83, respectively. For those wells with RGVIP values less than 70 we would predict that the ground water at these locations is not highly vulnerable to pesticides. For those wells in areas with RGVIP values greater than 70, we suggest that they are potential candidates for pesticide contamination.

Table 7. Selected properties of the high and moderate mobile pesticides used in Woodruff County, AR.

Pesticide	Half-life † days	Soil Partition † Coefficient koc	Leaching‡ Potential
Acifluorfen	14	113	M
Alachlor	60	170	L
Aldicarb	30	30	L
Atrazine	60	100	M
Bentozon	20	34	M
Carbofuran	50	22	L
Chlorimuron	40	110	L
Cyanazine	14	190	M
Diazinon	40	1000	L
Dicamba	60	400	L
Diuron	90	480	M
Fluometuron	85	100	M
Fomesafan	100	60	L
Imazaquin	60	20	L
Linuron	60	400	M
Metolachlor	90	200	M
Metribuzin	40	60	L
Norfluazon	30	700	M
Oxamyl	4	25	L
Propiconazole	110	650	M

† Adapted from Wauchope, 1992
‡ Adapted from Arkansas Cooperative Extension Service, 1992.
M = Medium, L = Large

Table 8. Pesticide application rates for crops grown on vulnerable soils in Woodruff County, AR.

	Crop†					
Pesticide	Soybean	Grain Sorghum	Corn	Cotton	Wheat	Fallow
	kg ai/ha					
Acifluorfen	0.49	--	--	--	--	--
Alachlor	3.92	2.24	2.24	--	--	--
Aldicarb	1.12	1.12	--	.34	--	--
Atrazine	--	2.24	2.24	--	--	--
Bentozon	0.84	0.84	0.84	--	--	--
Carbofuran	--	1.12	1.12	--	0.28	--
Chlorimuron	0.009	--	--	--	--	--
Cyanazine	--	--	1.79	0.90	--	--
Diazinon	--	--	--	--	--	0.56
Dicamba	--	--	--	--	--	--
Diuron	--	--	--	0.45	--	--
Fluometuron	--	--	--	1.57	--	--
Fomesafen	0.42	--	--	--	--	--
Imazaquin	0.12	--	--	--	--	--
Linuron	0.42	.84	--	0.84	--	--
Metolachlor	2.24	2.24	2.24	1.79	--	--
Metribuzin	0.42	--	--	--	0.42	--
Norflurazon	--	--	--	1.68	--	--
Oxamyl	--	--	--	0.28	--	--
Propiconazole	--	--	--	--	0.28	--

† Adapted from Arkansas Cooperative Extension Service, 1992

Table 9. Characteristics of the well sites sampled by USGS for pesticides in ground water (1989 - 1992). The nearest nine cells were characterized.

Site number	Category	Characteristics
1	RGVIP	2 cells 58; 3 cells 64; 4 cells 69
	LULC	1 cell grass, 5 cells soybean; 3 cells forest
	soils	7 cells Bosket; 2 cells Kobel
	geology	3 cells alluvium; 6 cells terrace deposits
2	RGVIP	6 cells 50; 3 cells 55
	LULC	1 cell no data; 1 cell rice; 7 cells wheat-double cropped soybeans
	soils	9 cells Kobel
	geology	9 cells alluvium
3	RGVIP	9 cells 64
	LULC	1 cell layout; 4 cells rice; 4 cells soybeans
	soils	9 cells Commerce
	geology	9 cells alluvium
4	RGVIP	6 cells 74; 3 cells 80
	LULC	1 cell rice; 8 cells soybeans
	soils	3 cells Bulltown; 6 cells Wiville
	geology	9 cells terrace deposits
5	RGVIP	3 cells 74; 6 cells 76
	LULC	1 cell corn/sorghum; 2 cells rice; 5 cells soybeans; 1 cell wheat/double-cropped soybeans
	soils	6 cells Bulltown; 3 cells Wiville
	geology	9 cells terrace deposits
6	RGVIP	1 cell 65; 8 cells 71
	LULC	6 cells grass; 3 cells forest
	soils	8 cells Askew; 1 cell Kobel
	geology	9 cells alluvium
7	RGVIP	1 cell 48; 2 cells 50; 1 cell 53;1 cell 54; 2 cells 56; 2 cells 60
	LULC	3 cells rice; 2 cells soybeans; 3 cells wheat-double cropped soybeans; 1 cell water
	soils	1 cell Amagon; 4 cells Commerce; 1 cell Grubbs; 1 cell Kobel; 2 cells water
	geology	9 cells alluvium

8	RGVIP	9 cells 83
	LULC	3 cells grass; 5 cells soybeans; 1 cell forest
	soils	9 cells Bosket
	geology	9 cells terrace deposits
9	RGVIP	6 cells 56; 3 cells 58
	LULC	1 cell grass; 1 cell rice; 1 cell soybeans; 6 cells forest
	soils	3 cells Askew; 6 cells Tuckerman
	geology	9 cells alluvium

SUMMARY

The threat of ground water contamination is a concern of Arkansas citizens as well as county, state and federal government officials. The public is aware that in using, storing and disposing of pesticides, ground water resources are potentially at risk. This study was conducted to determine the vulnerability of the ground water in one of the more intense agriculturally productive counties in eastern Arkansas.

The results have shown that a combination of ground water modeling, GIS and remote sensing techniques can be used to predict with greater precision the most vulnerable locations of ground water for pesticide contamination. For Woodruff County, approximately 2.2% of the area (8300 acres) had a RGVIP > 80. Landuse in this area included the usual agricultural crop production activities such as soybeans, rice, wheat, corn, grain sorghum and cotton. Some pesticides would be expected to be applied to these areas during the crop growing season. Also, included in this area of highly vulnerable ground water was layout land which included forest and water bodies where little or no pesticides would be expected to have been applied. Therefore, the areas of highly vulnerable ground water in Woodruff County have heterogeneous applications of pesticides varying in type of pesticide, amount applied and date of application. Also, in this area of vulnerable ground water are 28 wells that are registered with the Soil and Water Conservation Commission. These landuse characteristics are valid only for 1992 and would change over years.

The procedures utilized for creating the ground water vulnerability maps incorporated a greater use of soils and crop information which more closely reflects the environmental and landscape characteristics influencing pesticide transport. The resulting maps are useful tools for regional and local ground water resources planning and management. In this case, the maps can be used to assess potential contamination related to pesticide application. It is concluded, however, that there needs to be more extensive validation of the model with field sampling before many extrapolations of these results occur.

REFERENCES

Lavy, T., J. Mattice, J. Massey, G. Skulman, S. Senseman and E. Gbur. 1988. Minimizing the potential for ground water contamination due to pesticides. EPA Award No. CRT-815154-01-0.

Nichols, P. Vendrell, K. Steele, C. Armstrong and H. D. Scott. 1998 ~~1993~~. Completion Report: Arkansas State Pesticides in Ground Water Monitoring Project. Arkansas Water Resources Center Miscellaneous Report 136.

United States Geological Service. 1993. Pesticides in ground water in eastern Arkansas. Unpublished data.

Figure 1. A map of the counties in Arkansas showing the location of Woodruff County.

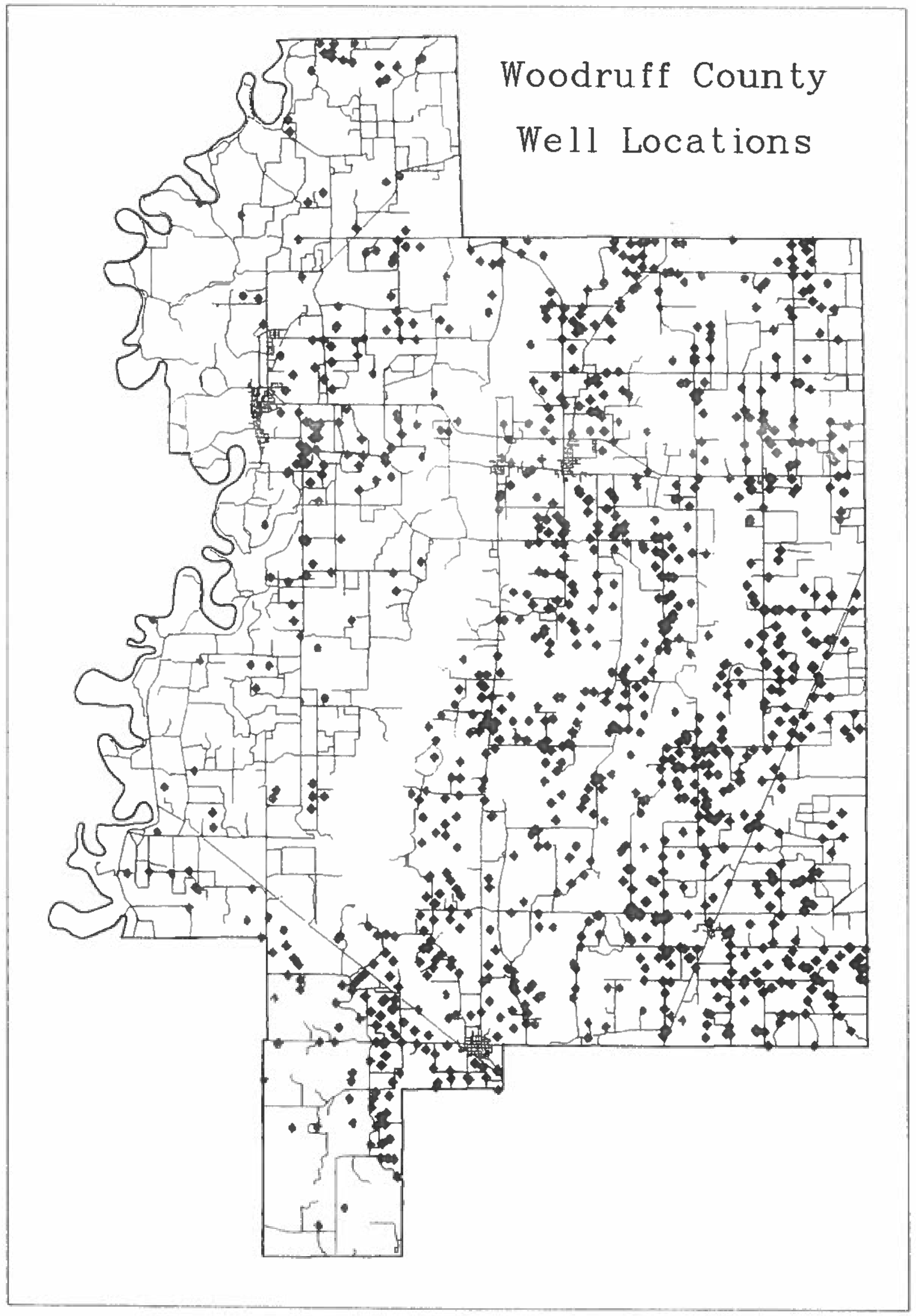

Figure 2. A map of the registered wells in Woodruff County.

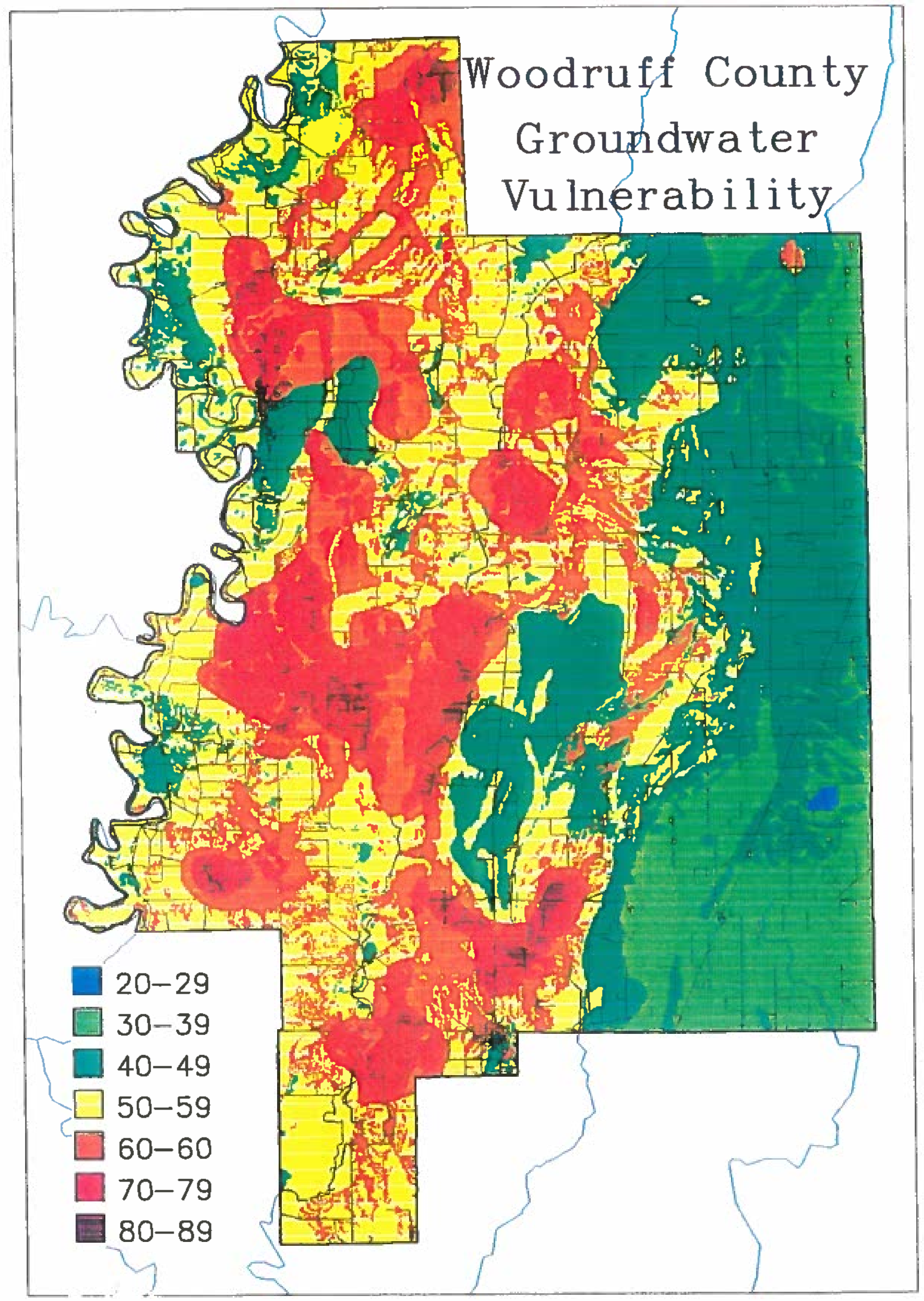

Figure 3. A map of the groundwater vulnerability to pesticides indices in Woodruff County.

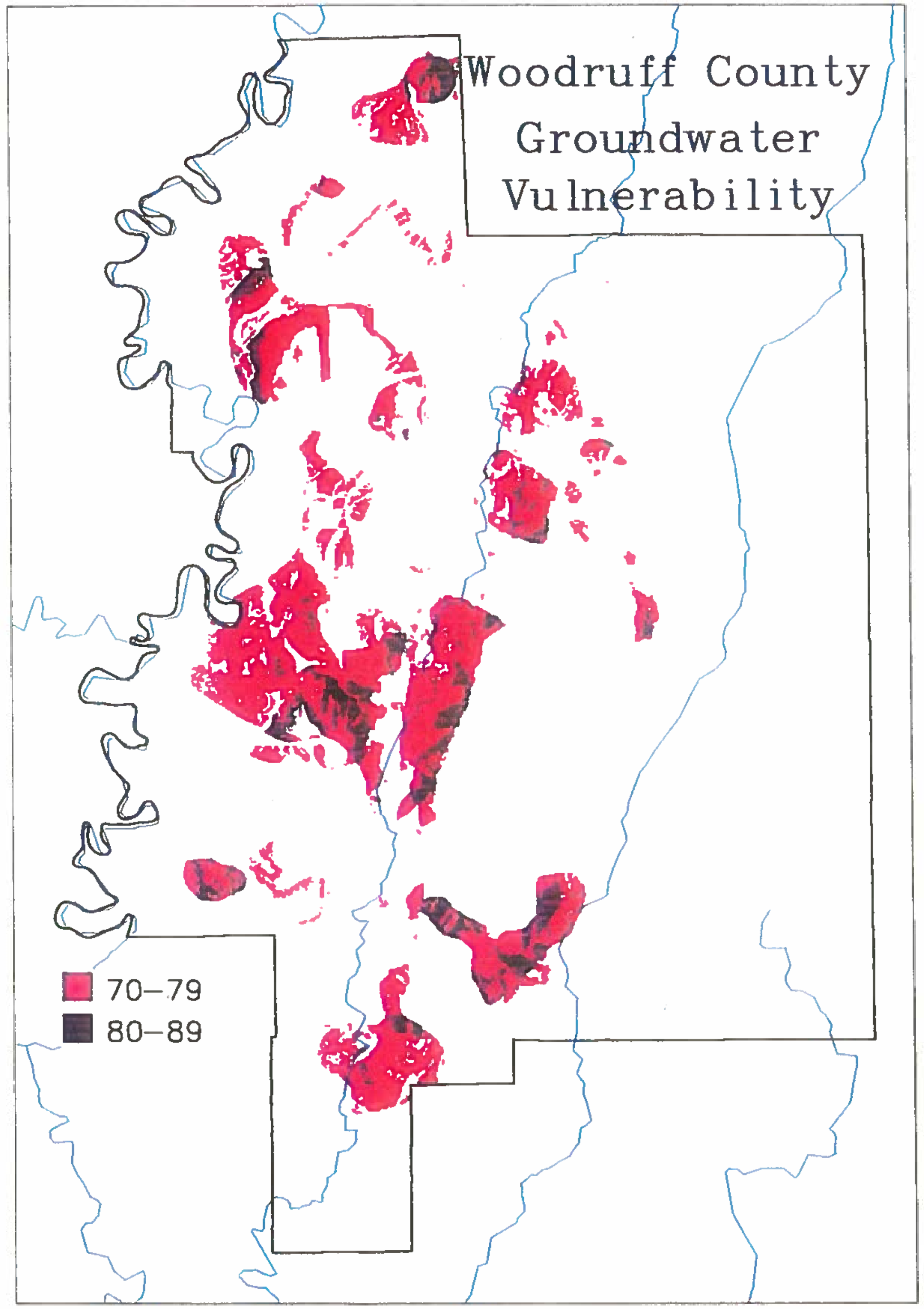

Figure 4. A map showing the locations of two highest classes of the RGVIP of Woodruff County.

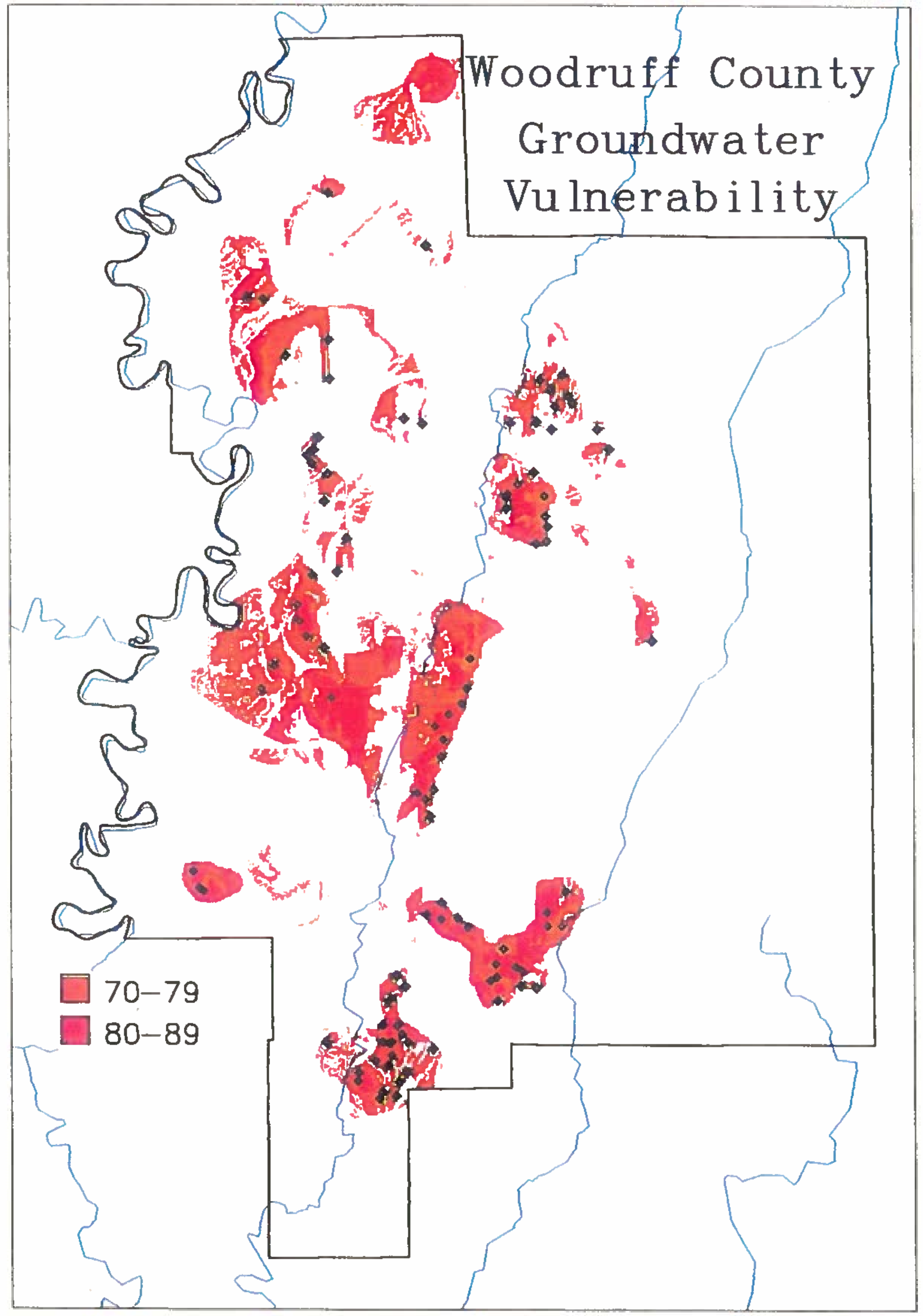

Figure 5. A map of the two highest classes of RGVIP and the registered wells in Woodruff County.

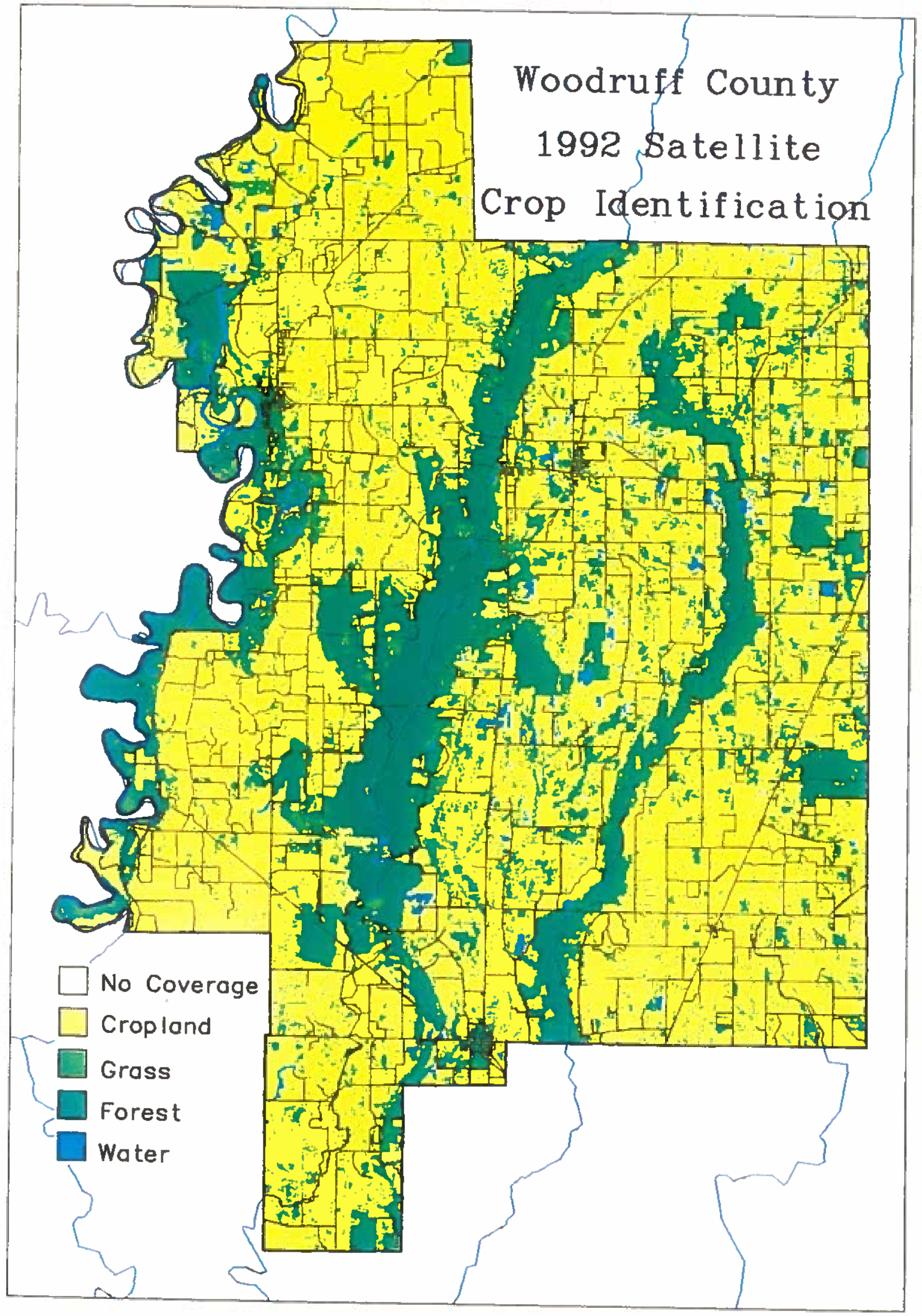

Figure 6. A general landuse/land cover map of Woodruff County during June 22, 1992.

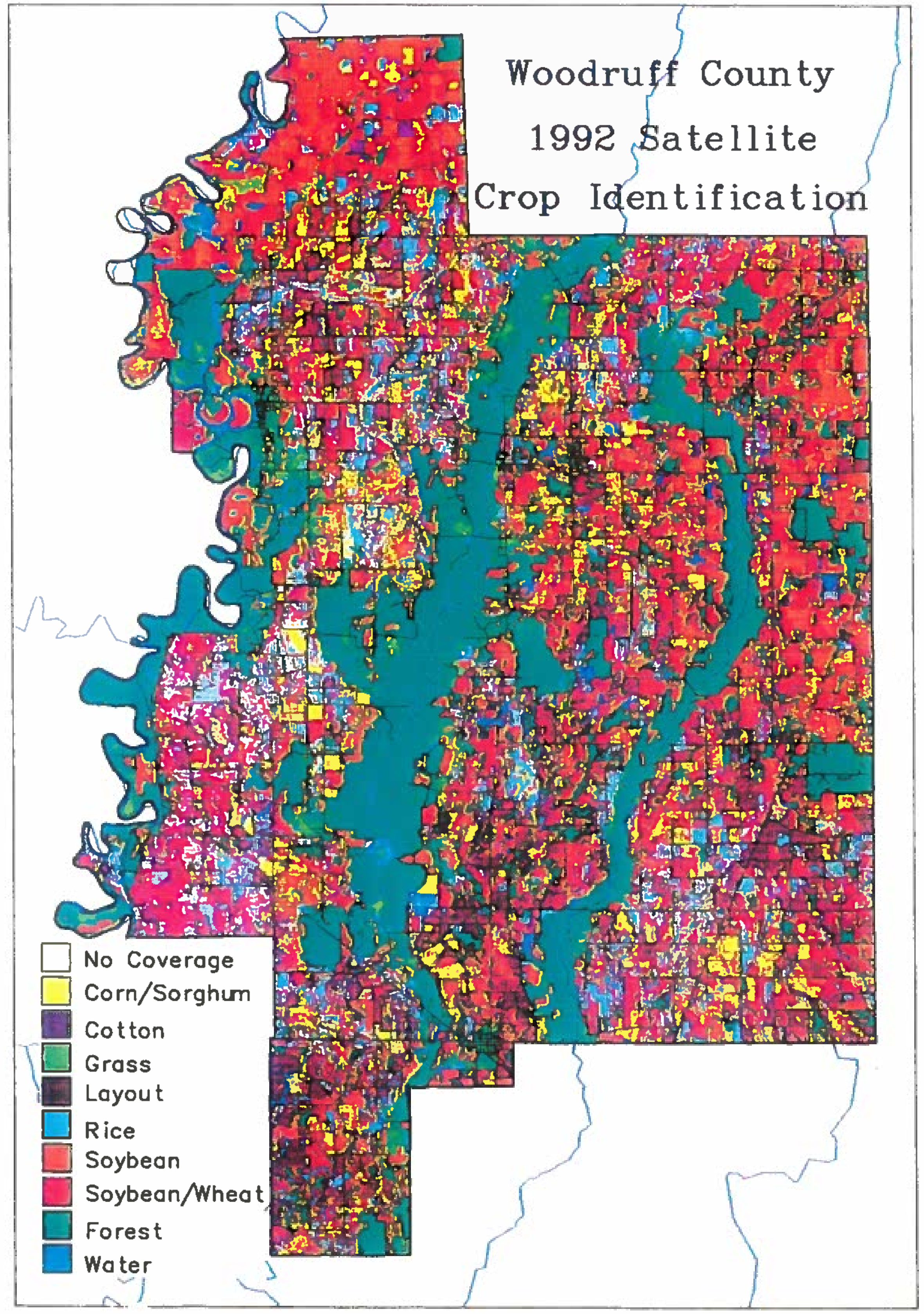

Figure 7. A map of the cropping patterns of Woodruff County during June 22, 1992.

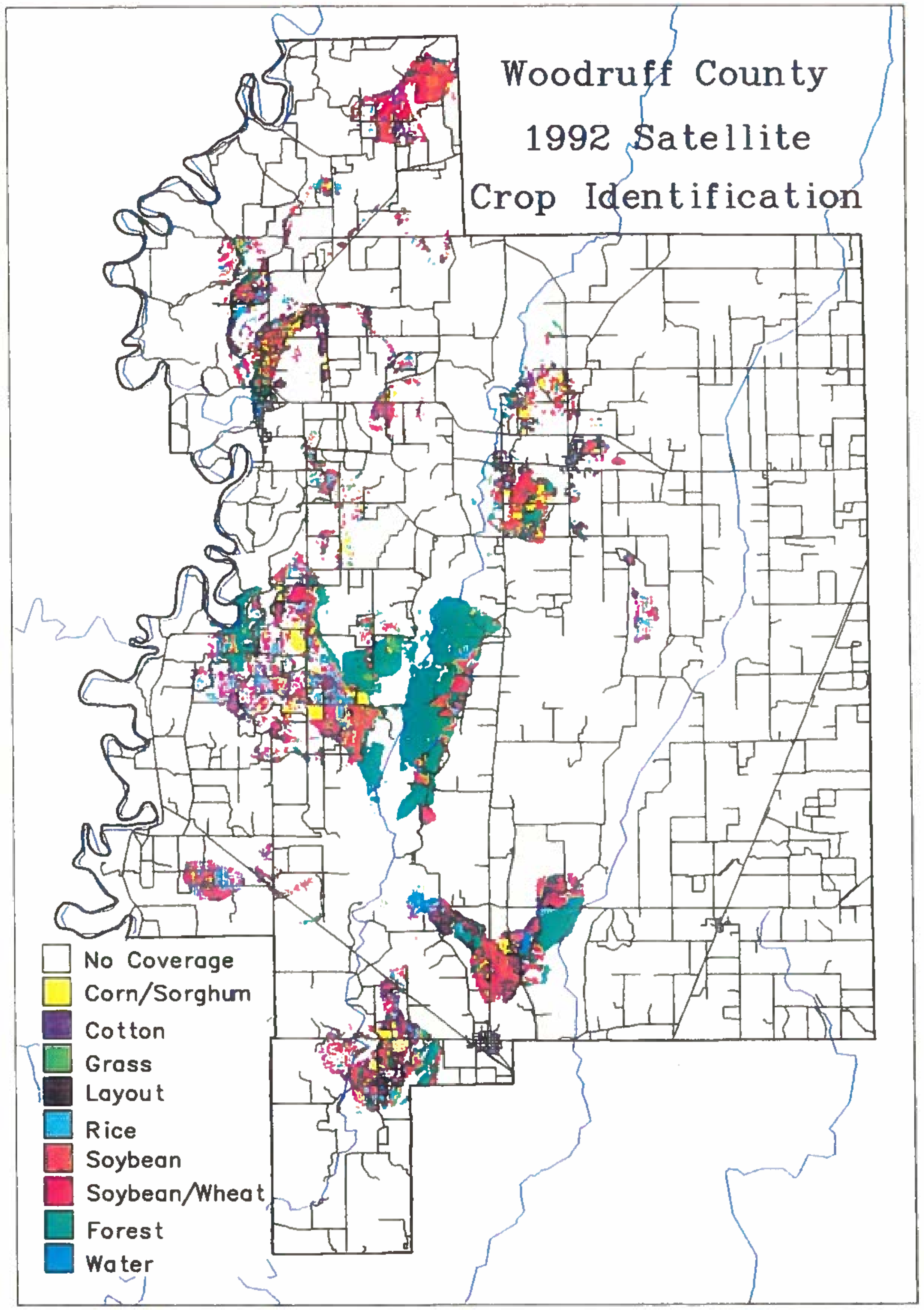

Figure 8. A map of the crop use in the areas of Woodruff County having RGVIP>70.

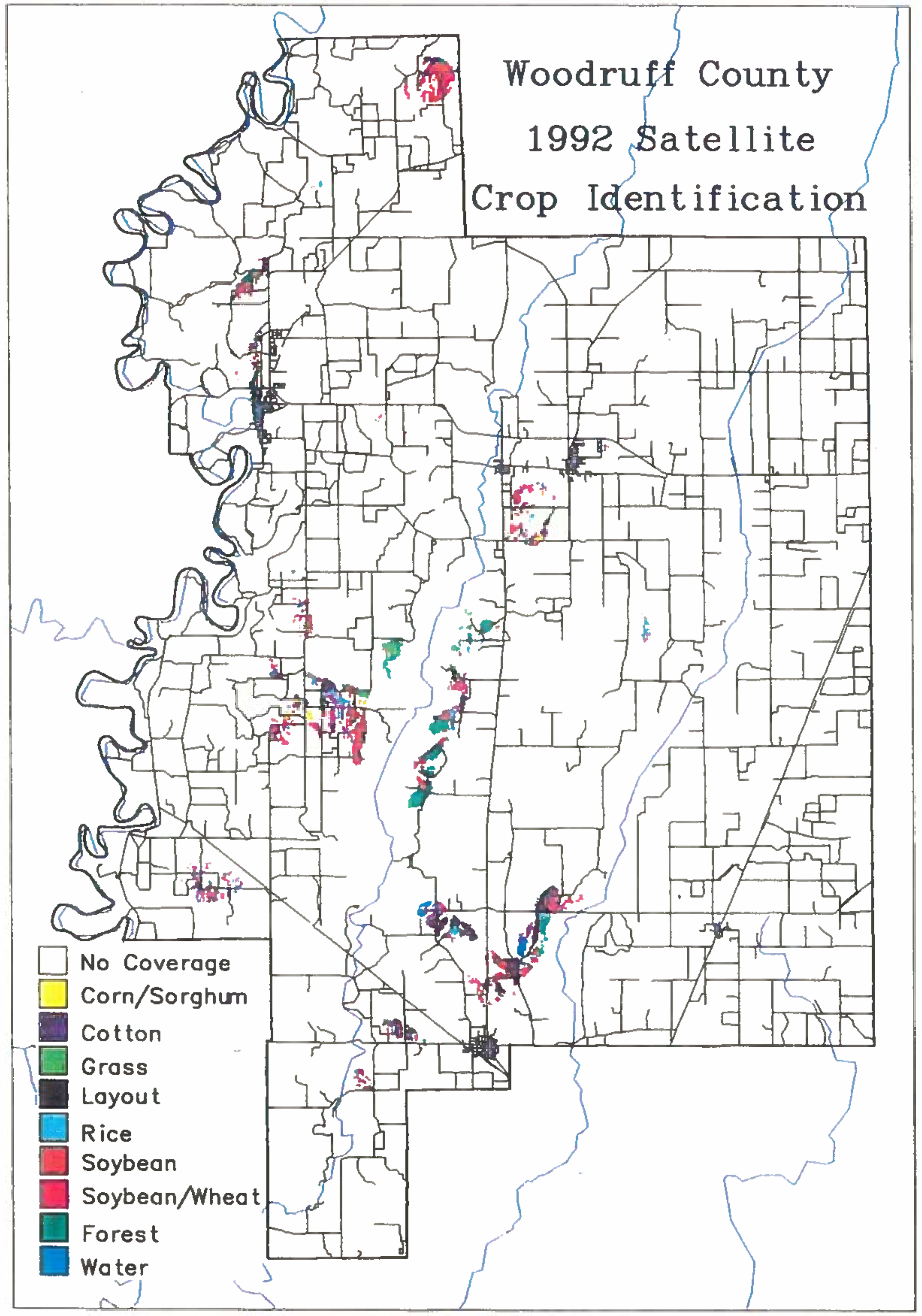

Figure 9. A map of the crop use in the areas of Woodruff County having RGVIP>80.

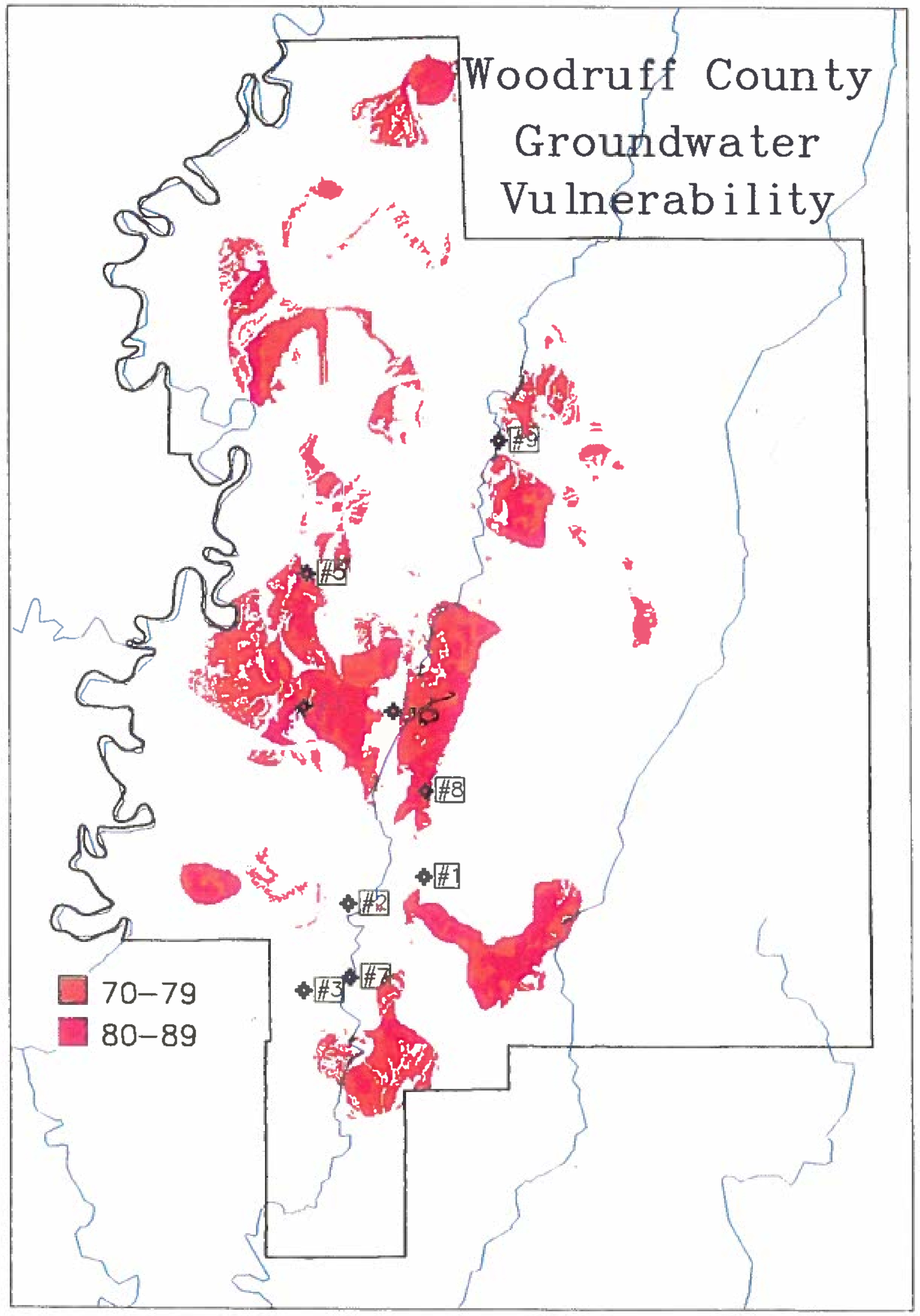

Figure 10. A map showing the locations of the USGS sampled wells and the areas of RGVIP>70 in Woodruff County.