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And

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Introduction

Changes in Land Use and Land Cover (LULC) in the upper White River Watershed from 1988 to 1992 were analyzed and plotted using the geographic information system known as Geographic Resources Analyses Support System (GRASS). This portion of the White River Watershed includes two sub-basins the East Fork and the Middle Fork. In addition, LULC changes were determined for two smaller sub-basins, Shumate Creek and Cannon Creek, located in the East Fork of the White River. The sources and methods of interpretation of the 1988 and 1992 of data were different. Thus, there were variations in how certain portions of the vegetative cover were classified. Methods of classifying each of these are discussed in the following section.

Methods

1988 Land Use and Land Cover

The Tennessee Valley Authority developed the 1988 LULC for the United States Army Corp of Engineers from infrared aerial photography (Figure 1). The mission was flown in March of 1988 over all 750,000 acres in the Beaver Reservoir Watershed. The photographs were taken at an approximate scale of 1:24,000. Interpretation of the photographs was performed by hand on 1:24,000 scale mylar media with geodetic registration based upon the 7.5 minute, 1:24,000 scale United States Geological Survey (UGSG) Topographic Series Maps. The LULC categories interpreted and associated spatial distributions within the Upper White River and Middle Fork White River watersheds are given in Table 1. The addition of the pasture quality categories was made possible by evidence of pasture growth vigor from the March photography. In addition to the vigor of pasture growth, evidence of fertilization was also noted as well as terraced and

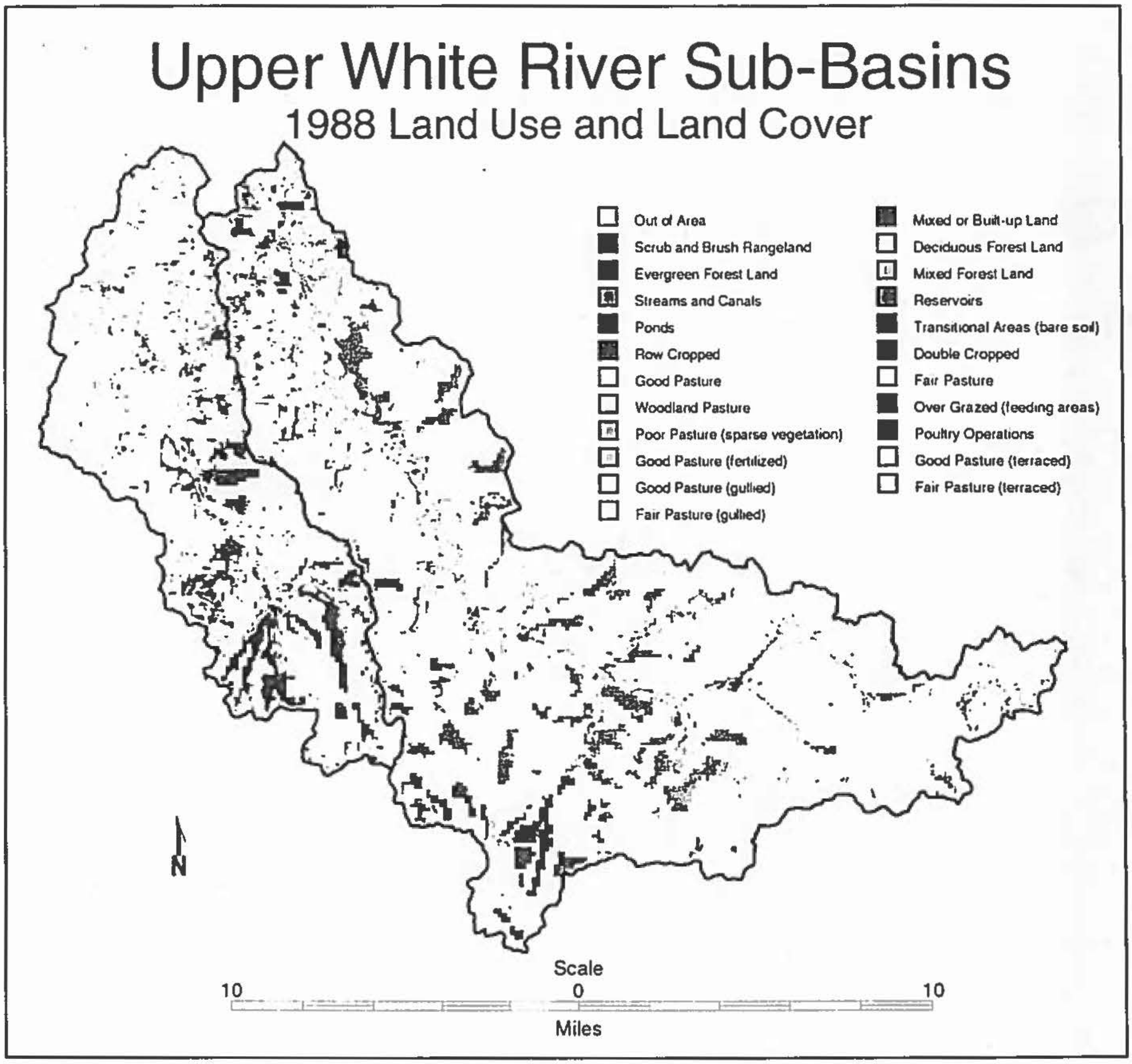

Figure 1. 1988 Land use and land cover interpreted from 1988 aerial photography by the Tennessee Valley Authority.

gullied pastures. These categories were added as yet more descriptive parameters for pastures. Confined animal structures were not included in the TVA data, but were interpreted and digitized by personnel in the Soil Physic Laboratory. These structures represent a combination of all structures found on the aerial photography and the existing structures taken from the USGS Topographic Series Maps.

Table 1. Spatial distribution of 1988 land use land cover in the Upper White River and Middle Fork watersheds interpreted by the Tennessee Valley Authority.

LULC Class	Acres	Hectares	% cover
Mixed or Built-Up	240	97	0.14
Scrub and Brush	1,532	620	0.90
Deciduous Forest	105,109	42,537	61.81
Evergreen Forest	904	366	0.53
Mixed Forest	27,256	11,030	16.03
Streams	211	85	0.12
Reservoirs	12	5	0.01
Ponds	8	3	0.01
Transitional Areas	57	23	0.03
Row Cropped	370	150	0.22
Double Cropped	478	194	0.28
Good Pasture	24,173	9,783	14.21
Fair Pasture	8,800	3,561	5.17
Poor Pasture	134	54	0.08
Woodland Pasture	204	83	0.12
Over Grazed Pasture	180	73	0.11
Confined Animal Structures	394	159	0.23
Total	170,062	68,823	100.00

1992 Land Use and Land Cover

The 1992 data were derived from 1992 Landsat Thematic Mapper imagery. These data were interpreted by the Center for Advanced Spatial Technologies (CAST) at the University of Arkansas in Fayetteville. The purpose of the analyses was to develop a vegetative cover image for Arkansas at a 30-meter resolution, i.e. cells with an area of $900m^2$. Interpretation methods radically differed from the 1988 data in that all interpretations were unsupervised computer based analyses (Figure 2). The categories and spatial distributions of LULC in the Upper White

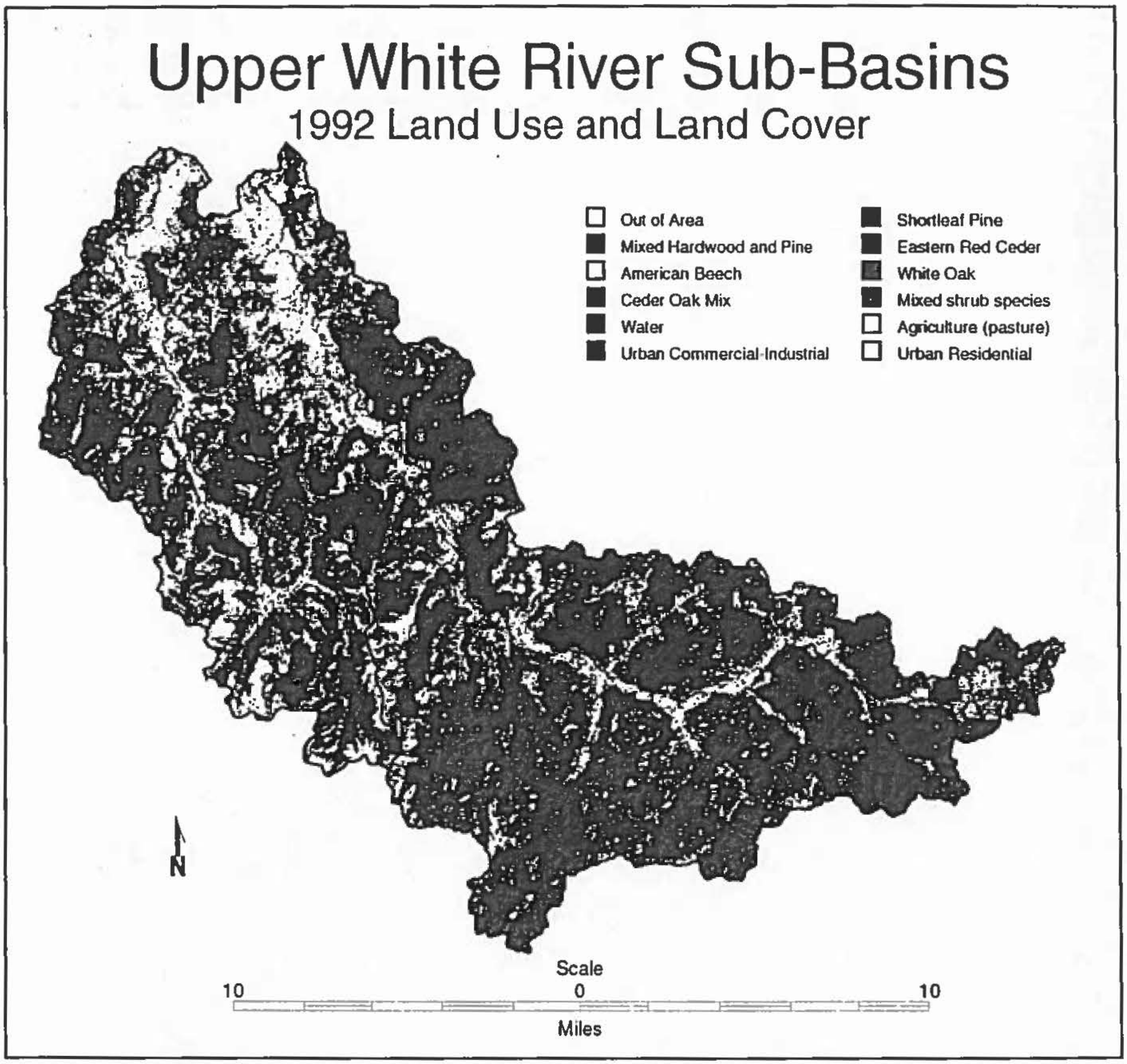

Figure 2. 1992 Land use and land cover interpreted from Landsat Thematic Mapper by CAST.

River and the Middle Fork watersheds are presented in Table 2. The majority of the descriptions are based on vegetative species with general categories for agricultural and urban areas. Although the original categories may not match standard LULC categories, they can be classified into similar general LULC categories.

Table 2. Spatial distribution of the 1992 Vegetative Cover in the Upper White River and Middle Fork watersheds interpreted by unsupervised analyses from 1992 Landsat Thematic Mapper imagery.

Vegetative Cover	Acre	Hectare	% cover
Short Leaf Pine	4,026	1,629	2.36
Mixed Hardwood and Pine	37,641	15,233	22.13
Eastern Red Cedar	7,104	2,875	4.18
American Beech	593	240	0.35
White Oak	83,791	33,910	49.27
Cedar Oak Mix	4,589	1,857	2.70
Mixed Shrub Species	115	46	0.07
Water	45	18	0.03
Agriculture (pasture)	32,078	12,982	18.86
Urban Commercial-Industrial	36	15	0.02
Urban Residential	44	18	0.03
Total	170,062	68,823	100.00

Comparison of Land Use and Land Cover

Tables of coincidence between the two LULC maps were created in order to quantify changes in area over the years. From these tables it was obvious that several problems were produced by the different interpretation methods.

The first problem was due to the inability of the 1992 interpretation methods to distinguish between trees and grass in areas smaller than 900m^2; thus, nearly 74% of 1988 woodland pastures were aligned with 1992 forest. Only 26% of woodland pasture were aligned with agricultural areas. It is likely that some of the woodland pasture did actually return to forest in 1992; however, it is most likely that interpretation methods are responsible for the majority of the changes in woodland pasture. Woodland pasture was only a small fraction of the 1988 LULC, but the same principle can be applied to all changes in pastures and forest areas. Changes in LULC occur at the edges of pastures and forest areas for the same reasons as given for the woodland pastures. The implication of this is much broader in that pasture edges occupy a large percent of the watershed and are the most likely areas where actual changes between pasture and forest would occur. Changes at edges were accepted as "real" with the reservation that some might not be accurate. The total coverage of areas where 1988 pastures align with 1992 forests was over 11,500 acres. This situation can also be applied to the inverse, i.e. 1988 forest to 1992 pasture. These areas cover over 8,600 acres, but the two situations do not always spatially coincide with each other. Future analyses may aid in correcting this problem. The following problems and solutions did effect some of these errors.

The second problem was the alignment of 1988 water features with forests and pastures. The resolution of the imagery was again responsible in that if a $900m^2$ area consisted of primarily pasture or forest with a smaller amount of water, the area was assigned the value of the major feature. This left gaps in water features such as streams; reduced the coverage at the edges of reservoirs and large ponds; and in many cases omitted ponds. The simplest solution to this error was to assume that water features defined from the 1988 imagery also existed in 1992. The mechanics were to classify 1992 locations as the coinciding water feature from 1988. This method left any 1992 water feature not in the 1988 data with the 1992 data and was represented as new water. This reduced the spatial distribution of combined forest and agricultural areas in the 1992 LULC by 219 acres.

The third problem was the definition of urban areas. This was a combination of interpreting urban areas as forests or pastures and the interpretation of urban areas at the edge of forests and pastures on the 1992 LULC. These errors are a combination of both the previous errors defining water, pastures and forest. The assumption, solution and mechanics used to correct these errors were the same as those used with the water features. Again, the assumption was if LULC was urban in 1988 it was also urban in 1992, i.e. no loss of urban areas, but some new urban areas could be shown. The largest problem with interpreting new residential areas is that if the new area was previously pasture, it could still be interpreted as pasture or new forests if trees were planted in the yards. The later is most likely. If new urban areas were previously forests they would most likely remain as forests unless the trees were cleared in which case the area could be interpreted as new pasture. The addition of the 1988 urban areas to the 1992 LULC reduced the combined forest and pasture areas by 200 acres.

All of the previously discussed assumptions resulted in the classification scheme given in Table 3. The only category that could not be matched was transitional areas in the 1988 data and was designated as an individual class (Figures 3 and 4). The spatial distribution of the resulting maps for both years is presented in Table 4. A coarse description of changes in LULC can be calculated from the information in Table 4. The data shows a gain of 4,008 acres in forest and a loss of 2,607 acres of forest. However, this table does not show the total loss or gain of any

Table 3. Classification scheme for both the 1988 and 1992 LULC maps.

#	New Category	1988 LULC Categories	1992 LULC Categories
1	Forest	Deciduous Forest Evergreen Forest Mixed Forest Woodland Pasture	Short Leaf Pine Mixed Hardwood and Pine Eastern Red Cedar American Beech White Oak Cedar Oak Mix
2	Scrub Brush	Scrub Brush	Mixed Shrub Species
3	Pasture	All Cropped Areas Confined Animal Structures All Pastures (less Woodland)	Agriculture
4	Urban	Mixed or Built-Up	Urban Commercial-Industrial Urban Residential
5	Water	Streams Reservoirs Ponds	Water
6	Transition Areas	Transition Areas	N/A

single category. A much more precise description of change can be calculated by numerical analyses in the GIS environment. Descriptions include not only loss and gain of categories but also the new category of areas lost and the original category of areas gained. In the case of water and urban areas, only gains could be calculated due to the classification scheme previously discussed. In addition the location of LULC changes were mapped.

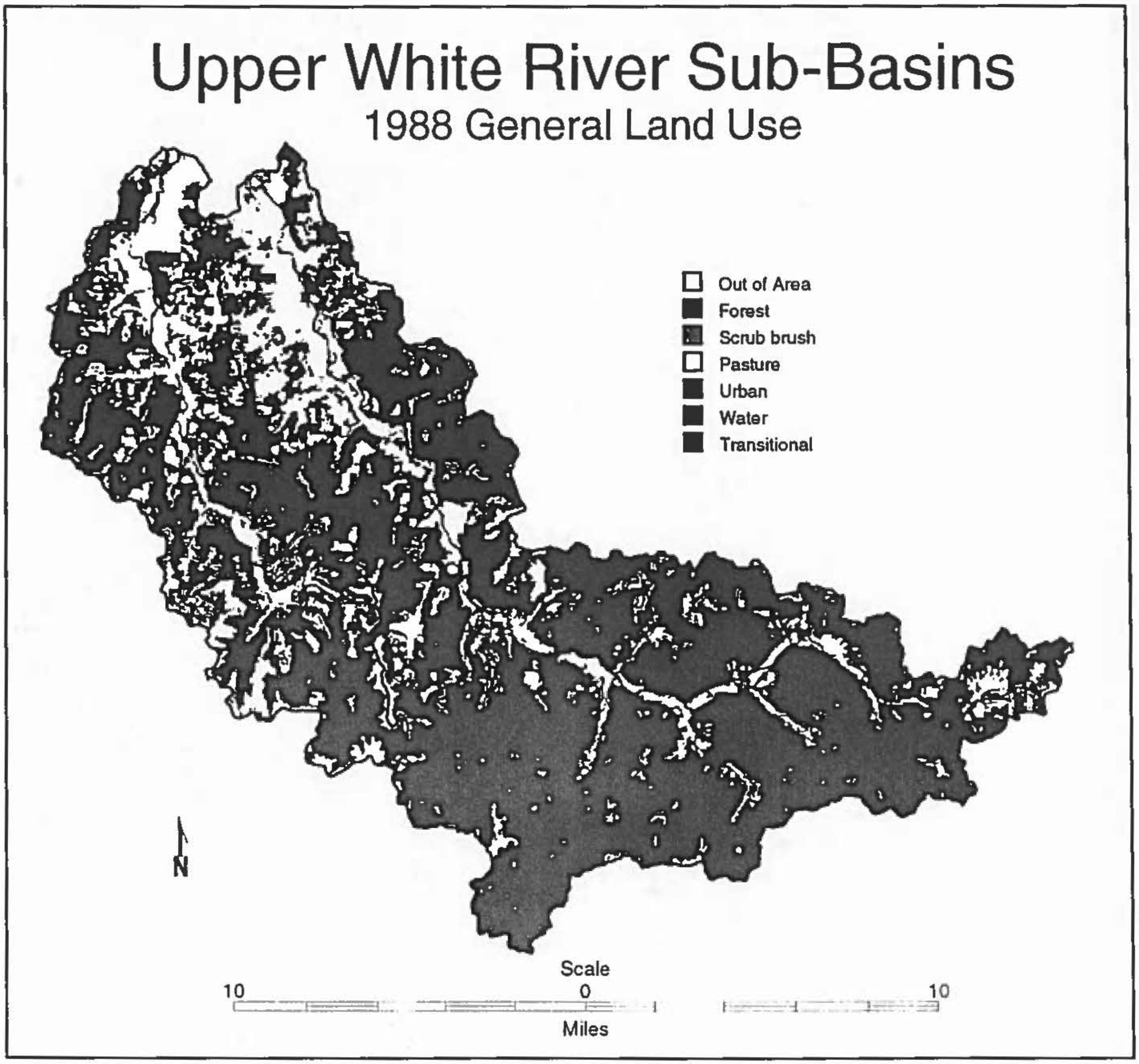

Figure 3. 1988 general land use classified from Figure 1.

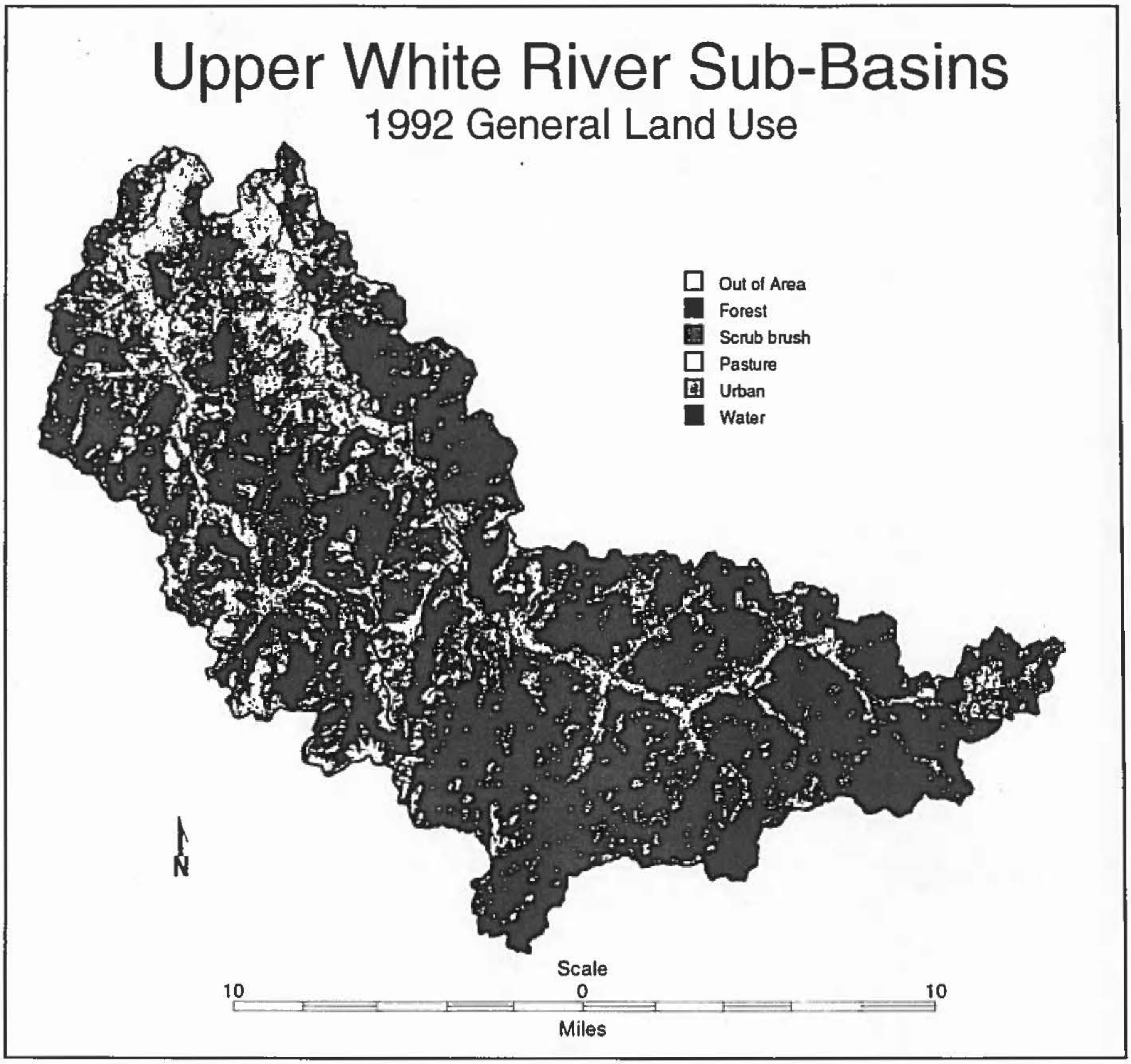

Figure 4. 1992 general land use classified from Figure2.

All changes in LULC were determined using a map calculator in GRASS where values in and between maps can be arithmetically manipulated. The numerical values representing each LULC category are given in Table 3. These values were arbitrarily assigned to the categories

Table 4. Spatial distribution of the classified 1988 and 1992 LULC in the Upper White River and Middle Fork watersheds.

LULC	1988			1992		
	Ac	Ha	%	Ac	Ha	%
Forest	133,473	54,016	78.49	137,481	55,638	80.84
Scrub Brush	1,532	620	0.90	115	46	0.07
Pasture	34,529	13,974	20.30	31,922	12,919	18.77
Urban	241	97	0.14	280	113	0.16
Water	230	93	0.14	264	107	0.16
Transitional Areas	57	23	0.03	N/A	N/A	N/A
Total	170,062	68,823	100.00	170,062	68,823	100.00

and were used only as a means of identification rather than a quantity. The mathematical operation for calculating loss and gain of LULC categories was a simple additive function with conditions set by Boolean logic. The logic was defined as follows using forests as an example:

a = if forest.88 and forest.92, then $a = 1$, else $a = 0$
b = if forest.88 and not forest.92 then, $b = 2$, else $b = 0$
c = if not forest.88 and forest.92 then, $c = 3$, else $c = 0$
$\Sigma (a + b + c)$

The first three lines are variable assignments (a, b and c) based upon the conditions stated. If the conditions for one of the three variables is satisfied a value of one, two or three is assigned; otherwise, the variable is assigned a value of zero. There is a fourth condition that is not listed where the location on neither map is forest. In such a case zero is assumed. Only one of the four conditions is possible at any given instance; thus, the summation function in the last line returns the assigned value of the one and only one variable that is not zero. Variable a represents no change, b represents forest loss and c represents forest gain. This function was performed for each 900m^2 area in the watershed and with the desired categories given in Table 3.

Results and Discussion

White River Middle Fork Watersheds

The changes in LULC are given for each watershed, East Fork and the Middle Fork of the White River, as well as the total area of both watersheds in Table 5. The changes in forest distribution are shown in Figure 5. The majority of "forest lost" areas are located away from pasture areas. The larger areas bounded by "no change" areas are most likely new pasture and not due to differences in interpretation methods. These larger areas tend to occur away from streams on and near the tops of hills. Moderately sized forest loss areas tended to be at the head of the intermediate streams. The smallest forest loss areas could actually be losses or it could also be large gaps in the forest canopy that were not interpreted in the 1988 data.

Table 5. Spatial distribution of LULC changes from 1988 to 1992.

LULC	Upper White River Watershed								
	East Fork			Middle Fork			Total		
	ac	Ha	%	ac	ha	%	ac	ha	%
Forest									
No Change	93,724	37,930	77.35	30,945	12,523	63.28	124,669	50,453	73.31
Gain	7,591	3,072	6.26	5,221	2,113	10.68	12,812	5,185	7.53
Loss	5,781	2,339	4.77	3,023	1,224	6.18	8,804	3,563	5.18
Net Gain	1,810	733	1.49	2,198	889	4.50	4,008	1,622	2.35
Pasture									
No Change	13,392	5,419	11.05	9,483	3,838	19.39	22,875	9,257	13.45
Gain	5,943	2,405	4.91	3,104	1,256	6.35	9,047	3,661	5.32
Loss	6,807	2,755	5.62	4,846	1,961	9.91	11,653	4,716	6.85
Net Loss	864	350	0.71	1,742	705	3.56	2,606	1,055	1.53
Urban									
No Change	237	96	0.20	3	1	0.01	240	97	0.14
Gain	32	13	0.03	8	3	0.02	40	16	0.02
Water									
No Change	196	79	0.16	34	14	0.07	230	93	0.14
Gain	11	5	0.01	23	9	0.05	34	14	0.02

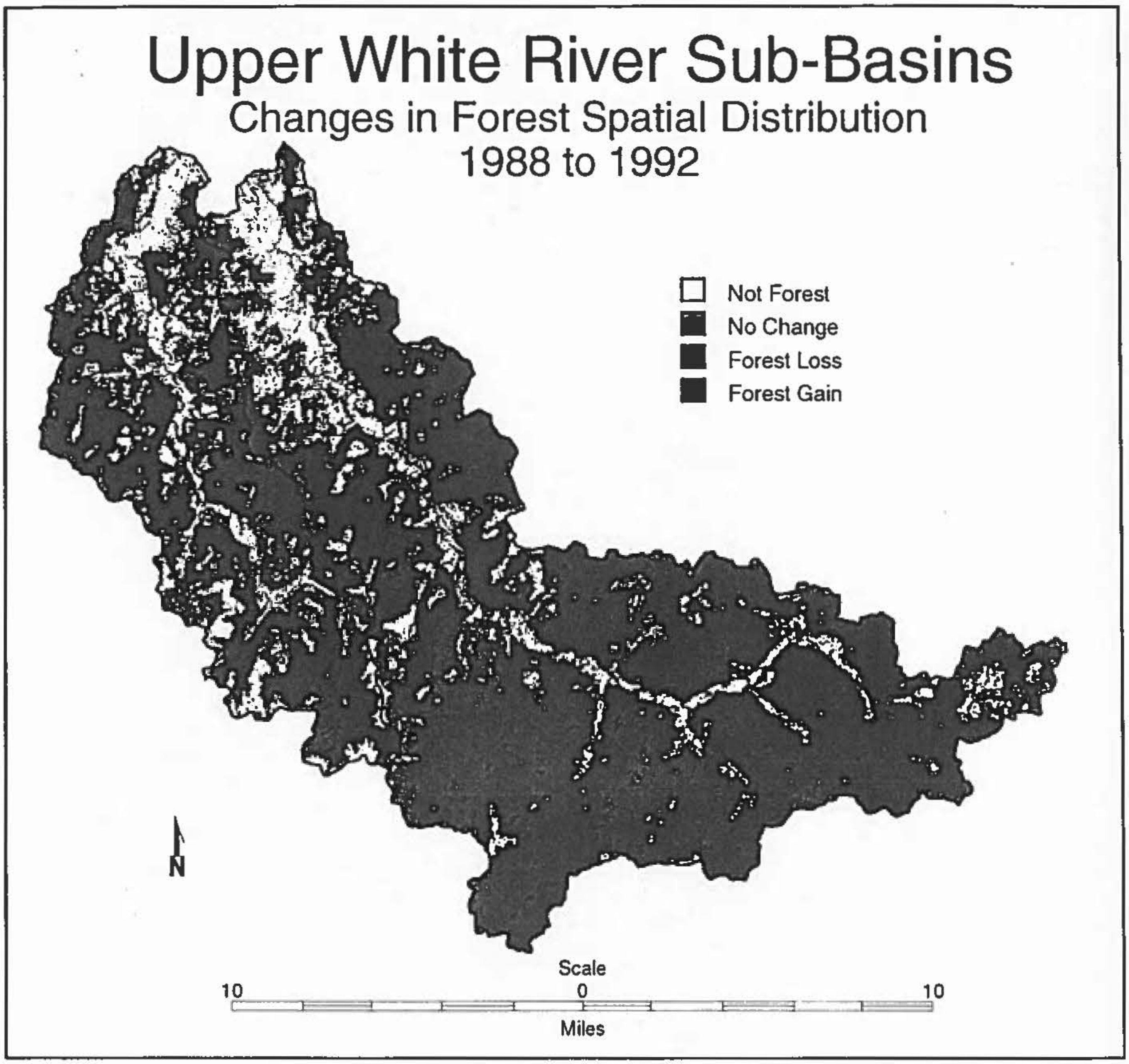

Figure 5. Changes in Forest spatial distribution from 1988 to 1992.

Forest gain areas occur mainly in the downstream areas of the watershed. Smaller areas in the river valleys could be due to differences in interpretation differences where trees along fences, streams, drainage ditches and roads were not interpreted on the 1988 data. The larger areas in the downstream portion of the watershed could be due to urban growth particularly at the very northern portion of the watershed. Forest gain in the upstream portion of the watershed is likely due to the return of pasture to forest given the size of the areas. Some of the smaller areas could be interpretation differences.

Changes in pasture spatial distribution are presented in Figure 6. This map appears to be

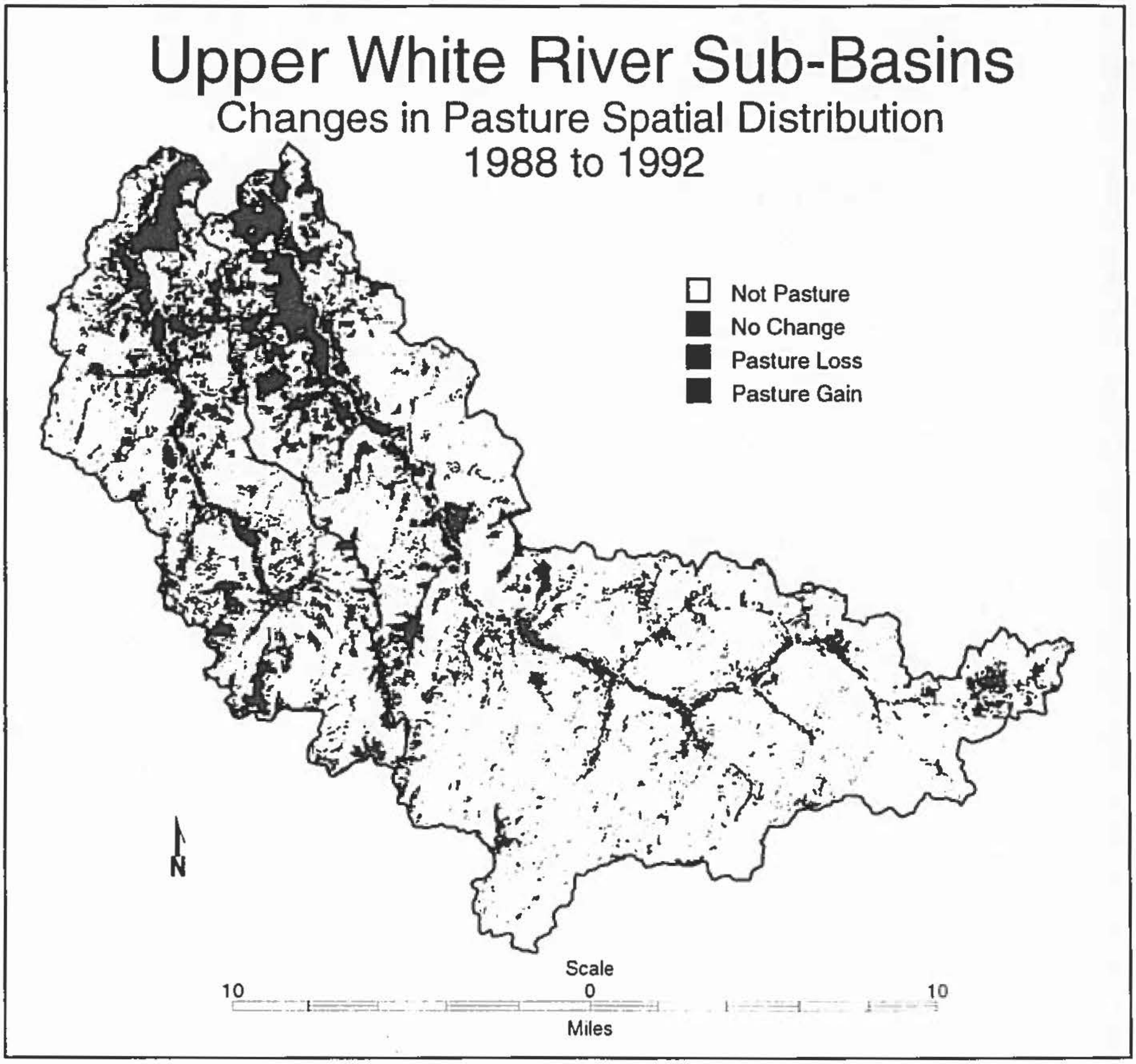

Figure 6. Changes in pasture spatial distribution from 1988 to 1992.

the inverse of the forest change map. This supports the theory that pasture loss is the inverse of forest gain. This map shows the forest loss was due to new pasture in the upstream portions of the watershed. The pasture loss in the lower portion of the watershed is not tied to any specific area while the most loss is limited to areas adjacent to streams in the upper portion.

When new forests and pastures are plotted with the 1992 LULC (Figure 7 and 8), a better understanding of the distribution can be obtained. New Forest areas tended to occur adjacent to existing forest and adjacent to existing pasture. Again, the change was more intense in the northern half of the watershed, while changes in the southern half of the watershed generally involved larger New Forest areas but with a lesser frequency. New pasture was most intense between the White River and the Middle Fork watershed boundary. These areas are larger but more widely dispersed than New Forest areas.

Tables of coincidence were created between changes in forest and pasture distribution and the previous categories, in the case of gains, or the new category, in the case of losses. (Table 6). It is evident that there was a larger loss of pasture to forests than forest to pasture; although, much of the forest gain was due to differences in interpretation methods and were located in the northern portion of the watershed. Again, these forest gains are most likely trees along fences, roads and streams that were not interpreted in the 1988 data. Otherwise, minor forest losses were to scrub brush, urban and water areas. Forest loss areas may be due to gaps in the forest canopy that were not interpreted in the 1988 data. Similar changes were noted with pasture losses and gains with the exception that there was a larger change to urban areas. There was also a gain in water coverage with the larger change in the Middle Fork and may be due to new ponds. The majority of 1988 transitional areas were changed to pasture. It is possible that these areas are actually new urban areas. This may be also true for 1988 scrub brush areas.

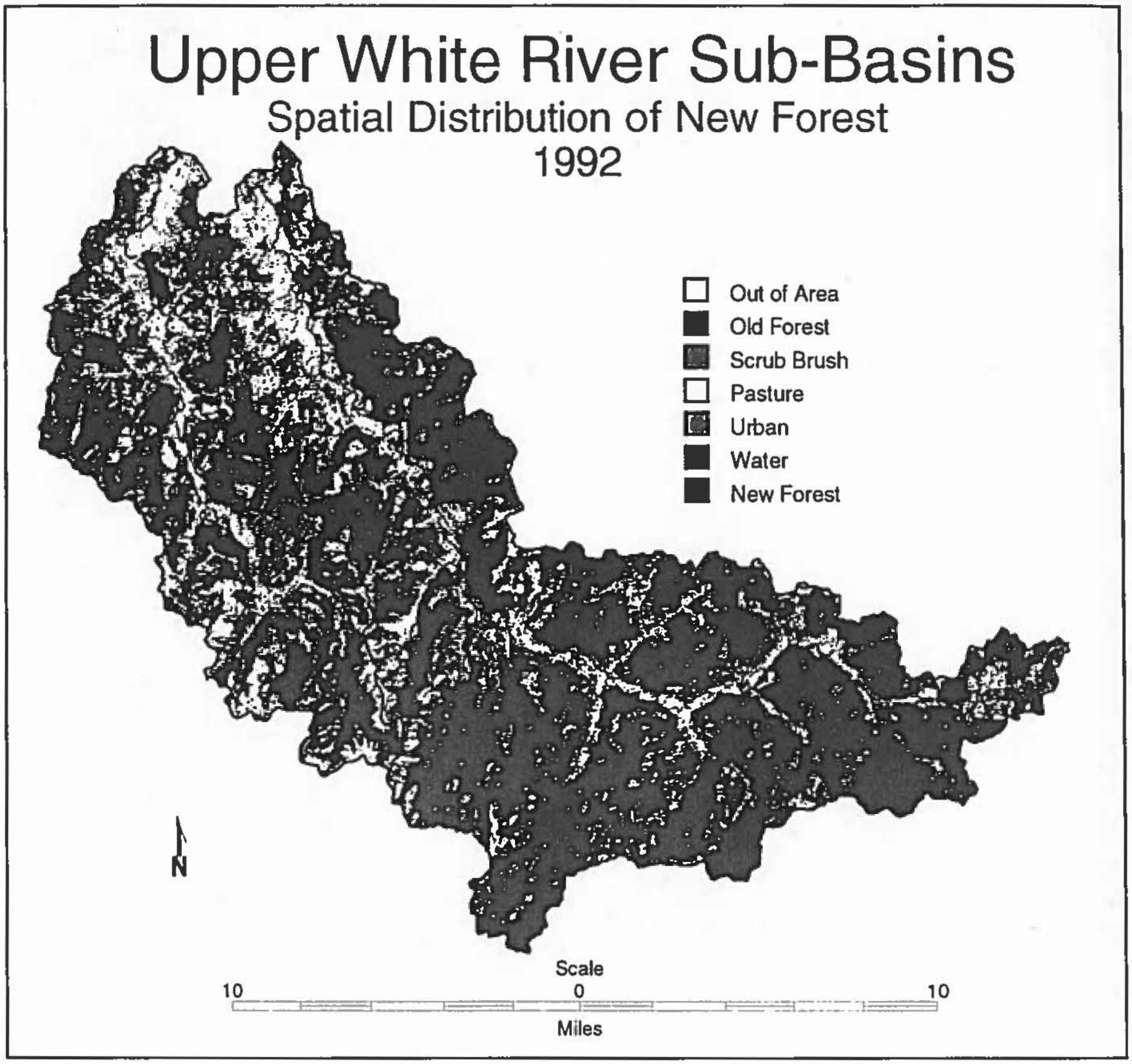

Figure 7. Spatial Distribution of new forest in 1992.

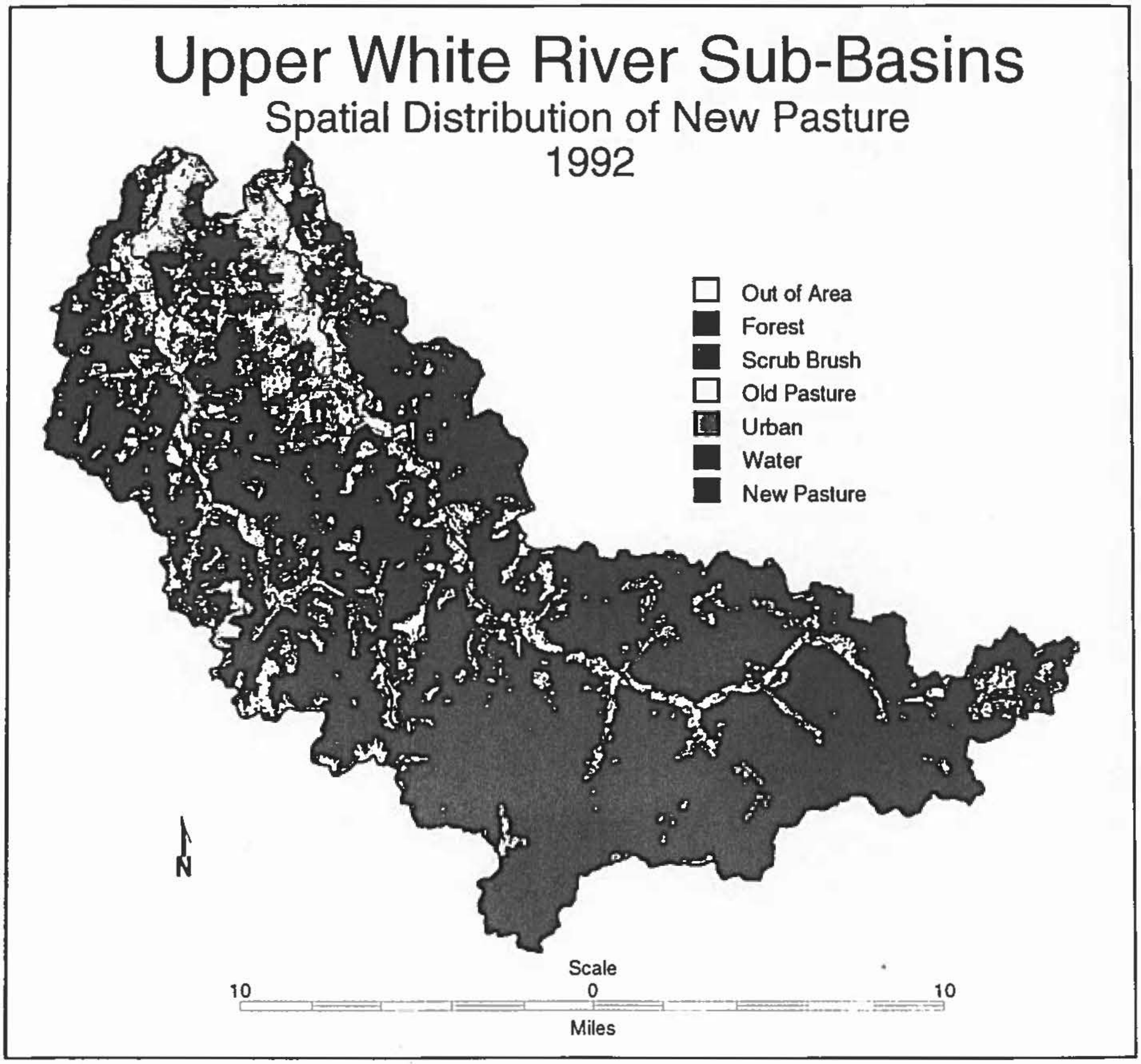

Figure 8. Spatial distribution of new pasture in 1992.

Table 6. Quality assessment of pasture and forest losses and gains from 1988 to 1992.

	White River Watershed								
	East Fork			Middle Fork			Total		
	ac	Ha	%	ac	ha	%	Ac	Ha	%
Forest Loss	5,781	2,339	4.77	3,023	1,224	6.18	8,804	3,563	5.18
Pasture	5,757	2,330	99.58	2,956	1,197	97.79	8,713	3,527	98.96
Urban	8	3	0.13	--------	--------	--------	8	3	0.09
Scrub Brush	11	4	0.20	52	21	1.72	63	25	0.72
Water	5	2	0.09	15	6	0.49	20	8	0.23
Forest Gain	7,591	3,072	6.26	5,221	2,113	10.68	12,812	5,185	7.58
Pasture	6,757	2,735	89.02	4,804	1,944	92.02	11,561	4,679	90.24
Scrub Brush	818	331	10.77	410	166	7.86	1,228	497	9.58
Transitional	16	6	0.21	7	3	0.12	23	9	0.18
Pasture Loss	6,807	2,755	5.62	4,846	1,961	9.91	11,653	4,716	6.85
Forest	6,757	2,735	99.27	4,804	1,944	99.13	11,561	4,679	99.22
Urban	25	10	0.36	8	3	0.16	33	13	0.27
Scrub Brush	19	8	0.28	26	11	0.55	45	19	0.39
Water	6	2	0.09	8	3	0.16	14	5	0.12
Pasture Gain	5,943	2,405	4.91	3,104	1,256	6.35	9,047	3,661	5.32
Forest	5,757	2,330	96.86	2,956	1,197	95.26	8,713	3,527	96.31
Scrub Brush	162	65	2.73	137	55	4.39	299	120	3.30
Transitional	24	10	0.41	11	4	0.35	35	14	0.39
Urban Gain	32	13	0.14	8	3	0.02	40	16	0.02
Forest	8	3	23.61	--------	--------	--------	8	3	18.99
Pasture	24	10	76.39	8	3	100.00	32	13	81.01
Water Gain	11	5	0.01	23	9	0.05	34	14	0.02
Forest	5	2	44.23	15	6	64.71	20	8	57.79
Pasture	6	3	53.85	8	3	35.29	14	6	0.65
Scrub Brush	<1	<1	1.92	--------	--------	--------	<1	<1	41.56

Shumate and Cannon Creek Sub-Basins

Shumate Creek and Cannon Creek sub-basins are primarily forested watersheds with nearly equal total areas (Table 7). There are more pastures in the Shumate sub-basin than in Cannon Sub-basin. There were also more confined animal structures in the Shumate sub-basin than in the Cannon sub-basin, 13 and 4 acres respectively. The area coverage of these structures was included in pasture areas in Table 7. These areas were not interpreted in 1992 and were reported as pasture (Figures 9 and 10).

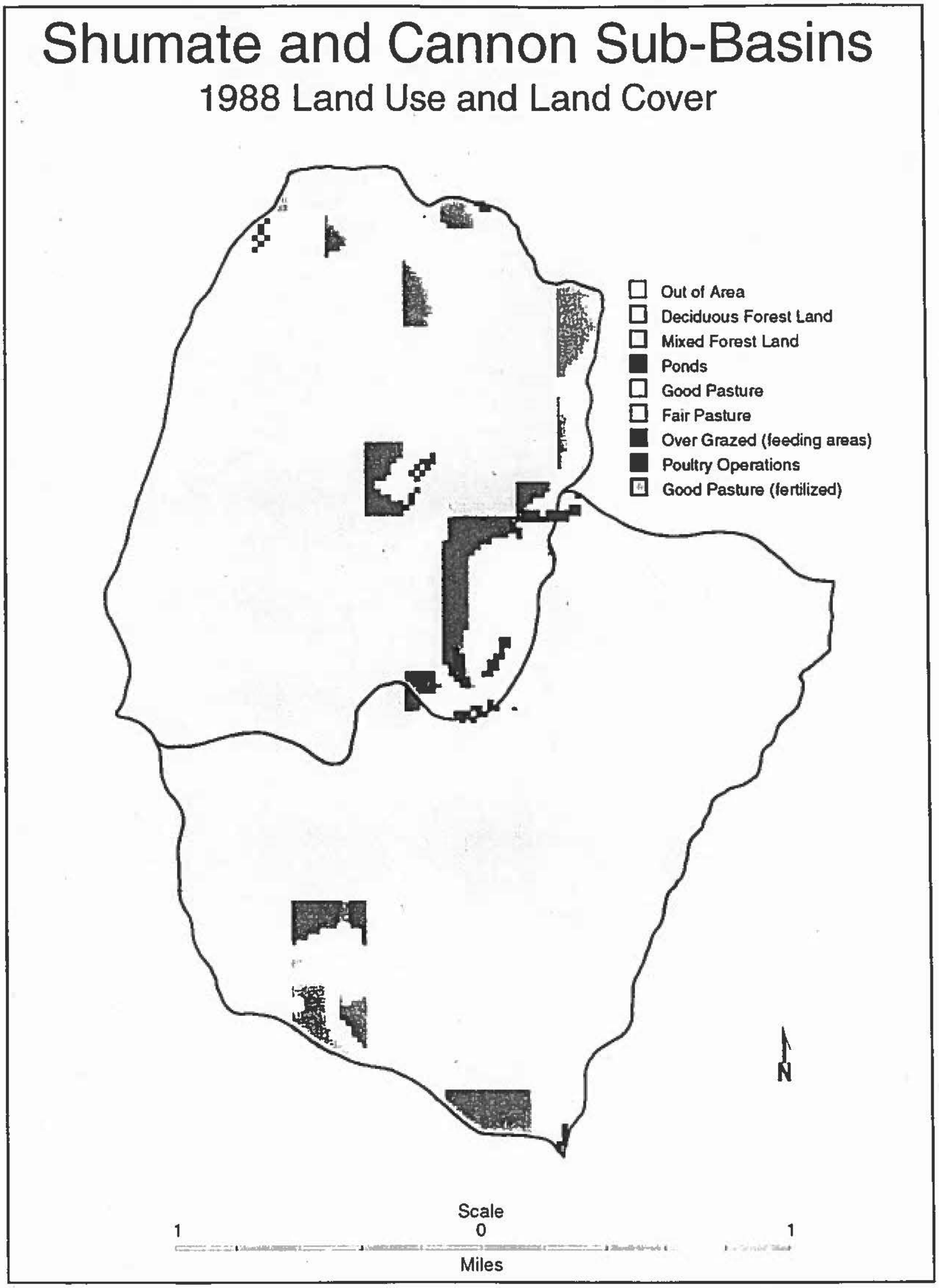

Figure 9. 1988 land use and land cover for Shumate and Cannon Creek sub-basins.

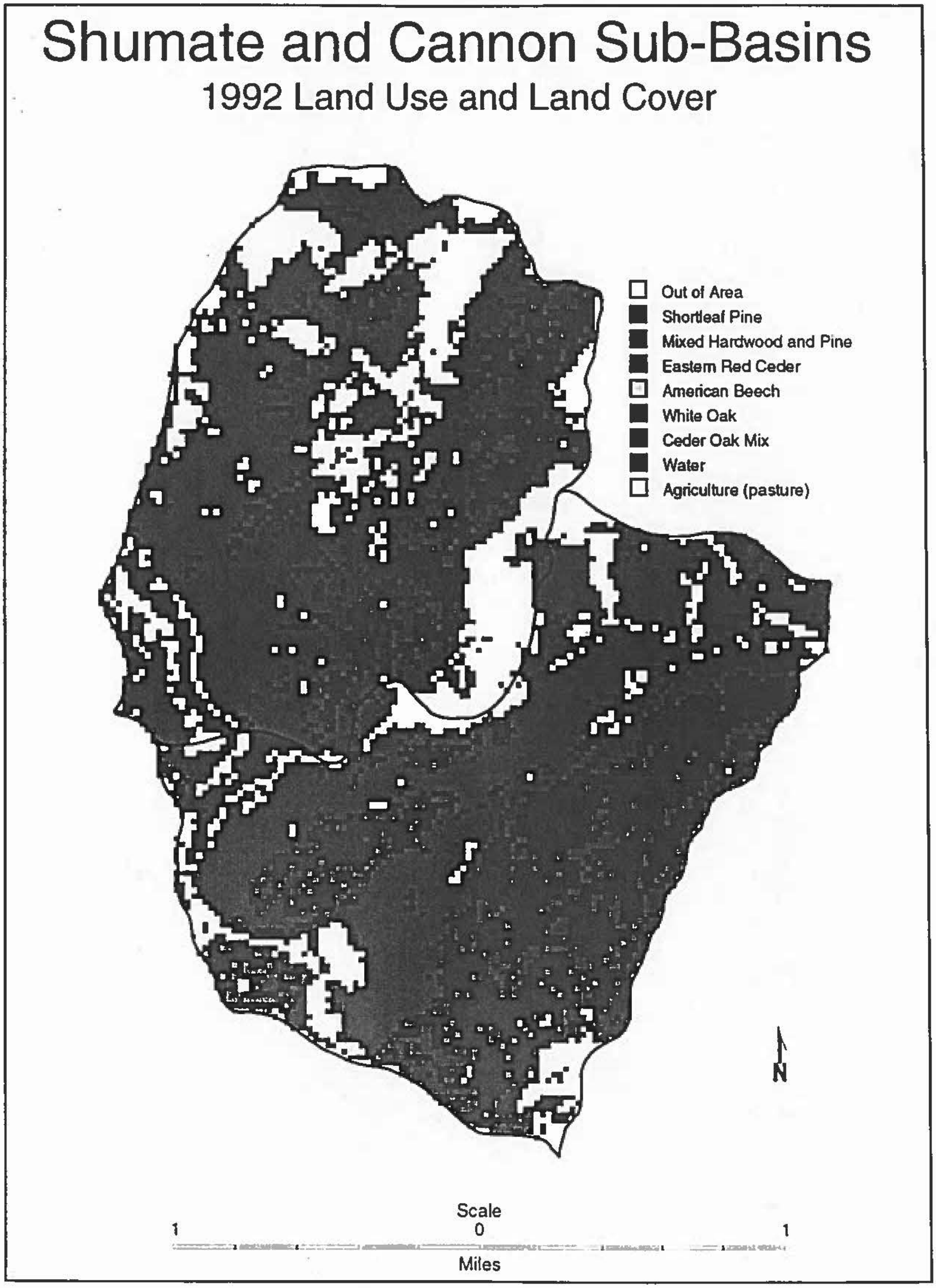

Figure 10. 1992 land use and land cover for Shumate and Cannon Creek sub-basins.

Table 7. Spatial distribution of 1988 and 1992 LULC in Shumate and Cannon creeks watersheds.

	1988			1992		
	Ac	Ha	%	Ac	Ha	%
Shumate Creek	1,455	589	48.36	1,455	589	48.36
Forest	1,162	470	79.87	1,126	456	77.42
Pasture	290	118	19.96	326	132	22.39
Water	3	1	0.17	3	1	0.19
Cannon Creek	1,553	628	51.64	1,553	628	51.64
Forest	1,416	573	91.18	1,382	559	89.00
Pasture	137	55	8.82	171	69	11.00

Forest loss and gains from 1988 to 1992 in the two sub-basins are presented in Figure 11. Most losses that occur as single pixels or as thin strips were due to interpretation differences and coincide with 1992 pasture gains (Figure 12 the loss of 1988 forest was strictly due to 1992 pasture gain. However, the larger red areas in the central portions of Shumate Creek sub-basin are actual changes in LULC and coincide with 1992 pasture gains. Small areas of forest and forest gains at forest and pasture boundaries are most likely due to interpretation differences. By comparing Figure 11and 12, it can be concluded that forest loss is due totally to pasture gain and vice versa (Table 8). In Shumate Creek and Cannon Creek sub-basins there was a net forest loss of 36 and 34 acres, respectively. Both of these losses were to pasture except for the addition of a small water area in the Shumate sub-basin.

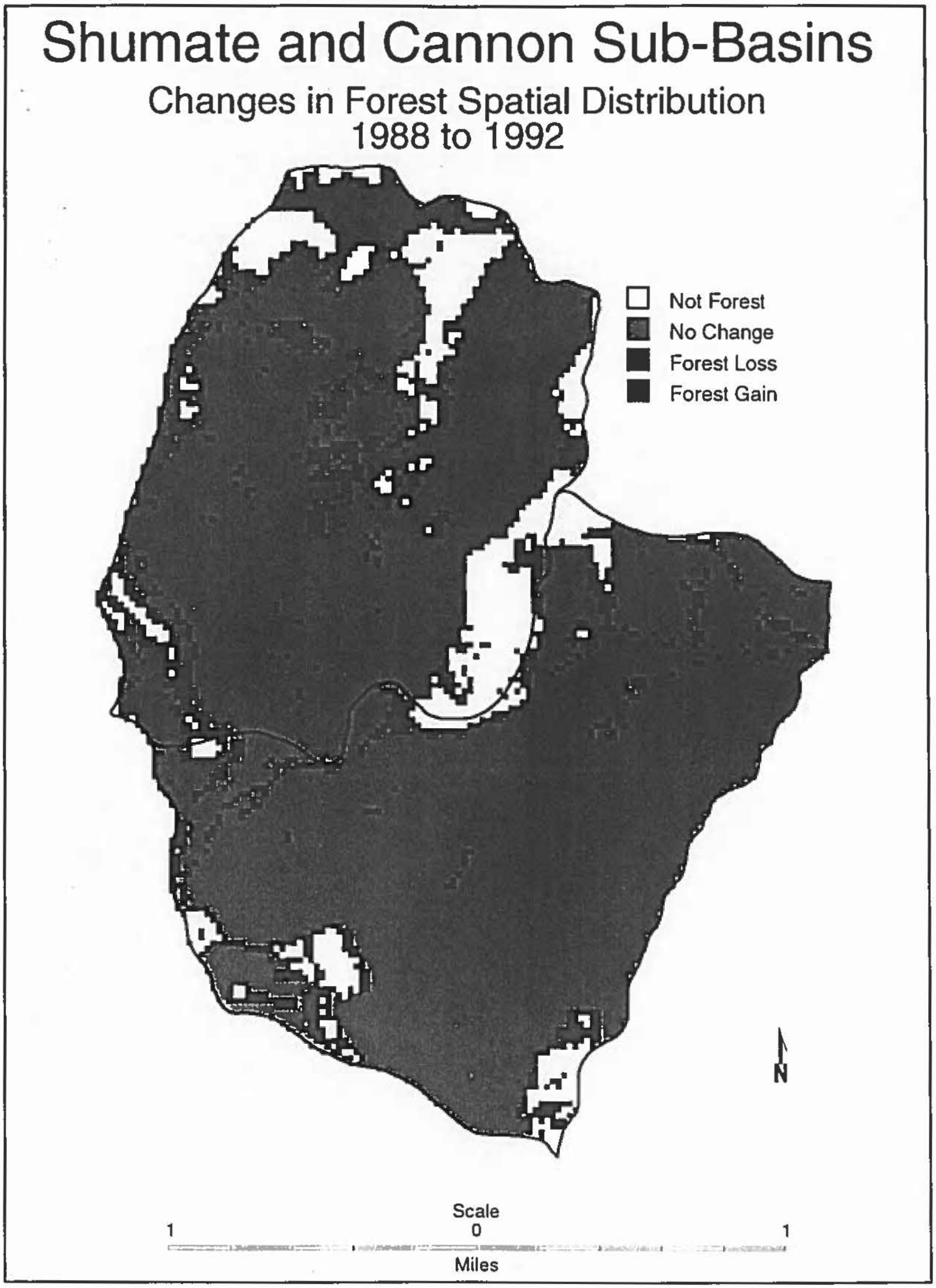

Figure 11. Spatial distribution of forest changes from 1988 to 1992.

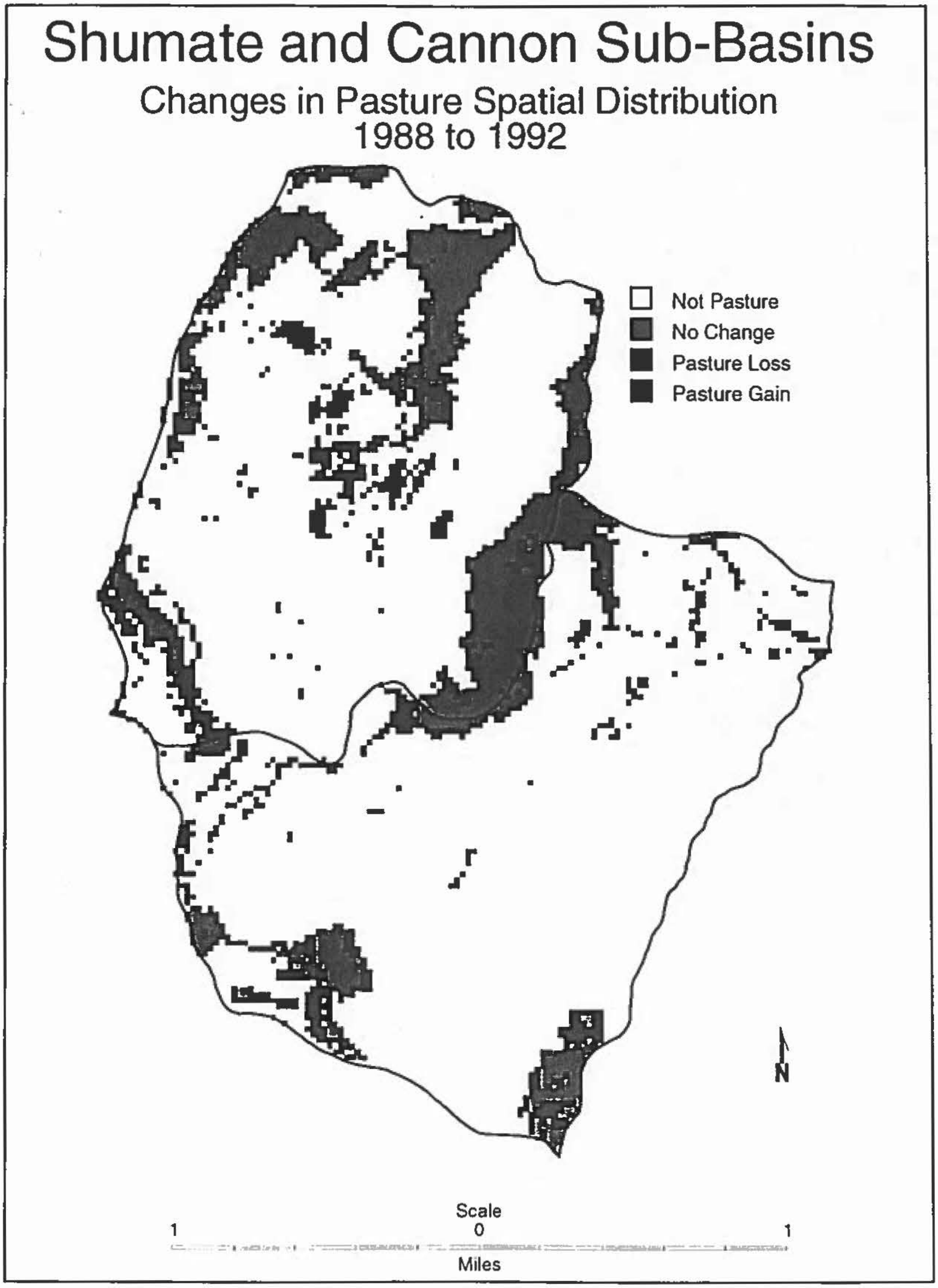

Figure 12. Spatial distribution of pasture changes from 1988 to 1992.

Table 8. Spatial distribution of LULC changes from 1988 to 1992 and quality of changes.

	ac	ha	%
Shumate Creek	1,455	589	48.36
Forest Loss	126	51	8.65
Water	>1	>1	0.18
Pasture	125	51	99.82
Forest Gain	90	36	6.20
Pasture	88	36	97.52
Confined Animals	2	1	2.48
Pasture Loss	90	36	6.20
Forest	90	36	100.00
Pasture Gain	126	51	8.63
Forest	126	51	100.00
Cannon Creek	1,553	628	51.64
Forest Loss	89	36	5.74
Pasture	98	63	100.00
Forest Gain	55	22	3.56
Pasture	55	22	99.60
Confined Animals	>1	>1	0.40
Pasture Loss	55	22	3.56
Forest	55	22	100.00
Pasture Gain	89	36	5.74
Forest	89	36	100.00

Summary

The previous discussion points out the advantages and limitations of the two interpretation methods used to develop this LULC data in the Upper White River Watershed. Although the accuracy may have suffered because of these differing methods of interpretation, the information is valuable in that it shows that there were changes in LULC between 1988 and 1992. The changes between forest and pasture are real although the spatial distribution may be skewed due to interpretation differences. Much of the forest gain was located in the river valley in the northern portion of the watershed. These areas could be isolated using a number of methods and excluded from the temporal analysis. One method would be to clump contiguous areas and assign each individual area the coverage it occupies and then exclude any area smaller than a set limit such as $900m^2$. This method would eliminate smaller point type features such as gaps in the forest canopy and individual tree clusters in the river valleys. Undesired line type features such as trees along roads and streams can be eliminated by creating buffer zones on either side of roads and streams and excluding any feature within this zone from analysis. A similar solution could be applied to forest and pasture edges; however this is not suggested because these are legitimate areas were changes would occur.

One element that neither method nor data address sufficiently is the urban category. It is our opinion that neither the 1988 nor the 1992 LULC data sets identified urban areas with sufficient accuracy to portray spatial and temporal changes. Changes in urban areas could affect a whole host of environmental conditions within a given watershed. Neither of these data sources provides sufficient information to study urban effects. The data could be modified to enhance what urban areas that are defined. One method would be to classify any area with a high density of roads as urban; however, the date of the roads source data would be significant in determining urban areas. TIGER census data provides such road data with varying source dates. These are the only data available for the White River Watershed with multiple dates, but the scale at which they were compiled may not be suitable for this study.