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REMOTE SENSING - IMAGE PROCESSING
LANDSAT GENERATED MAPS

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This study was undertaken to explore the potential use of Landsat for updating the New York State Land Use and Natural Resources (LUNR) maps. The results of this study could help pave the path for regular use of Landsat products at the county and local level in New York State. Schoharie County, situated in the Catskills, was the study area. Computer generated maps, similar to LUNR maps in appearance, were created. A Burroughs B6810 system with an on-line Calcomp digital plotter was used to analyze the Landsat data and create the maps. Support for this project was provided by NASA's Eastern Regional Remote Sensing Applications Center.

BACKGROUND

In 1966, the late Governor Nelson Rockefeller directed the New York State Office of Planning Coordination to develop a comprehensive land use and natural resource inventory of the entire state. This inventory, referred to as LUNR, was based on aerial photography taken in 1967 and 1968 of upstate New York and in 1969 and 1970 of Long Island and New York City. From these photographs, land uses were mapped on mylar film overlays, using the standard U.S. Geological Survey 7.5 minute quadrangle as the base.

Land use data for the inventory were divided into two types: area and point data. Two overlay maps, one for area and the other for point data, were made to correspond in coverage and scale to each of the 7.5 minute USGS maps within the state. The area maps delineated all the land within the state according to 51 land use classes. Point maps designated by symbol the specific location of 68 different types of land use. At the county level, the area land use maps have proven to be much more valuable than the point maps because they contain needed information not readily available from other sources. Point information, generally man-made features on the landscape, has been easily obtainable from various public and semi-public agencies at the state level. From the information on these maps a computerized geodata base was structured on the Universal Transverse Mercator (UTM) grid with a cell resolution size of one square kilometer or 247.1 acres.

In 1972, the Temporary State Commission to Study the Catskills was established by the state legislature. One of the charges given to this commission was to analyze land use conditions in the seven-county area designated as the Catskills. Schoharie County was one of the seven counties. Based on aerial photographs taken in 1973, updated LUNR maps were made of the region. Thus, the Commission was able to compare the 1968 and 1973 maps, a five-year interval. The geodata base was not updated. In 1976, the Commission was dissolved with no plans for updating LUNR maps in the future.

Even though many local governments have expressed a desire to have new, up-to-date LUNR maps and many state agencies have stated a strong need for an updated geodata base, the high costs of acquiring aerial imagery for the entire state, of interpreting the photography, and of manually drafting the maps and entering information into the geodata base make it impossible to maintain the LUNR system. Conseqently, a need exists but funds are not available to accomplish the task using traditional methods.

In 1975 the Schoharie County Planning and Development Agency and OLCGSA entered into a cooperative arrangement called the Schoharie County Cooperative Program (SCCP). Under this program several major projects have been undertaken by OLCGSA for the county. One major project was the development of a countywide automated geographic information system. This information system contains terrain, soil, cultural, and land use data. When this information system was developed, land use data were extrapolated manually from the 1973 LUNR maps and entered into the system's geodata base - a long, tedious task. This geodata base is very similar in structure to the State LUNR data base but it has a smaller cell size and additional variables. The land cover information produced under this project was also entered into the Schoharie County geodata base; thus, the data base now possesses both 1973 and 1978 land use data. Because this information was generated from Landsat digital data, entering it into the data base was an easy automated procedure.

Based on this longterm working relationship between OLCGSA and Schoharie County and the type of products developed by OLCGSA for the county, Schoharie County makes an ideal case study area for this project. In addition, the county possesses a good variety of land uses, typical of many sections of upstate New York.

PROCEDURE

The initial step was to select an appropriate Landsat scene. Since the LUNR inventories were conducted in 1968 and 1973, county officials expressed a desire to maintain the five year interval between inventories which made it necessary to acquire a 1978 scene. Like much of northeast United States, Schoharie County is located in a hilly-mountainous region usually covered with heavy haze and clouds. This condition made it extremely difficult to find a workable scene. A November 2 scene was selected initially because it was the only cloud-free data set with high quality rating in all four multi-spectral scanner (MSS) channels. However, due to the low sun angle at the time of the year shadows darkened the west facing slopes and bright reflecting surfaces appeared on east facing slopes. A variety of ratioing techniques were employed in an attempt to rectify this situation but little success was obtained. In addition, the time of year was not the best for detecting various vegetation patterns. Later, an August 22 scene was acquired. This scene had high ratings in all four channels but some small clouds existed in the upland areas of the county. Due to its good reflectance patterns showing different types of vegetation and the high sun angle during the summer, this August scene became the data base for the study.

After selecting a scene, the next step was the preprocessing and analysis of the data. OLCGSA has developed a computer system known as LAP (Landsat Analysis Package) for handling multispectral data. Using the LAP system the scene was initially rectified to eliminate some of the errors resulting from unbalanced radiometric responses from the scanner and reformatted to make the data easier to handle during analysis. Channel 1 (MSS band 4) contained some unusual data irregularities making it undesirable for the study. Since channels 1 and 2 are highly correlated, the loss of channel 1 should not have significantly altered classification results.

Once the scene was rectified and reorganized, a modified version of the technique known as SEARCH was used to obtain training fields, and thereby, spectral classes (groups of similar training fields). Originally developed by NASA's Earth Resources Laboratory, SEARCH is an unsupervised method to the extent that training fields are automatically selected and a supervised method with respect to how class statistics are generated. The SEARCH algorithm is based on moving a window of prescibed size through the data set searching for areas which are spectrally homogeneous. Such areas are called training fields. In this study a window size of 3 rows by 3 columns (9 pixels) was used. To establish the level of spectral homogeneity desired for selecting training fields and to stress certain general land cover conditions, an investigator must define a set of parameter values within the SEARCH program. By varying these values, different groups of pixels within the scene will become training fields resulting in various land cover patterns being observed. After investigating numerous combinations of parameter values, an acceptable set was obtained in terms of the specific objectives of this study. Thirty five spectral classes were produced based on these values.

These spectral classes were processed through the maximum likelihood classification technique to classify each pixel within the study area. Each spectral class was then assigned a land cover class by the analyst who compared through photointerpretative methods the spatial and land surface patterns on the aeral photography to similar patterns on the Landsat alphanumeric computer generated maps. Generally, several spectral classes were grouped together to form a single land cover class. The defined land cover classes are listed in Table 1.

TABLE 1: LAND COVER CLASSES

AG	Agriculture
DF	Deciduous Forest
CF	Coniferous Forest
BW	Brushwood
WW	Wooded Wetlands
UR	Urban
SB	Suburban
HA	Hamlet
SM	Surface Mining
WT	Water
RE	Reservoir

Once the scene was statistically classified, it was necessary to redefine the land cover for some pixels. As previously indicated a few small clouds existed over the study area in the August scene. These clouds and their respective shadows were cosmetically removed from the classified scene and replaced by the land cover patterns indicated on 1975 high altitude color IR photography. Each of these cosmetically altered areas related to a mature forest environment and no noticeable land cover change occurred in any of these areas between 1975 and 1981 when they were field checked. Also, in order to show on the land cover maps a continuous water pattern for the Schoharie river, it was necessary to link sections of the river together where overhanging vegetation blocked or modified potential water reflectances and to insert water pixels on the river's bends where the rectangular shaped pixels did not display well formed curves. Finally, certain spectral classes could not be easily assigned to any one land cover. In certain sections of the scene they related to one land cover; whereas, in other sections they were best grouped into another land cover. Rather than grouping one of these classes completely under one land cover throughout the entire scene, they were assigned to different land covers in different sections of the scene. This procedure was done cosmetically by an analyst using an interactive computer system, a component of LAP, to change the classified values of selected pixels. None of these spectral classes were extensive in their areal coverage and none of them were split between more than two land cover classes.

VALIDATION

Two different methods were employed to validate the accuracy of the land cover classes generated. First, by overlaying the mylar based 1968 and 1973 LUNR maps on the 1978 Landsat computer line printer maps produced at the same scale, visual comparisons were made for general compatibility between land surface features over the three different years. This method allowed the investigators to determine if the Landsat land cover classes corresponded spatially with the land use classes of the earlier inventories. In general, a high degree of spatial correlation existed between the classified maps and the LUNR maps. The noticeable differences were due to either landscape alterations not in existence in either 1968 or 1973 or variations in land cover definitions between inventories.

The second method, a more rigorous test of accuracy, involved the statistical sampling of individual classified pixels. The classified scene was organized in a grid pattern with scan lines and elements sequentially numbered. Using random numbers in correspondence with the numbered lines and elements forty randomly selected pixels were obtained for each land cover class. The selected pixels were compared to the 1975 color IR photography to determine their relative accuracy. Next, a grid was superimposed on the aerial photography covering the classified scene. Employing, again, random numbers in relationship to the lines and elements of the gridded photography, forty pixels were compared to the classified scene. This cross-checking procedure of photography to scene reduces the possibility that certain land cover locations within the study area will be overlooked as might be the case when comparing only the scene to photography. None of the areas altered cosmetically were used for sample points.

TABLE 2

COMPARATIVE ACCURACY RESULTS BETWEEN THE LANDSAT CLASSIFIED LAND COVER MAP AND THE PHOTOGRAPHICALLY INTERPRETED INFRARED AERIAL PHOTOGRAPHY

Land Cover	Scene to Photo (Percent)	Photo to Scene (Percent)	Combined (Percent)
AG	92.50	90.00	91.13
DF	95.00	90.00	92.50
CF	87.50	92.50	90.00
BW	85.00	90.00	87.50
WW	87.50	82.50	85.00
UR	90.00	92.50	91.13
SB	85.00	85.00	85.00
HA	70.00	72.50	71.13
SM	92.50	90.00	91.13
WT	97.50	95.00	96.13
RE	100.50	97.50	98.63

Table 2 illustrates the quantitative results of this second accuracy test. Overall, the land cover classes recorded percent marks in the high 80s and low 90s, an accuracy level comparable to most large land use inventories produced under traditional methodologies. The two water classes have very high marks; however, some problems existed in separating water from wooded wetlands. The lowest marks relate to the class entitled "Hamlet". Some hamlets were not detected due to the size of community and the density of tall, full-crown trees which hid them from the satellite's sensors. Although the accuracy results for this study are very good, they must be considered with respect to the investigator's interpretation of the landscape on the aerial photography.

LAND COVER CLASSES

The specific goal of this project was to examine the feasibility of using Landsat data to update the New York State LUNR information base. The ideal outcome would be to produce the identical land use classes created under the LUNR inventories. This outcome has been partially realized. In general, some of the derived land cover classes correspond to LUNR classes but others need to be refined. The forest classes relate well to LUNR forest classes but the single agricultural class does not provide the detail found in the LUNR system. An agricultural landscape is more dynamic than a forest environment; thus, the timing of the data becomes critical in order to detect certain land cover conditions. For example, to separate cropland from pasture, a late spring data set would be valuable because most cropland would be bare of any vegetation coverage.

To measure the project's outcome based strictly on the direct correlation between the Landsat and LUNR land cover classes is not possible. Certain indirect correlations must be considered. Some LUNR classes are inherent within the Landsat-derived maps although not specifically indicated on them. Classes associated with heterogeneous land surfaces frequently fall into this condition. Brushland, for example, is a mosaic composed of small patches of either grass, shrub, or forest. Under the traditional air photo interpretation methodology, an investigator would identify a brushland area by grouping these mixed patches together under one category. However, the Landsat methodology is based upon classifying each pixel. With a pixel approximately an acre in size, nearly every patch within the mosaic can be identified according to its basic land cover. The Landsat-derived maps display areas consisting of clusters of single pixels and small groups of pixels classified as brushwood, agriculture, and deciduous forest. Collectively these distinct pixels or groups of pixels form a brushland condition. Individuals working with these maps must recognize the existence of these inherent land cover classes and how these classes apply to the LUNR system or any other land use inventory.

In addition to the inherent land cover classes, another method exists for obtaining LUNR classes indirectly from the Landsat classes. As previously demonstrated in the section entitled "Procedure", different land cover information can be obtained by relating the generated land cover data to other data sets. Elevation and slope data might be used to subdivide the agricultural land cover class into grassland versus cropland. Schoharie County with its geographic information system could relate each pixel classified agriculture with the elevation and slope information available in its geodata base. Other counties without established geographic information systems could overlay Landsat-derived maps on topographic maps and accomplish the same basic outcome.

MAP PRODUCTS

Once an acceptable classification was developed, the scene was geometrically corrected and rescaled to relate to the 7.5 minute USGS quadrangle map size. Employing a digital plotter, land cover maps were plotted onto a mylar surface. See Figure 1. These maps were similar to the LUNR maps in appearance. Mylar, a durable mapping surface, is a transparent film making it possible to overlay the land cover maps on the county's topographic and soil maps. This overlay ability will allow county officials to note spatial relationships between terrain, soil, and land cover. Also, the mylar will permit excellent blue print copies of the land cover maps to be made. The blue print copies can be used as work maps for a variety of purposes. These land cober maps are different from the LUNR maps in two ways. First, due to the size and shape of the pixels the land cover patterns on the maps are block-like in appearance. Second, because point data are impossible to detect with the Landsat resolution, only area data are being classified and mapped. Consequently, one land cover map was developed for each 7.5 minute USGS quad rather than two maps which was the case under the LUNR inventories. The elimination of problem. As previously indicated, conty government officials are much more interested in the area land use information.

These maps are best suited as work maps. They are designed to allow county officials to examine in relative detail various planning and development issues spatially. As work maps they fulfill a certain need.

COMPUTER FACILITIES

The Oneonta Computer Services Center maintains a Burroughs B6810 system with 6 million bytes of memory and the following peripheral devices: three magnetic tape drives, sixteen disk packs with a total storage of 2.7 billion bytes, and 140 workstations (mainly Lear Siegler ADM31's and some ET1100's). The system supports a multi-user environment ranging from GEMCOS controlled transactions for administrative applications to CANDE/WFL instructional-research processing based on a wide variety of programming languages. The college has approximately 5800 students, mainly undergraduates, and 300 faculty of which 1800 students and 30 faculty actively use the system during a normal semester.

To undertake this remote sensing project the following computer resources were required: a tape drive to handle the image data when initially received from the United States Geological Survey's EROS Data Center, an entire disk pack to accommodate large files varying in size from 40,000 sectors to 165,000 sectors, a large amount of CPU cycles to process and analyze the large volume of data through various statistical and graphic routines, and an on-line Calcomp digital plotting workstation to draw the final maps. To provide these resources in a multi-user environment required careful scheduling and tailored programming. For example, much of the number crunching processing was scheduled through WFL (Work Flow Language) to run during off hours. Also, to handle the slow speed of a digital plotter and not use memory needlessly, plotting software was designed to place graphic output commands into a disk file. Later this disk file was read by a small ALGOL program which transmitted the commands to the plotter. This ALGOL program permitted recovery on long plots (generally three to four hours in length) if system interruptions occurred. Techniques of this type allowed this project to be completed on time while not interfering significantly with other users.

Work on this project was made possible by the fact that both the academic researcher and the academic programmer/analyst have solid backgrounds in georgaphy-remote sensing and computer programming. This situation permitted ease of communications between the Geography Department and the Computer Services Center in understanding each others goal and problems.

ACKNOWLEDGEMENTS

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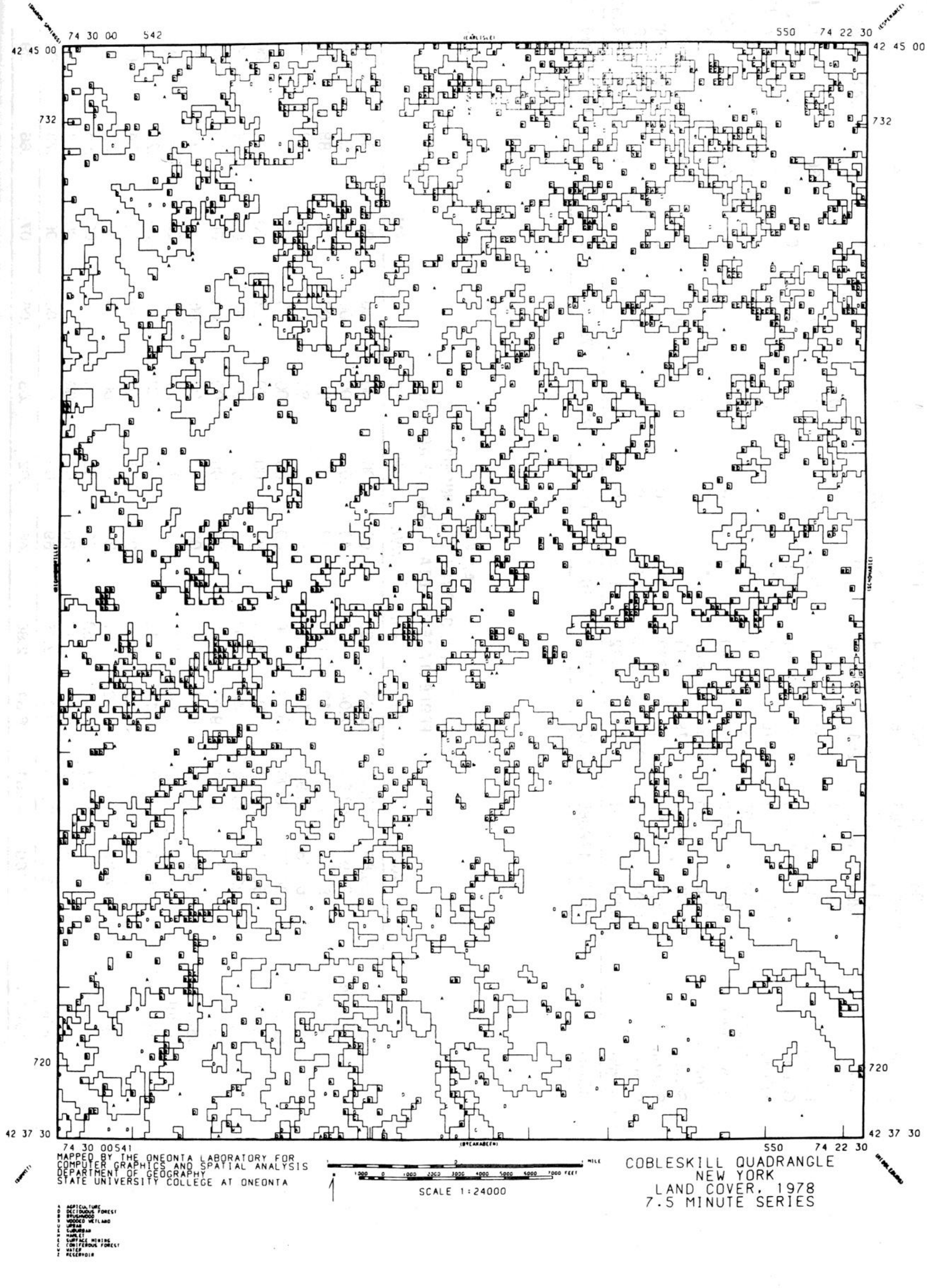
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MAPPED BY THE ONEONTA LABORATORY FOR
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STATE UNIVERSITY COLLEGE AT ONEONTA
SCALE 1:24000
COBLESKILL QUADRANGLE
NEW YORK
LAND COVER, 1978
7.5 MINUTE SERIES

TABLE 3
LAND COVER BY TOWNSHIP
ACREAGE

	AG.	DF.	CF.	BW.	WW.	UR.	SB.	HA.	SM.	WT.	RE.	TOTAL
Blenheim	3577	14479	2773	193	14	0	0	0	0	208	318	21562
Broome	8906	17685	3707	220	133	0	0	0	1	111	0	30758
Carlisle	12566	6183	26	2496	420	0	0	0	0	192	0	21882
Cobleskill	11944	5024	516	1229	107	41	162	0	209	109	0	19341
Conesville	7852	14629	2613	248	0	0	0	0	0	2	341	25684
Esperance	6716	3411	9	2256	128	0	0	49	0	318	0	12887
Fulton	9697	26129	4707	403	102	0	0	0	0	266	0	41286
Gilboa	12942	19809	3455	584	145	0	0	0	0	216	915	38066
Jefferson	11785	14174	1416	133	17	0	0	17	0	78	0	27621
Middleburg	11253	16205	3133	463	115	0	0	26	27	289	0	31510
Richmondville	11494	6412	404	590	2	26	41	24	0	42	0	19035
Schoharie	11208	5585	867	820	248	2	0	116	17	294	0	19158
Seward	14976	7461	519	203	73	0	0	8	1	79	0	23321
Sharon	17852	6092	106	633	155	0	0	0	0	141	0	24979
Summit	11124	9904	2353	279	48	0	0	0	0	232	0	23940
Wright	10274	7601	723	432	126	0	0	15	16	43	0	18330
COUNTY	174147	179880	27322	11183	1834	69	202	256	272	2621	1573	399360

TABLE 4:
LAND COVER BY TOWNSHIP
PERCENTAGE OF TOTAL TOWNSHIP ACREAGE

	AG.	DF.	CF.	BW.	WW.	UR.	SB.	HA.	SM.	WT.	RE.
Blenheim	16.59	67.15	12.86	.89	.06	.00	.00	.00	.00	.96	1.47
Broome	28.95	57.50	12.04	.71	.43	.00	.00	.00	—	.36	.00
Carlisle	57.54	28.25	.12	11.41	1.92	.00	.00	.00	.00	.88	.00
Cobleskill	61.76	25.97	2.66	6.35	.55	.21	.84	.00	1.08	.57	.00
Conesville	30.57	56.96	10.17	.96	.00	.00	.00	.00	.00	—	.00
Esperance	52.11	26.47	.07	17.51	.99	.00	.00	.38	.00	2.47	.00
Fulton	23.44	63.29	11.40	.97	.25	.00	.00	.00	.00	.65	.00
Gilboa	34.00	52.04	9.08	1.53	.38	.00	.00	.00	.00	.57	2.40
Jefferson	46.67	51.32	5.13	.48	.06	.00	.00	.06	.00	.28	.00
Middleburg	35.71	51.43	9.94	1.47	.37	.13	.21	.08	.08	.91	.00
Richmondville	60.38	33.68	2.12	3.10	.01	.00	.00	.13	.00	.22	.00
Schoharie	58.50	29.15	4.52	4.28	1.29	.01	.00	.60	.09	1.54	.00
Seward	64.22	32.00	2.22	.87	.31	.00	.00	.03	—	.34	.00
Sharon	71.47	24.39	.42	2.53	.62	.00	.00	.00	.00	.56	.00
Summit	46.46	41.37	9.83	1.17	.20	.00	.00	.00	.00	.97	.00
Wright	56.05	36.56	3.94	2.35	.69	.00	.00	.08	.09	.23	.00
COUNTY	43.60	45.04	6.84	2.80	.46	.02	.05	.06	.07	.66	.39