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USING AREA POINT SAMPLES AND AIRPHOTOS TO ESTIMATE LAND USE CHANGE

By Kathryn A. Zeimetz, Elizabeth Dillon, Ernest E. Hardy, and Robert C. Otte*

A two-stage sample of airphoto prints and point sampling was used to examine changes in land use patterns in 53 selected counties that had grown rapidly and substantially in population between 1960 and 1970. Point sampling, 20 points per square mile, was used on a sample of airphoto prints approximating 15 percent of the land area to study 12 categories of rural and urban land use. This approach evolved from experience with different scales of photos, areal samples of photos, random traverses, and point sampling in varying combination. This technique, an inexpensive one, resulted in data that satisfactorily correlated with comparable data from other sources and provided detail on the dynamics of land use change.
Keywords: Airphoto interpretation, remote sensing, point sampling, urbanization, land use inventory.

INTRODUCTION

Aerial photographs have proved to be a valuable source of data on land use, particularly in obtaining historical data that could not have been gained otherwise. The automated remote sensing techniques that are being developed hold promise as an inexpensive source of broad-scale data on land use and other resources. But for specific detailed studies of land use and land use change, conventional airphoto interpretation remains an important tool. Sampling is one way to make it more efficient and less costly. This article reviews some of the experience of Economic Research Service (ERS) staff and other researchers in interpreting aerial photos and developing a two-stage sampling technique to obtain detailed data on land use change in 53 selected counties. Though not without some statistical shortcomings, the approach appears to have specific advantages over other techniques, and the statistical weaknesses can be overcome by suitable randomization and probability sampling.

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HISTORICAL USE

Airphoto Interpretation

The late Francis J. Marschner, while in the Land Economics Division of USDA's Bureau of Agricultural Economics, pioneered in the use of aerial photos as a source of land use data. In the 1940's, he developed a land use map of the United States based in large part on airphotos (*13, 14*). Since then, his division, now the Natural Resource Economics Division of ERS, has used airphoto interpretation in various ways.

An important factor in expanding the application of aerial photo interpretation was its use by the military during World War II. After the war, persons trained in the technique adapted it for civilian purposes. One major application has been in local land use inventories and analyses of land use change made to accompany comprehensive land use planning at the local level. A more general application is Avery's study of land use change in Clark County, Georgia, which produced six-category inventories for 1944 and 1960 and a detailed land use map of the county (*4*).

An example of the use of airphoto interpretation in a statewide resource inventory is the New York LUNR project (Land Use and Natural Resources). LUNR was designed to "identify and record how the state's land resources are being utilized." Project staff relied heavily on aerial photo interpretation for data on land use and other resource characteristics. Data can be retrieved by computer through a statewide grid system with cells of 1 square kilometer. Gessaman and Hardy used this system when they analyzed historical land use change in a 2,086 square mile area of southern New York in which they employed 8 land use categories (*10*).[1]

The main source of photos for ERS has been USDA's Agricultural Stabilization and Conservation Service, which has had aerial photography produced for agriculturally important areas of the country at intervals of approximately 8 years since the late 1930's. Other sources are USDA's Forest Service and Soil Conservation Service, and the U.S. Geological Survey. These airphoto

[1] For a review and discussion of land classification schemes used with remote sensing, see (*1*) and (*3*).

archives contain a wealth of information on land use, as yet largely untapped.

Generally, the analyst has examined photos of an entire study area. Some variation in intensity of coverage is possible by use of photos of different scales. In some cases, the technique has been used to obtain a complete land use inventory of an area. Different categories of use are identified and circumscribed on the photos and measurement estimates are made either by planimeter or dot grid. A major use of the approach by ERS in earlier years was to determine land use by flood frequency zone as a basis for estimating flood damages in river basin studies.

However, most ERS airphoto interpretation has been used not to develop comprehensive inventories but to identify and measure specified changes between two points in time. For example, Anderson and Dill studied clearing and drainage in North Carolina between 1950 and 1957, using large-scale photography (1:20,000) (*2*). Dill and Otte focused on urbanization in Western States between 1950 and 1960, in which they used photo index sheets (uncontrolled mosaics) in a scale of 1:63,360 (*8*).

Area Point Sampling

ERS has used sampling on a limited scale. Nobe and Dill, with traverses, developed estimates of land use by flood stage zones in the flood plain of the Potomac River (*15*). In a study of urbanization of land in 96 counties in the Northeastern States, Dill and Otte used the sample plots of the Conservation Needs Inventory (*7*). This stratified sample of 100-acre plots comprises 2 percent of the rural, non-Federal land in each U.S. county. Dill and Otte identified change to urban use within each plot and measured the extent through aerial photography of 1:20,000 scale.

ERS first used point sampling for land use studies as a result of research with the Department of Geography at the University of Chicago on rural floodplain use during 1959-63. In a report on that work, Brian Berry examined various sampling methods for obtaining flood plain data, including the use of points (*5*).

Sloggett and Cook made the first major use of point sampling in ERS resource studies when they evaluated flood prevention benefits in small watershed projects in Oklahoma (*16*). They used aerial photos as maps to locate the sample points, and they gathered data on land characteristics and use through ground survey and from secondary sources.

Point Sampling and Airphoto Interpretation Combined

The first combined use of point sampling and aerial photo interpretation by ERS occurred in Frey and Dill's study of land use change in the lower Mississippi River alluvial plain (*9*). From the U.S. Air Force, they obtained airphoto coverage of the entire area for 1969 in a scale of 1:125,000. Earlier coverage—for 1950, on the average, but ranging from 1949 to 1953—came from ASCS photo index sheets in a scale of 1:60,000 or smaller.

Frey and Dill used a systematically aligned sample of points, one per square mile. The origin point for each print was randomly selected. Six land use categories were identified: (1) cropland, (2) grassland, (3) transitional land, (4) forest, (5) urban and buildup land, and (6) other. The basic objective was to obtain data on conversion of forest land to cropland. However, six-category inventories were developed for both 1950 and 1969, as was a matrix of change among all uses between the 2 years (table 1).

As the most important change, cropland increased from 9,963,000 acres to 13,710,000 acres. This increase resulted from conversion to cropland of 3,818,000 acres of forest land, 219,000 acres of grassland, and 61,000

Table 1.—Changes in land use, lower Mississippi alluvial plain, 1950-69

Major use, 1969	Major use, 1950						Total, 1969
	Cropland	Grassland	Transition	Forest	Urban	Other	
	1,000 acres						
Cropland	9,601	219	61	3,818	1	10	13,710
Grassland	186	686	13	209	0	1	1,095
Transition	93	22	24	18	0	0	157
Forest	20	20	28	7,386	1	2	7,457
Urban	46	9	2	28	362	0	447
Other	17	2	1	61	1	1,131	1,213
Total, 1950	9,963	958	129	11,520	365	1,144	24,079

Source: (*9*).

acres of transition land. (Also, an insignificant amount of urban-type use was eliminated.) Cropland lost 186,000 acres to grassland, 93,000 acres to transition use, 46,000 acres to urban use, and 17,000 acres to other uses.

This type of matrix can be used in Markov and other simulation techniques to make projections based on historical relationships. Burnham used Markov analysis on table 1 to project land use for the Mississippi Valley study area to 1988, 2007, 2026, and to equilibrium (*6*).

STUDY OF SELECTED URBANIZING COUNTIES

In mid-1973, ERS and the Department of Natural Resources at Cornell University developed a cooperative research project to measure and analyze land use change where urbanization is having maximum impact on previously rural areas. To identify such areas, both relatively and absolutely, analysts listed counties that showed at least a 30-percent population increase and an absolute increase of 20,000—for a U.S. total of 129 counties (*17*). From this list, 53 counties were selected that had complete airphoto coverage for 1 year as close as possible to 1960 and 1 year as close as possible to 1970. Thus, the period of observed land use change would be comparable to the two most recent population censuses (fig. 1).

A common scale of photography provides greater economy and more accuracy of interpretation by permitting development of procedures that can be uniformly and repetitively applied. Therefore, only ASCS photographs were used in the study. Though limiting the source of photography simplified the interpretation and sampling procedures, it introduced some bias into selection of counties. ASCS uses aerial photography in the operation of various farm programs; therefore, almost all U.S. cropland has been photographed. Counties with frequent full airphoto coverage by ASCS are generally those with a significant acreage of cropland distributed over most of the county.

Further, an area is rephotographed when it is deemed that significant changes in the cropland acreages and boundaries have occurred—on the average, at intervals of about 8 years. ASCS photographs of the counties sampled in the ERS study usually were not made in census years, and the intervals generally were not 10 years. The longest interval between photographs of the counties sampled was 18 years; the next longest, 13 years. For 14 counties, the interval was 6 years, the shortest period. For the study, the average year of

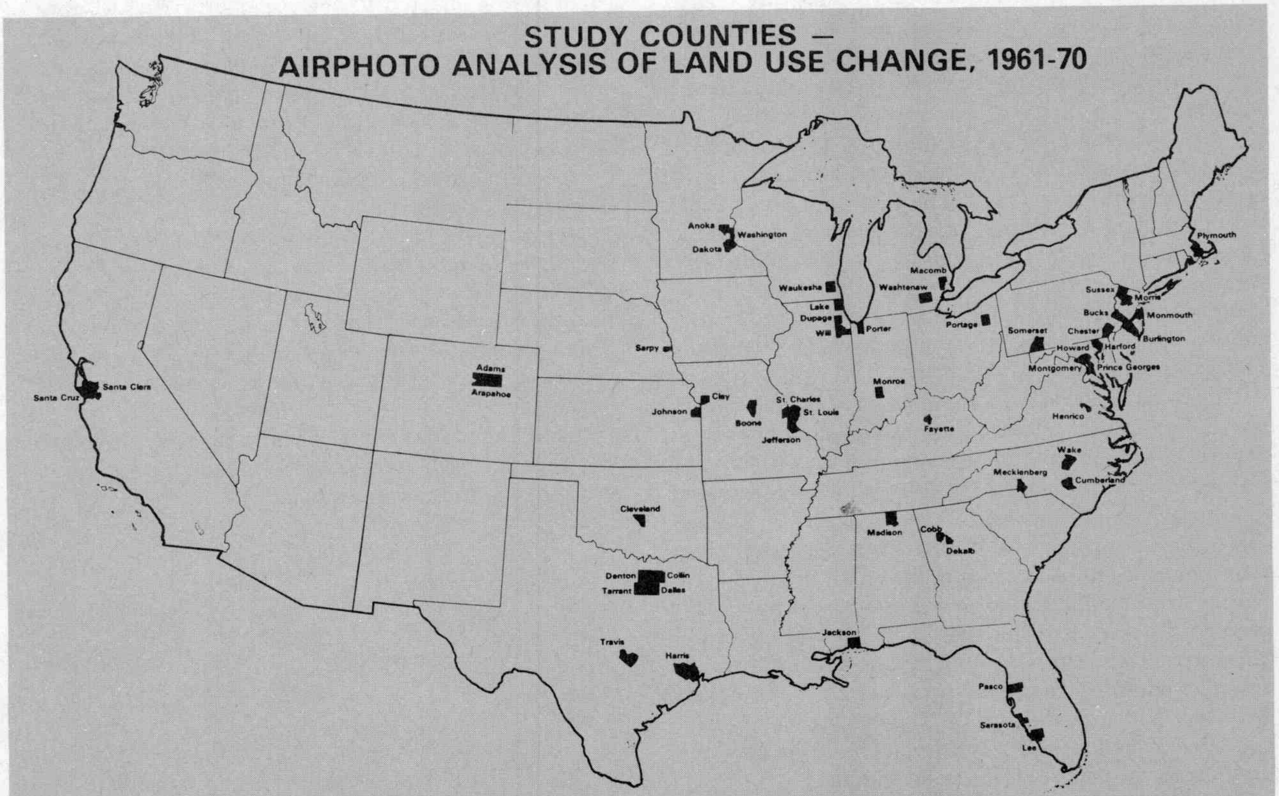


FIGURE 1

coverage was 1961 for the earlier reading and 1970 for the later one.

Sampling Procedure

Information on land use and changes in such use came from a two-step sampling procedure. First, areas were selected from county photos; second, points were chosen within each selected photo.

If aerial photography could have been obtained specifically for this study, the procedure might have been randomized as follows. A plane would fly at random across the county. Photos would be taken along each traverse at random locations sufficiently far apart to preclude overlap. However, because of the cost factor, existing ASCS photographs had to be used.

ASCS photographs are made with a 65-percent overlap along each flightline (traverse) and a 30-percent overlap from one flightline to the next—to provide stereoscopic coverage for any given point. Points near the center of each flightline appear on three separate photos. Points near the edge, where the flightlines overlap, may appear on six separate photos. Thus, specific points have different probabilities of being included in a sample of prints, which introduces a possible source of bias because all points in a selected photo were weighted equally in the ERS analysis.

A sample of prints was selected on a systematic, geographically stratified basis that would insure a cross section of each county and would preclude any point entering the sample more than once. The procedure produced a sample similar in appearance to one obtained with a specifically designed set of traverses and random photos.

The procedure used for each county was to pick photos from alternate flight strips on photo index sheets. Whether to start with the first or second strip was determined by flipping a coin. A number from 1 to 10 was picked randomly to specify the first photo of the selected flight strip. Starting from this photo, every tenth photo in each alternate row was chosen. Hence, the first photo was selected at random and the remaining photos were chosen systematically.

The original aim was to obtain an area sample of at least 10 percent or more of the surface area of each county. The number of photos required for this coverage was based on two calculations. Each photo was assumed to represent a usable area of 8 square miles. The average size of the counties being studied was 646 square miles; thus, about 80 photos per county would be needed. Photos from 2 different coverages overlapped about 65 percent. The effective area represented by each pair of photos was thus reduced to 5.2 square miles, which indicated 13 photos were needed for a 10-percent coverage. With this guideline, the goal of 10-percent coverage was exceeded and approximately 15 percent of the area was used for the second step, the point sample.

In this step, the interpreter sampled within each photo using (1) a random set of points, 20 per square mile, which has been selected from a random numbers table and (2) a piece of 9″ by 9″ graph paper with a mesh of 1/20 inch. Thus, any point representing an area on the ground 83 feet square had an equal chance of being selected. The points marked on the graph paper were transferred to a heavy acetate template.

Five templates were drawn up, each providing eight sample possibilities (four cardinal positions times two sides). The templates received a major number — I, II, III, IV, or V — and opposite sides of each template were labeled A and B. The template corners were subnumbered 1 through 4 in a clockwise direction. The template to be used was placed on the airphoto; the specified subnumber was at the top of the right-hand corner of the template (or left-hand corner if side B was selected). After the template had been placed on the most recent photo, the equivalent points were located on the older photo, and the land use could be interpreted on each photo. Interpreters used magnification as necessary and they interpreted all points monocularly. For some counties, early coverage was at a 1:20,000 scale while the later coverage was at 1:40,000. For these, the template was placed on the earlier photo and the equivalent points were located on the newer coverage.

The original goal, to average at least two points per square mile for the total sample area, was more than met in every county. The average sampling rate for all counties was 3.0 points per square mile. The point sample data were converted to acreage figures; each county's total surface area, as given in Census publications, was divided by the total number of points in the sample for that county. Thus, for each county, a point had a specific acre equivalent that provided a constant for conversion of all point data to acreage data.

County aggregates were achieved by summing the county acreage estimates.

Coefficients of variation were computed for the estimates of the area in each use category in 1967. (Table 2 shows these coefficients for a group of three counties in Illinois.) Analysts made the computations using point counts. However, they would have obtained nearly identical results using the conversion to acreage estimates.

With a random sample of photos and points assumed, variance for each category of use could be estimated through the following formula:[2]

$$v(\hat{y}) = \frac{\left(1-\frac{n}{N}\right) \sum^{n} \left(M_i p_i - \frac{\sum^{n} M_i p_i}{n} \right)^2}{n(n-1)} + \frac{n}{nN} \sum^{n} \frac{M_i p_i (1-p_i)}{(m_i - 1)}$$

[2] Formula adapted by Huddleston from (*11*, pp. 183-186, 206-208). Also see (*12*).

Table 2.—Land use change in Dupage, Lake, and Will counties, Illinois, 1961 and 1967

Land use in 1967	Land use in 1961											Land use in 1967	
	Crop-land	Pasture and range	Open idle land	Farm-stead	Forest land	Resi-dential land	Trans-porta-tion	Recrea-tion	Comm. Ind. Inst.[a]	Water bodies > 40 acres	Miscel-laneous use	Total	Coeffi-cient of variation
Cropland	550,876	3,618	1,704								186	556,384	9.0
Pasture and range	1,427	14,288										15,715	18.8
Open idle land	10,008	3,184	74,068						186	1,984	372	89,802	17.7
Farmstead				18,244	432							18,676	15.3
Forest land	372	1,240	1,641		80,163	216						83,632	15.0
Residential	5,362	248	2,105		434	110,794					402	119,345	21.0
Transporta-tion	1,638	216				432	51,393				648	54,327	12.5
Recreation	432							11,284		248		11,964	27.9
Commercial, Industrial, Institu-tional	5,327		2,261			186			43,216		1,084	52,074	26.6
Waterbodies less than 40 acres	216		864							40,343		41,423	39.2
Miscellane-ous[b]	216		1,178								16,376	17,770	16.5
Total, 1961	575,874	22,794	83,821	18,244	81,029	111,628	51,393	11,284	43,402	42,575	19,068	1,061,112	

[a]Commercial, industrial, and institutional land.
[b]Includes urban idle land.

Note: Blanks indicate zero quantities.

where:

$\hat{\bar{y}}$ = Estimated average number of points in specified land use per print

$$\frac{1}{n}\sum^{n} M_i p_i$$

N = Total number of prints in counties
n = Number of sampled prints in counties
M_i = Total number of points on ith print
m_i = Number of sampled points on ith print
p_i = Proportion of points in specified land use on ith print based on sample

The coefficient of variation was estimated using the following formula:

$$c.v.\,(\hat{\bar{y}}) = \frac{\sqrt{v(\hat{\bar{y}})}}{\hat{\bar{y}}}$$

Coefficients of variation (c.v.) for the 1967 inventory of the three Illinois counties ranged from 9.7 for cropland, 52 percent of the total area, to 39.2 for water bodies, which comprised 4 percent of total area and were concentrated within a relatively few sample prints (table 2). Some individual components of change would show very high c.v.'s. However, these components have some utility as evidence of a particular direction or shift, if viewed within the entire matrix.

Land Use Categories

The 12 categories selected covered most possibilities of urban and rural land uses:

Cropland. Even tone and texture. On occasion, distinct row patterns visible. Lack of natural vegetation, sharply defined boundaries, and, in some cases, machine tracks leading to the field.

Pasture and range. Up to 30-percent tree crown cover showing unmistakable signs of animal use, such as stock ponds, animal trails, and salt blocks. Usually lacked appearance of recent tillage. Frequently a regular shape with distinct boundaries.

Open idle land. Less than 10-percent crown cover and no evidence of other use. Uneven in texture and tone, often irregular in shape. Vegetation often uneven and shrubby in appearance.

Farmsteads. All farm buildings and farm facilities except farm residence. Included barns, silos, machinery sheds, farm lanes, exercise yards, watering points, and feed lots.

Forest land. Over 10-percent tree crown cover and no other visible uses. Areas of less than 10-percent tree crown cover with evidence of logging.

Residential. Houses and yards associated with them (including farm and rural dwellings), apartment complexes, mobile home sites, and urban residential streets.

Urban idle land. Unused or vacant land surrounded on three sides by urban activity. Construction sites where future use could not be determined. (In table 2, urban idle land was included in "miscellaneous.")

Transportation. Facilities and land areas associated with movement of people and goods. All highways and roads (except streets within residential areas), railroad lines and yards, clearly distinguishable rights-of-way, airports, and docks.

Recreation. Mainly forms of human-made activity associated with resident population. Camp grounds, golf courses, drive-in theatres, race tracks, ski facilities, and public swimming pools.

Commercial, industrial, and institutional. Institutions and land obviously associated with them, such as central business districts and churches, schools, hospitals, cemeteries, and shopping centers that are found in the central business district and other business areas.

Water bodies. Dams, reservoirs, and lakes greater than 40 acres. Streams and rivers wider than 200 feet from bank to bank.

Miscellaneous. Primarily streams or other bodies of water less than 40 acres, drainage ditches, irrigation ditches, and Commodity Credit Corporation storage bins. Used only as a last resort to avoid excessive use of a category which provides minimum information. (In table 2, urban idle land is in the "miscellaneous" category.)

FOCUS ON THREE ILLINOIS COUNTIES

Data on three Illinois counties illustrate the type of information obtained by the analysis (table 2). Dupage, Lake, and Will are typical of the 53 study counties; they are located at the periphery of a Standard Metropolitan Statistical Area (SMSA)—in this case, Chicago. Dupage county's population increased 178,000 from 1960 to 1970—56 percent. Lake county's rose 89,000 and Will's, 58,000—slightly over 30 percent for each. These counties, along with McHenry county, also in the Chicago SMSA, were the only Illinois counties with relative population increases of 30-plus percent and absolute increases of more than 20,000.

Airphoto coverage was available for 1961 and 1967. The sample contained 4,886 points, each representing an average of 217 acres. Table 2 presents a matrix of land use change for the three counties. The lowest row gives an inventory of land use in 1961 by 11 land use categories. The right-hand "total" provides a similar inventory for 1967.

When using the table, read up a column to determine the disposition, by 1967, of the acreage in a given use in 1961. For example, in 1961, the three counties contained an estimated 575,874 acres of cropland. Six years later, 5,362 acres of this land had changed to residential use, 5,327 acres had been developed for commercial, industrial, and institutional uses, and 10,008 acres had been idled. Smaller acreages had shifted to other uses; and 550,876 of the cropland acres in 1961 remained as such.

Read across the rows for the 1961 use of 1967 acreage in a given category. For example, an estimated 119,345 acres were in residential use in 1967. Of this total, 110,794 acres had been in this category in 1961. The new residential acreage came from cropland (5,362), open idle land (2,105) and pasture, forest, and miscellaneous use (small quantities).

Figure 2 shows graphically the shifts among major land use categories.

Conversion Coefficients

Assuming uniform population increases yearly between 1960 and 1970, the three counties gained a total of 195,000 people between 1961 and 1967. Urban acreage rose 20,000. Thus, an estimated 0.10 acre was converted to all urban uses for each unit of increase in population—about 0.04 for residential use and 0.06 for transportation, recreation, and commercial-industrial-institutional uses. In addition, another 0.03 acres per capita was added, on net, to open idle acreage.

Pool of Idle Land

From data for the three Illinois counties, we can identify land shifts from agricultural to urban-type uses. At the beginning of the period, 83,821 acres—a little under 8 percent—was used as open idle land. That is, it had less than 10-percent tree cover and no evidence of pasturage or any other use. By 1967, some of this land had added enough tree cover to be classed as forest, although probably little or no change occurred in actual use. An estimated 4,366 acres had been developed for residential and commercial-industrial-institutional uses, about half for each category by 1967. Also, some previously idle land had been brought under tillage.

In general, much open idle land is probably in transition to urban uses. Of the estimated 20,000 acres converted to urban use, about one-fourth came from open idle land. However, in the urbanization process, some land will likely be idled for long periods, possibly indefinitely, because of its isolation or other disadvantages compared with surrounding land that is being developed.

DATA SOURCES COMPARED WITH OTHER SOURCES

Two procedures were used to evaluate the data-generating technique chosen for the study. First, analysts subjected four counties (Dupage, Ill., Prince Georges, Md., Clay, Mo., and Tarrant, Tex.) to the same sampling and interpretation procedure twice for 1960, resulting in two sets of land use data for the same counties for the same year. The *t*-dependent tests of expanded acreage data were used to check the ability of the sampling procedure to replicate results (table 3).

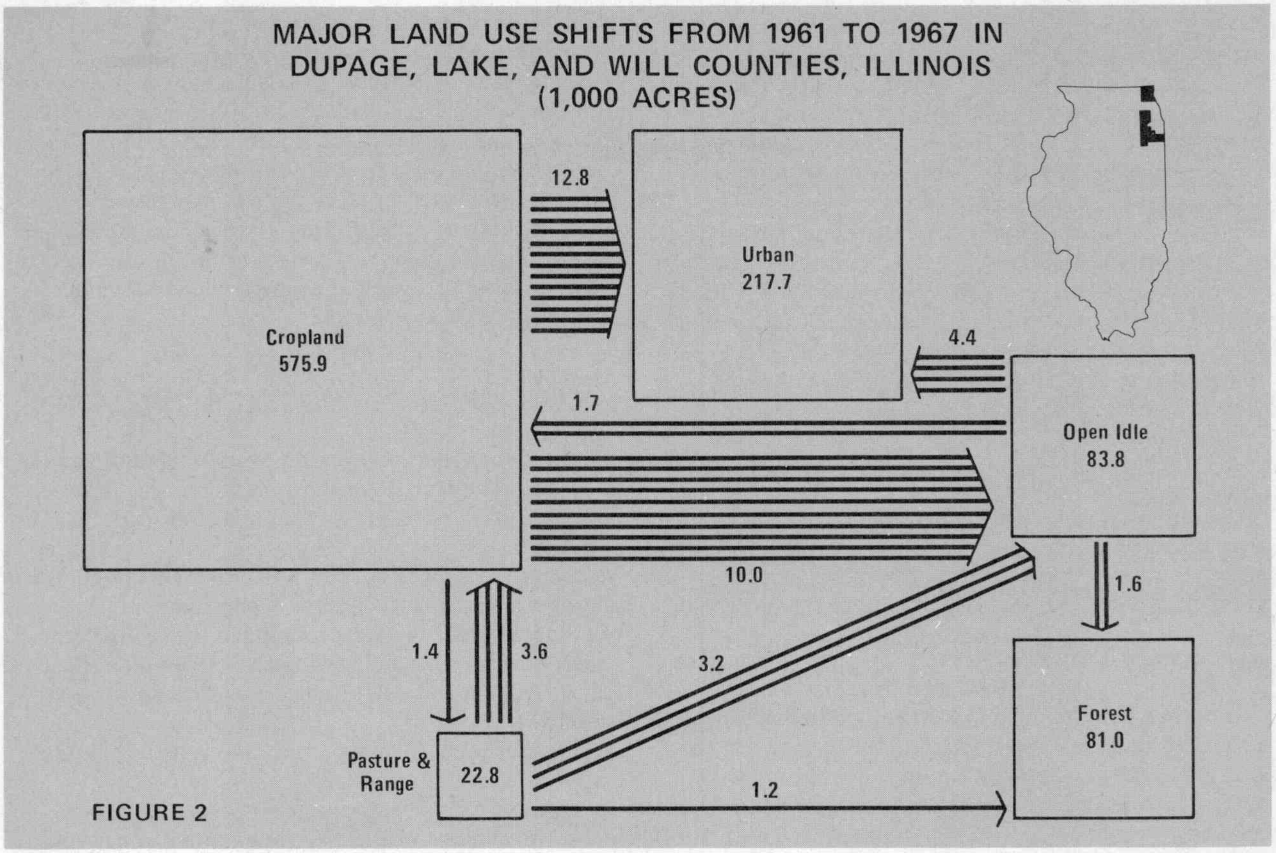


FIGURE 2

Thus, for example, the t-dependent was calculated based upon the cropland data for each of the two samples from each of the four counties. The same procedure was followed for the 11 other land use categories. The hypothesis being tested was that variation in the two inventories resulted from chance alone. In all cases, except for commercial-industrial-institutional use, t was not exceeded; thus, the hypothesis was verified.

Second, using simple regression analysis, analysts compared county land use data obtained from aerial photos in this study with county land use data from other sources. The correspondence was quite high (table 4 and fig. 3). In comparisons for cropland, forest, and water areas, the airphoto data tended to give slightly higher readings for small acreages of the observed variables and slightly lower readings for larger acreages compared with other data sources.

Differences with other sources could be expected because methods of data collection differed and, in some cases, category definitions varied between sources. For example, in the Census of Agriculture, the farmer respondents identify what part of their land is cropland. They may include pasture and idle land that has not been tilled for some years. In airphoto interpretation, identification of cropland hinges on evidence of recent tillage; thus, this method could be expected to be less inclusive than that of the census.

Surface area of many lakes and reservoirs varies both by season and between years; thus, some discrepancies would occur even with the same technique of measurement. Also, water area showed the highest coefficient of variation of any of the uses.

Acreage figures developed for pasture-range and open idle land could not be checked, for two reasons. No comparable data exist from other sources for the open idle land category. Also, significant acreages of land identified as open idle land in the airphoto study were probably included as pasture-range in the census and CNI. Urban areas could also not be compared because no suitable source of data exists.

A valuable feature of a point sample is that the resulting data are site-specific. Though study data were aggregated by county, they could be aggregated by river basin or other *ad hoc* geographic basis with the proviso that number of points be large enough for statistical reliability. Also, data on total land area probably would not be available. This lack could be remedied by measuring the study area on a map. Or the sampling procedure could be designed to give a precise number of points per square mile with a constant acreage value for each point. Simple expansion would become possible for any geographic configuration. The county was used as the unit for the study because most of the data we needed were available only by county. Also we could obtain statistics

Table 3.—Comparison of land use data derived in two separate point samples of four study counties for 1960

Land use	Average proportion of the four-county area	The t-dependent*
Cropland	29.4	2.30
Pasture range	14.9	0.06
Farmstead	1.1	0.84
Open idle	7.5	0.20
Forest	20.4	1.87
Residential	12.8	0.70
Urban idle	19	3.00
Transportation	4.9	0.26
Recreation	.9	1.56
Commercial-industrial-institutional	2.9	3.43
Water bodies over 40 acres	2.8	3.17
Miscellaneous	1.7	1.90

*At the point 0.05 level of significance, t equals 3.182.

on total areas of counties from other sources, so we did not attempt to estimate total area from the sample.

Another value of a point sample: attributes can be associated at a disaggregated level. Census and similar data are usually available by county. In examining land use shifts from this type of data, the analyst can only observe how one use increases as another decreases—for the county as a whole. For example, urban land use may have risen between 2 census years while that for cropland may have fallen. In effect, one must use associations at the aggregate level as a surrogate for associations at the individual level. However, a point sample permits observation at the site-specific level. Thus, the data become more amenable to Markov and similar analytical techniques requiring site-specific data.

Finally, a combination of point sample and airphoto interpretation costs relatively little when photographs obtained through secondary sources can be used. Drawing the sample and acquiring and interpreting photos totaled approximately $500 per county. Though types of data obtained by airphoto interpretation are limited to phenomena observable visually from the air (directly or by inference), they complement and supplement data obtained by other methods.

VALUE OF AIRPHOTO INTERPRETATION

Airphoto interpretation can provide helpful data on land use. The technique serves as a source of data on past uses that could not be obtained elsewhere. In some circumstances, use of a photo print sample can reduce cost and hold loss of precision to a tolerable level. For interpretation of a given print, a point sample serves two functions. First, further cost reduction results because areas with specific uses need not be circumscribed and measured. Second, variables can be associated at a site-specific level.

The resulting land use transition matrix provides three types of information:

- Land use inventories for two points in time
- Breakdown of the disposition in the later year of the acreage in each category for the earlier period
- Prior use of the acreage found in each category in the later period.

Thus, the analyst gains data on the dynamics of land use change which cannot be obtained by comparison of simple inventories of land use for two points in time.

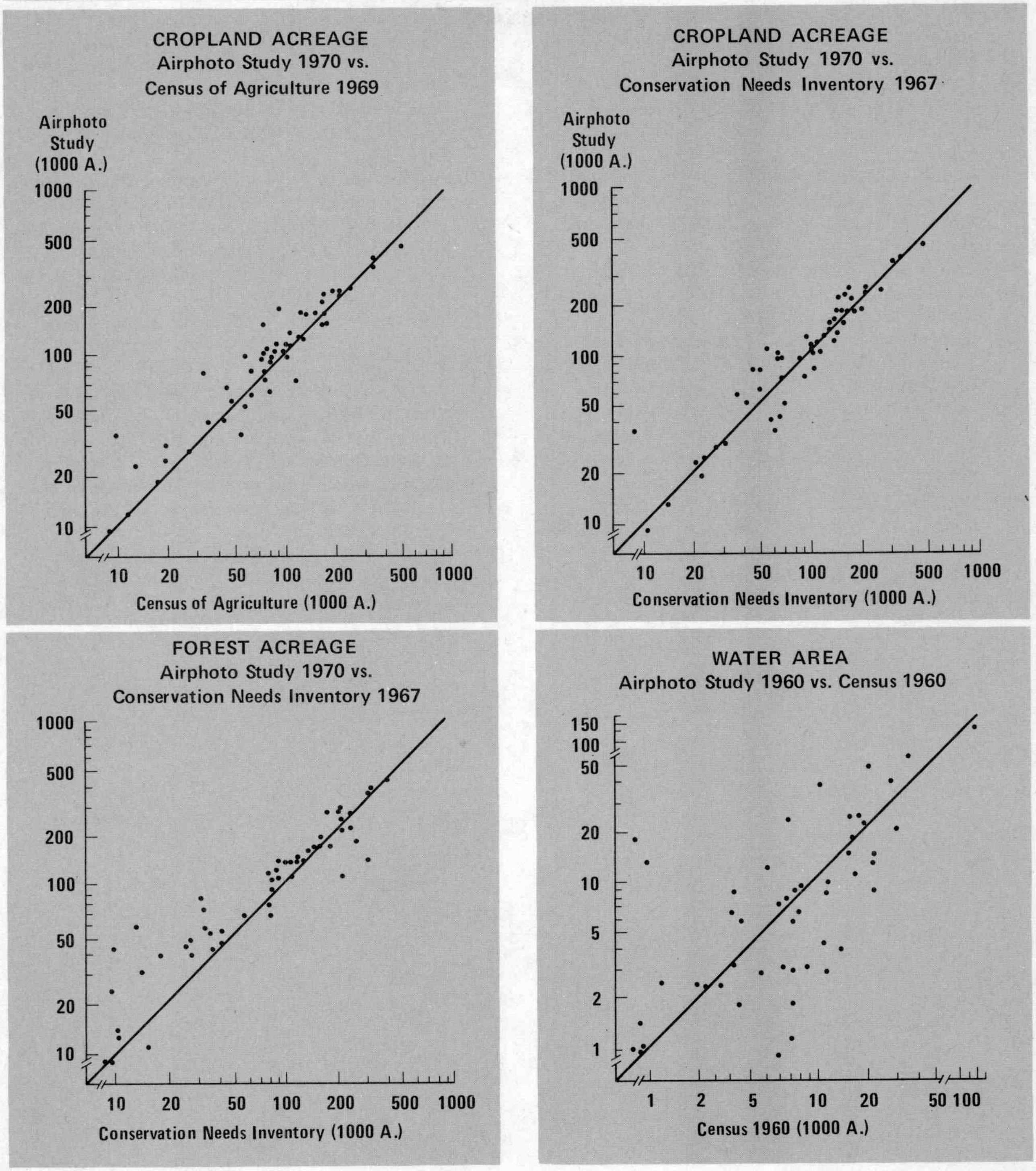
Table 4.—Comparison of current study's land use data with data from other sources

Land use $\frac{X}{Y}$	Cases	Correlation coefficient (r)	Equation	t^a
Cropland-				
Total, Census of Agriculture, 1969[b]				
Current study, 1970	54	0.97	$y = 0.94X + 16{,}000$	28.9
Total, CNI, 1967[c]				
Current study, 1970	52	.96	$y = .96X + 12{,}000$	24.6
Forestland:				
CNI, 1967[c]				
Current study, 1970	53	.94	$y = .86X + 24{,}000$	19.2
Water bodies over 40 acres:				
Area measurement reports, 1960[d]	54	.88	$y = .85X + 1{,}600$	13.3
Current study, 1960				

[a]All significant at the .001 level. [b]1969 Census of Agriculture. County Data Books, table 1. [c]1967 State Conservation Needs Inventories. [d]U.S. Dept. Commerce, Bur. of Census. Area Measurement Reports, by States, 1960.

FIGURE 3

AIRPHOTO DATA COMPARED WITH OTHER SOURCES



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