AGRICULTURE INFORMATION BULLETIN NO. 336

AIRPHOTO USE IN RESOURCE MANAGEMENT

A Survey of Non-Federal Purchasers of Agricultural Stabilization and Conservation Service Airphotos

ECONOMIC RESEARCH SERVICE

U.S. DEPARTMENT OF AGRICULTURE

PREFACE

This survey was intended to determine the nature and extent of non-Federal use of airphotos purchased from the Agricultural Stabilization and Conservation Service (ASCS), U.S. Department of Agriculture. A questionnaire for airphoto purchasers, along with a sample mailing list, was drawn up with the cooperation of Joseph Clifton, Director of the Aerial Photography Division, ASCS, and his staff. The questionnaire, sampling plan, and statistical tests are explained in the appendix.

Results were used as part of a more comprehensive Economic Research Service study to estimate the potential economic benefits to agriculture of remote sensing from orbiting spacecraft. The overall study was done for the National Aeronautics and Space Administration under interagency fund transfer Nos. R-09-038-001 and R-09-038-002 (see Agricultural Information Bulletin No. 328 and Agricultural Handbook No. 344).

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SUMMARY

In fiscal 1966, the Agricultural Stabilization and Conservation Service (ASCS) supplied 471,000 airphotos, or two-fifths of its total airphoto production, to non-Federal customers. Nine-tenths of the orders from that customer group were small, averaging four prints per order. The remaining orders averaged 85 prints per order and accounted for 72 percent of all non-Federal purchases of ASCS prints.

Three customer categories -- business, State and local government, and education and research -- were credited with purchases of 465,000 airphotos. The business share of all ASCS prints purchased in 1966 was 56 percent, with the great majority of business sales from agriculture, mineral, real estate, construction, and utility sectors.

Within agriculture, a large number of small orders were received from farmers, while many sizable requests came from the private forestry industry. Customers in the mineral- and petroleum-oriented industries, particularly in the exploration sectors, frequently bought many prints. Although most orders from the real estate sector were from sales agencies, especially farm, a significant number of requests came from planning and development firms. Orders from the construction industry varied from a few photos for local projects to many prints covering extensive areas for highway construction projects. Using airphotos primarily for planning local distribution and long-line routes, utility companies generally placed few but very large orders.

State and local government units, placing relatively large orders, accounted for only 13 percent of the non-Federal orders but for 173,900 prints, or 37 percent of the total. Most State orders were from forestry, conservation, highway, engineering, natural resource (minerals and petroleum), and planning and development agencies. At the county level, orders were mainly from taxation, highway and engineering, and conservation offices. City orders were usually placed by planning and development, taxation, street maintenance, and utility agencies, while village and town orders were mainly for property tax work.

Most education-research customers were employed by institutions of higher learning, though some worked for foundations, institutes, and private research organizations. As a group, with 4 percent of the orders, education and research customers purchased 29,000 ASCS airphotos -- 6 percent of the non-Federal total.

Scaled 3.2 inches per mile, contact prints accounted for two-thirds of all prints ordered; they were favored in business for forest management, utility rights-of-way projects, and mineral exploration. State and local governments preferred such prints for public land management and for use in land record and tax problems. Most orders for education and research work were contact prints because of the need for stereo viewing. Enlargements (up to 13.2 inches

per mile) were favored by the real estate industry for development and sales purposes, by agriculture for field measurement and recordkeeping purposes, and by State and local governments for planning and development projects. Most of the photo index sheets (1 inch per mile) were ordered by businesses with rights-of-way or geologic exploration projects and by education and research agencies desiring broad coverage to reveal extensive landforms or other features. Only 4 percent of all orders were for the synoptic coverage supplied by the photo index sheets, compared with 66 percent for the contacts and 30 percent for the enlargements.

As another indication of the degree of interpretability desired, 69 percent of the customers surveyed said that observable detail was adequate, 29 percent that larger detail with less coverage was preferred, and only 2 percent that more synoptic imagery (smaller detail with greater coverage) was preferred.

The ASCS maintains airphoto coverage of 80 percent of the Nation's land area and offers prints on order at approximate cost. ASCS photography ranges up to 8 years of age and has an average age of 3 or more years. Most customers preferred more recent coverage for their purposes, with 39 percent reporting that such coverage would be "much more" valuable. Among those reporting were foresters, utility people, State highway personnel, real estate development and sales people, appraisers, planners, market researchers, engineers, and mapmakers.

Of the total prints purchased by ASCS customers in fiscal 1966, almost two-thirds were ordered from the ASCS, about a fourth from private contractors, and about a tenth from other Federal agencies. As reasons for ordering from other sources, a third of the ASCS customers reported that they wanted more recent coverage, a fourth that coverage was not available from ASCS, and a fourth that they needed a different (mostly smaller) "ground resolution." The remaining 16 percent indicated they needed airphotos immediately, at an oblique angle, in color, in infrared, at a different season such as when vegetation is defoliated, or with snow cover.

Customers who buy all of their airphotos from sources other than the ASCS were excluded from this report. Only those customers who purchased some or all of their airphotos from the ASCS were surveyed.

AIRPHOTO USE IN RESOURCE MANAGEMENT: A Survey of Non-Federal Purchasers of Agricultural Stabilization and Conservation Service Airphotos

by

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INTRODUCTION

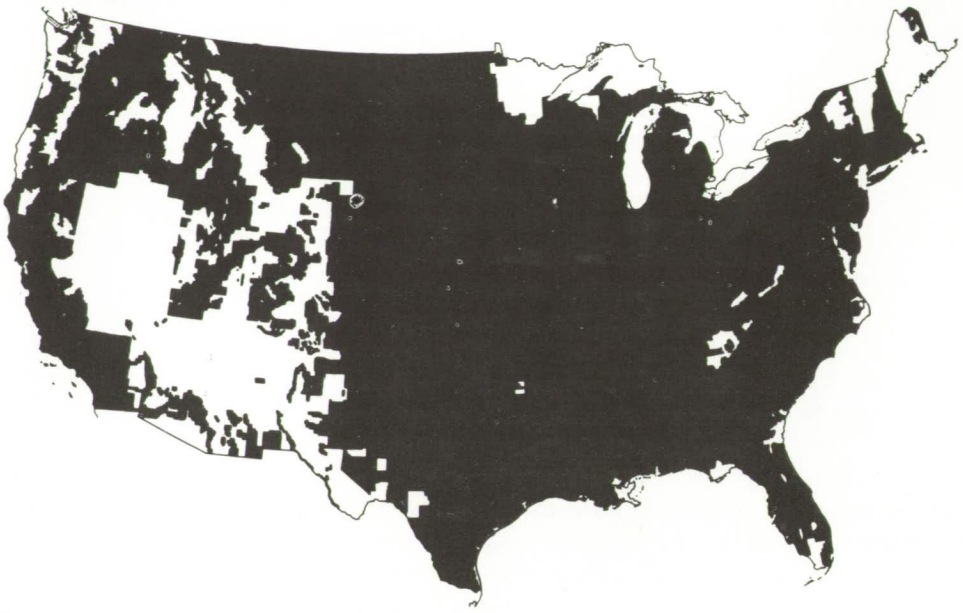
Aerial photographs acquired and used by the Department of Agriculture to administer farm programs are widely used by other government agencies and the public for various purposes. The Agricultural Stabilization and Conservation Service (ASCS) of the Department maintains airphoto coverage of practically all U.S. cropland (figure 1). In fiscal 1966, the ASCS produced nearly 1,157,000 photoprints and distributed 46 percent of them to other Federal agencies, 40 percent to non-Federal customers, and the remainder to ASCS offices.

Use of airphotos has increased greatly in recent years, yet little is known about the nature and extent of utilization. Consider the value of this information to potential users as well as to suppliers who want to know the types of potential users and the characteristics of imagery most desired. Consider also that the development of remote sensing programs, including sensing from satellite altitudes, will be influenced by existing imagery -- its uses and the demands on it -- and by technology now in the experimental or conceptual stage. Because most airphotos acquired by non-Federal users are supplied by the Agricultural Stabilization and Conservation Service, a sample survey of its customers in fiscal 1966 was conducted to determine their airphoto use.

Although some non-Federal customers buy photos exclusively from other sources, only those customers who purchased some or all of their photos from the Stabilization and Conservation Service are included in this report. The sample mailing list was drawn from a file of 40,141 orders that were divided into two groups: one for fewer than 15 prints, the other for 15 or more prints (table 1). The sample response covered 56 percent of all prints sold -- 76 percent of those in the large order group and 15 percent of those in the small order group. The sampling procedure is discussed in more detail in the appendix.

What follows is a presentation of the nature and extent of non-Federal uses of ASCS airphotos by number and size of photos ordered and by type of

AIRPHOTO COVERAGE, AGRICULTURAL STABILIZATION AND CONSERVATION SERVICE



Areas with ASCS coverage

U.S. Department of Agriculture

Figure 1

Table 1.--Airphoto sales to non-Federal customers by the Agricultural Stabilization and Conservation Service, 1966 1/

Class	Year ended June 30		
	Orders	Prints	Prints per order
	Number	Number	Number
Small orders (1-14 prints).....	36,184	133,390	4
Large orders (15 or more prints)..	3,957	337,594	85
Total orders.....	40,141	470,984	12

1/ Non-Federal customers include businesses, State and local government units, professionals, educators, and personal users.

Table 2.--Airphoto orders filled by the Agricultural Stabilization and Conservation Service, by type of non-Federal customer, 1966

Type of customer	Orders for year ended June 30	
	Number	Percent
Business	29,034	73
Government (State and local)	5,232	13
Education and research	1,790	4
Personal	3,534	9
All other	551	1
Total	40,141	100

customer. Also included are sections on customer opinions of phototone, photoresolution, and imagery age, on the number of airphotos acquired from other sources, and on why ASCS photography was not used.

TYPES OF NON-FEDERAL CUSTOMERS

In fiscal 1966, non-Federal customers purchased 470,984 photoprints, or 40 percent of ASCS output that year. Most orders, almost three-fourths, were from business users (table 2). Then came non-Federal government units with 5,232 orders or about an eighth of the total; big users in this category were State conservation, forestry, and highway departments and county assessment and planning units. Education-research agencies and institutions accounted for 1,790 orders, 4 percent of the total, and personal use for 3,534 orders, 9 percent of the total. A few orders were received from local conservation societies, boys' clubs, and related organizations.

Business

Five types of concerns -- agriculture, minerals, real estate, construction, and utilities -- placed 83 percent of the 29,034 business orders (table 3).

Agriculture.--Farming and ranching accounted for 40 percent of the total business orders, though many orders were for only one or two prints. Most farmers know about the usefulness and availability of ASCS airphotos through the local administration of farm programs. The 2,279 orders from the private forest industry, many of which were very large, formed 8 percent of the total. (Large numbers of airphotos are also used by Federal, State, and local government units for forest management).

Minerals.--Some 2,200 orders -- 8 percent of the business total -- came from petroleum- and mineral-oriented industries. In this group, most requests were from oil and gas industries, particularly from exploration sectors, and

Table 3.--Business uses of Agricultural Stabilization and Conservation Service airphotos, 1966

Type of business	Orders for year ended June 30	Type of business	Orders for year ended June 30
	Number		Number
Aerial survey	11	Real estate (cont.)	
Agriculture:		Real estate sales	3,552
Crop dusting	217	Recreation	364
Farming and ranching	11,726	Utility:	
Forestry and forest products	2,279	Electric	196
Construction:		Gas	41
Engineering and architecture	2,682	Multiple	42
Other	15	Pipeline	76
Land-use planning (city, regional)	311	Railroad	47
Map service	238	Telephone	30
Minerals:		Other:	
Aggregate (sand and gravel)	94	Attorneys	1,300
Coal	21	Banks, insurance companies	403
Drilling contractor	6	Chambers of commerce, civic organizations	254
Geologic consultant	187	Land management consultants	9
Geologic exploration	858	Manufacturing plants	402
Mining	182	Real estate appraisal	544
Petroleum and gas production	772	Retail merchant	20
Photogeology	73	Surveying	506
Photogrammetry and photointerpretation	21	Tax appraisal surveys	14
Real estate:		Traffic consultant	6
Housing development	552	Miscellaneous	825
Industrial development	158	Total orders	29,034

many were large orders for extensive airphoto coverage. A sizable number of orders (297) were also received from mining and aggregate (sand and gravel) concerns.

Real estate.--Over three-fourths of the orders were from sales agencies, but a considerable number came from housing and industrial development groups. Land-use planners accounted for about 1 percent of the total business orders and real estate in total (planning, development, and sales) for 16 percent. Most of these orders were relatively small, often covering only a single tract or farm.

Construction.--The construction industry, including architecture and engineering, accounted for 9 percent of the total orders. Types of businesses ranged from those engaged in local projects requiring only a few photoprints to highway construction firms requiring extensive coverage. Businesses related to real estate and construction, such as surveying, appraising, and loan departments of banks and insurance companies, each accounted for about 1 percent of airphoto orders by business organizations.

Utility companies placed relatively few orders (2 percent) but they were generally for many prints. Almost half of the utility subgroups were electric utilities; the remainder comprised gas, telephone, railroad, and pipeline companies.

All other.--Placing 1,300 small orders, attorneys usually requested coverage of specific local situations. Other important business customers included chambers of commerce, civic organizations, and manufacturing plants. Very few orders came from map service people, retail merchants, traffic consultants, private aerial surveyors, professional photogrammetrists, or independent photointerpreters.

Government

Government units, other than Federal, placed 5,232 orders for airphotos, many for thousands of prints (table 4). State governments accounted for 41 percent of the governmental total; city and county governments, for 23 percent each; villages or towns, 7 percent; and other units, 6 percent.

In general, airphoto use is indicated by the name of the ordering agency or department, although photos are frequently made available later to other agencies with different purposes. A tabulation of orders by State departments shows that conservation and forestry were the leading groups, with over a third of the orders. Customers in these groups found airphotos particularly useful in managing extensive areas that are poorly mapped and that have difficult access. Next in importance were the highway and engineering groups with a fifth of the State orders. Airphotos sold to these customer groups are used (1) to provide the synoptic imagery needed to consider alternative routes for new highways, (2) to plan land acquisition and develop construction plans for those highways, and (3) to aid current maintenance programs. The mineral and petroleum groups accounted for only 9 percent of the orders, but they were the leading groups in those regions where the extractive industries are concentrated. State-sponsored

Table 4.--Government 1/ purchasers of Agricultural Stabilization and Conservation Service airphotos, by purchasing department or office, 1966

Unit	Orders for year ended June 30
	Number
STATE	
Agriculture, farm	282
Conservation and forestry:	
Conservation	179
Forestry	222
Water	60
Wildlife (recreation)	300
Highways and engineering:	
Engineer	118
Highway	302
Surveyor	7
Minerals, oil, and gas:	
Geologic and mining	132
Natural resources	62
Planning and development:	
Development	72
Planning	75
Other:	
Public service	8
Tax	6
Transportation	54
Well permits	54
Not identified	220
Total	2,153
COUNTY	
Agriculture	58
Conservation:	
Conservation	54
Drainage	57
Flood control	5
Park	54
Planning and park	9
Highway and engineering:	
Engineer	66
Highways	18
Surveyor	84
Planning and development	68
Taxation:	
Assessor	330
Auditor	6
General	61
Map (tax)	118
Other:	
Civil defense	7
Fire	15
Well permits	42
Not identified	130
Total	1,182
CITY	
Planning and development:	
Industrial development	64
Planning	240
Urban renewal	52
Zoning	59
Streets and utilities:	
Engineer	65
Parks	6
Public works	10
Sewer and water	62
Streets	56
Taxation:	
General	180
Assessor	120
Other:	
Attorney	5
Board of education	61
Civil defense	4
Farm	54
Fire	18
Mosquito control	20
Not identified	135
Total	1,211
VILLAGE OR TOWN	
Assessor	126
Engineer	55
General	84
Planning	19
Other	63
Total	347
OTHER UNITS	
Flood control	6
Metropolitan	67
Regional planning	18
River regulation	5
School districts	63
Other	180
Total	339
Total, all orders	5,232

1/ Non-Federal government units (State and local).

planning and development, which have had increasing emphasis lately, accounted for 7 percent of all State orders.

Airphoto use in property tax administration was indicated as the most common use at the county level. Airphotos not only provide accurate base maps to determine boundaries and account for all land but also help indicate relative values for assessment. Next in importance at the county level were the highway-engineering and conservation groups, which include drainage, park planning, and flood control functions. Other significant county groups were agriculture and planning and development.

At the city level, planning and development -- including urban renewal and zoning -- led with a third of all orders, followed by taxation-related responsibilities with 25 percent of the orders. Street and utility management ranked next, ahead of such special uses as fire control, education, and civil defense.

At the village-town level, orders were placed in less specialized names so that the range of uses is not so apparent. A major use is clearly property taxation; additional uses appear to involve road work, utility management, and planning projects. Other units of government placing orders included school districts, metropolitan districts, and regional planning organizations.

ORDER CHARACTERISTICS

Number of Orders by Type of Customer

Of the ASCS prints sold in fiscal 1966 to non-Federal customers, private business purchased 262,300 or 56 percent of the total (table 5). The number of orders by business was 73 percent of the total but the average order was small, so that the total number of prints bought formed a lesser proportion.

Non-Federal government units, particularly State and county agencies, accounted for only 13 percent of the total orders, but acquired 173,900 prints or 37 percent of all non-Federal sales. Some orders in the government category were quite large to obtain coverage for broad areas such as State forests or entire counties.

Education-research customers worked mainly for institutions of higher learning though some were employed by foundations, institutes, and private research organizations. As a category, with 4 percent of the orders, they accounted for 29,000 airphotos -- 6 percent of ASCS's non-Federal sales.

Acquisition for personal use accounted for 9 percent of the orders but only 1 percent (5,100) of all prints sold to non-Federal purchasers in fiscal 1966. Some of these probably were used in private or individual business.

Customers in the "all other" category, including civic-oriented organizations, bought relatively few prints during the year.

Table 5.--Number of airphoto prints ordered from the Agricultural Stabilization and Conservation Service, by type of non-Federal customer, 1966

Type of customer	Prints acquired in year ended June 30	
	Thousands	Percent
Business	262.3	55.8
Government (State and local)	173.9	37.0
Education and research	29.0	6.1
Personal	5.1	1.0
Other	.7	.1
Total	471.0	100.0

Print Size by Type of Customer

The Agricultural Stabilization and Conservation Service produces airphoto prints ranging from 10-inch-square contact prints up to 40-inch-square enlargements plus photo index sheets. Virtually all ASCS photography conforms to the same specifications. It is taken to yield a negative scaled 1:20,000 with tilt not to exceed 4°. Exposures are made through a haze filter on 9- by 9-inch panchromatic film which is overlapped to provide for stereoscopic viewing. A 65-percent forward endlap and 30-percent sidelap are specified. Flying for ASCS photography in the United States is divided into three categories -- summer only, winter, and year round -- and, for ASCS purposes, must be accomplished with ground free of snow, sun at high angle, and the day cloud-free. Resolution on the 9-inch-square film is about 20 lines per millimeter. New photoflights periodically update the coverage, depending on how much ground change occurs in both natural and cultural features. Ordinarily, an area is reflown each 5-8 year period, so that, as of a given date, the age of film used to make prints ranges from quite recent to 6 or 7 years old, but is sometimes older.

Contact prints are a positive reproduction of film imagery. Measuring 10 inches square and scaled 3.2 inches per mile, they cover an area of about 10 square miles. Considerable detail is easily discernible -- landforms, land use, and major types of landcover and roads -- particularly with the aid of magnification. Fairly accurate measurements are possible; for example, a side of a square 40-acre field would measure 0.79 inch. Items as small as a house or barn, however, measure about 0.03 inch across, making measurement and even specific identification more difficult.

Measurement and interpretation by the unaided eye are helped by using a photoprint enlargement of the basic film imagery. Enlargements range from 14 inches square (4 inches per mile) to 40 inches square (13.2 inches per mile). Clarity decreases with enlargement but, for most purposes, is adequate. On a 40- by 40-inch enlargement, a typical house measures almost an eighth inch long.

Table 6.--Sizes of photoprints available from the Agricultural Stabilization and Conservation Service, 1966

Type of photoprint	Size of print	Scale			Cost per print ordered (maximum)
		Ratio	Feet per inch	Inches per mile	
	Inches		Feet	Inches	Dollars
Contact	10 x 10	1-20,000	1,667	3.2	1.00
Enlargements	14 x 14	1-15,840	1,320	4.0	2.30
	18 x 18	1-12,000	1,000	5.2	2.50
	26 x 26	1-7,920	660	8.0	3.00
	40 x 40	1-4,800	400	13.2	7.00
Sectional, left or right	26 x 26	1-3,960	330	16.0	3.00
Photo index	20 x 24	1-63,360	5,280	1.0	2.00

Table 7.--Size of photoprints ordered from the Agricultural Stabilization and Conservation Service, by type of customer, 1966 1/

Size of print ordered in inches 2/	Type of customer, year ended June 30					All
	Business	State and local government	Education, research	Personal	Other	
	Percent					
10 x 10, contact	54	75	84	33	63	66
14 x 14, 18 x 18	15	11	4	3	0	12
26 x 26	20	9	3	52	25	14
40 x 40	6	3	3	10	10	4
Photo index	5	2	6	2	2	4
Total prints	100	100	100	100	100	100

1/ Frequency distributions, based on number of reports, are statistically different at the 99-percent confidence level.

2/ See table 6 for airphoto print specifications.

Examples of portions of ASCS airphotos listed in table 6. Top of photo is turned southward so shadows will face viewer as a perception aid. Arrows point to the same location in each of these 1967 photos of Polk County, Iowa.

Figure 2.--Photo index sheet, scale of 1" per mile

Figure 3.--Contact print, scale of 3.2" per mile

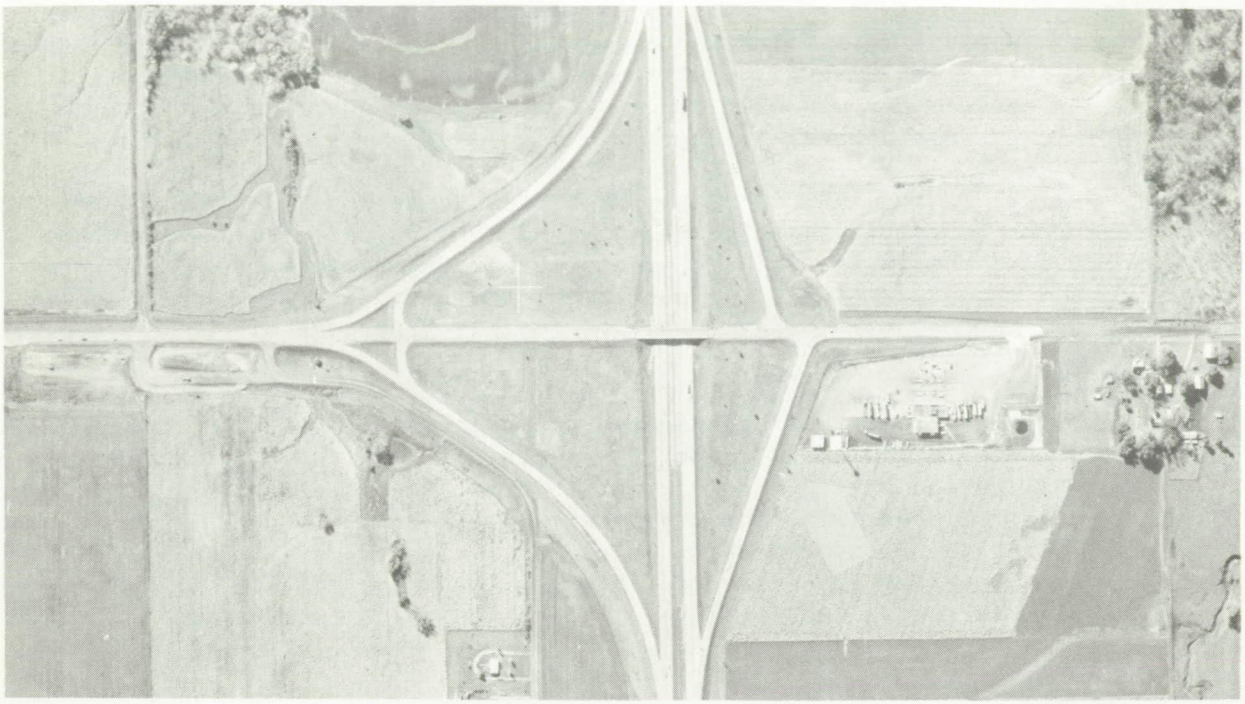


Figure 4.--Photo enlargement, scale of 8" per mile

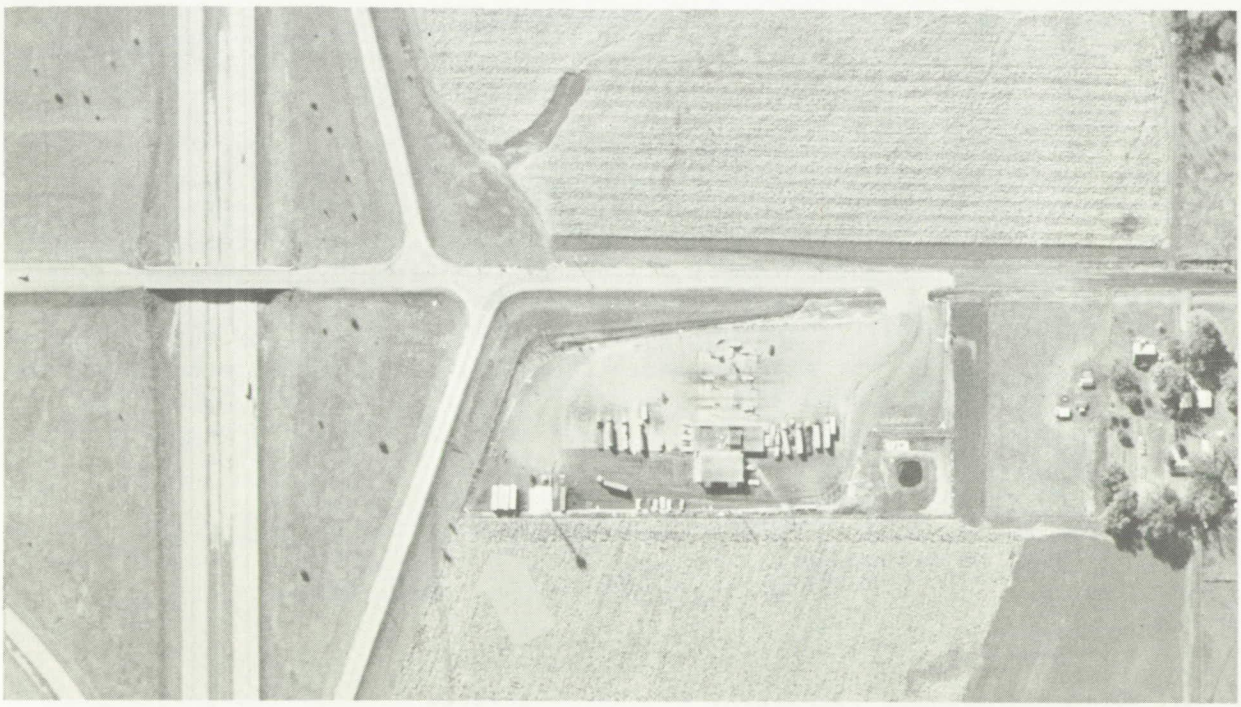


Figure 5.--Sectional enlargement, scale of 16" per mile

Photo index sheets (average of four sheets per county) are a rough mosaic of contact prints, and cover an area of roughly 16 by 20 miles or 320 square miles maximum on 20- by 24-inch sheets. After prints for an area are laid out, overlapped, and matched, this layout is photographed to the scale of about 1 inch per mile. Each print has an index number so that, by looking at a photo index print, one can identify the individual prints as desired. Photo index sheets, or photo mosaics, are also used for photointerpretation when broad synoptic coverage is desired for studying major landforms, for geologic exploration, or for preliminary consideration of possible rights-of-way.

Two-thirds of the 471,000 ASCS prints ordered by non-Federal customers were contacts, by far the most common size purchased (table 7). Popular enlargements were the 26-inch-square print (14 percent of total sold) and the sizes 14 and 18 inches square (12 percent of the total). The 40-inch-square enlargement and the photo index each came to only 4 percent of the non-Federal sales.

The business category of customers showed interest in a broad range of sizes, reflecting their varied needs. Contact prints were favored by the forest industry, the utility industry with its major interest in "rights-of-way," and the mineral industry, especially for use in geologic exploration. The real estate industry, for development and sales uses, and agriculture, for field measurement and recordkeeping uses, favored enlargements. Overall, 54 percent of the business purchases were contacts, 41 percent were enlargements, and the remainder (5 percent 1/) were photo index sheets.

State and local governmental units were interested mostly in contact prints for public land management (particularly forest) and for land records and tax problems. Contacts accounted for 75 percent of governmental purchases, reflecting the need for only moderate detail. An appreciable number of enlargements, however, were ordered by urban developers and planners. Relatively few photo index sheets were acquired by governmental users.

For education and research work, contact prints were by far the most popular. Professional photogrammetrists and photointerpreters, many of whom are found in this category, purchase these prints primarily for stereo viewing. Larger scale, if desired, can be achieved by using various professional equipment, though stereo viewing itself gives some magnification. In some research work (such as geology or archeology), broad coverage was desired to reveal extensive landforms or other features that are sometimes more obvious on the contact print than on the enlargement. These extensive features may be more evident on photo index sheets where the scale is a mile to the inch. Six percent of the prints ordered by the groups in this category were photo index sheets. 2/

In the personal-use category, most orders were for enlargements, which provide the great detail needed for a local area such as a home, camp, or farm. Contacts accounted for a third of these orders, but some customers indicated that

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1/ Range is 4.5 to 5.5 percent at the 95-percent probability level.

2/ Range is 5.2 to 6.8 percent at the 95-percent probability level.

this size was ordered because the price was lower or because greater detail was expected.

The "other" customer category, which included such benevolent or civic-oriented organizations as boys' clubs or conservation societies, accounted for relatively few purchases.

AIRPHOTO USES

Table 8 shows, by type of user category, the percentage of customers reporting each general use listed. There is an overlapping of uses since a customer reporting "mapmaking" might also report "land-use inventory." The overall average was more than two uses per customer, with most customers giving more than one use.

One-third of the non-Federal purchasers of ASCS airphotos in fiscal 1966 reported mapmaking as a use. This appears to include not only those who actually made maps but also those who used the photos themselves as maps. Types of maps produced for publication included highway, city street, tax plot, topographical, and landcover. To help determine soil boundaries, some customers made detailed soil maps by combining field sampling of soils with stereo interpretation of airphotos. Special-purpose maps were produced, for instance, by foresters to show temporary access routes for logging operations, by construction people for various large-scale planning and construction contracts, and by professional planners for zoning. Among those using photos as maps were farmers, foresters, prospectors, hunters, and fishermen. Mapmaking as a use was reported by more than 40 percent of the government and education-research customers and by 32 percent of the business customers.

About an eighth of the purchasers claimed uses involving geologic exploration. Many of them ordered many prints, so that the proportion of prints used for that purpose was much greater than 12 percent. Sizable orders were placed not only by the large extractive corporations (oil, gas, and mineral) but also by professional consultants serving these corporations. These groups, requiring synoptic coverage to interpret extensive landforms, preferred contact prints and aerial mosaics. More than a fourth of the customers in the education-research category listed geologic exploration as a use. Colleges and universities with extensive geology programs formed over half of that customer category. To research the possible location of merchantable minerals was one specific interest in the broad field of geology. Government units surveyed showed an appreciable incidence of this use (8 percent), with an increasing concern to promote industrial development through departments of natural resources.

Forest survey as a use was reported by 16 percent of all customers. Among business and government groups, this interest reflected the problems of managing extensive forests. Government users included State, county, and local units concerned not only with public forest management but also with conservation. Business users included paper and lumber companies and farmers as well as realtors. Aspects of forest management aided by airphoto use included disease control and cutting plans, mensuration (volume determination) for purchase or sale of timber, and access road mapping.

Table 8.--Agricultural Stabilization and Conservation Service airphotos: Percentage distribution of uses reported by non-Federal customers in 1966, by customer category 1/

Use reported, year ended June 30	Type of customer					All types
	Business	Government, State and local	Education or research	Personal	Other	
	Percent of customers					
Mapmaking	32	45	42	16	10	32
Geologic exploration	13	8	27	5	-	12
Forest survey	17	19	10	12	-	16
Land-use inventory	38	40	38	26	30	37
Soil survey	13	12	21	1	-	12
Urban or rural planning	19	33	17	1	10	20
Right-of-way planning	17	28	1	1	-	16
Assessment or census	1	20	1	-	-	4
Farm management	48	12	9	4	-	36
Write-in categories:						
Customer exhibit	7	-	-	-	-	5
Map use	10	5	1	2	-	8
Appraisal	5	1	1	1	-	4
Market research	4	-	1	-	-	3
Legal use	5	1	-	-	-	4
Industrial or commercial planning	4	4	-	-	-	3
Other	2/	3/ 33	4/ 60	5/ 57	6/ 90	14
Number of customers	29,034	5,232	1,790	3,534	551	40,141

1/ Does not add to 100; most customers reported more than one use. (See text.)
2/ Less than 0.5.
3/ Various government plans and programs.
4/ Teaching and research projects in various fields.
5/ Various types of recreation.
6/ Includes benevolent organizations.

Customer development of land-use inventories required the highest proportion of airphoto use -- 37 percent. Such inventories ranged from the simple classification of land as wooded or not wooded for use by hunters to quite detailed classifications for land planners, zoners, and tax assessors. Almost all types of ASCS customers, discussed earlier in detail, reported various land-use inventory interpretations requiring airphotos, along with a wide range of specific projects.

Airphoto use in soil surveys was reported by 12 percent of all customers. That the soil surveys were for various purposes is indicated by the types of users which included engineers, contractors, farmers, realtors, foresters, investors, and a wide variety of professions in education and research. Airphoto use in soil surveys is largely interpretation by inference, while surveys in other fields study objects fully or partly visible in airphotos. Conventional soil surveys study soil characteristics to a depth of 3 to 6 feet or more. Soils, however, can be interpreted from airphotos by studying the patterns created by the parent rock, the mode of deposition, and the climatic, biotic, and physiographic environment, extrapolating from a minimum of data obtained on the ground. Since similar soils appear in similar patterns, photographic characteristics can be correlated with soil properties observed in field and laboratory. 3/

Engineers and construction people were interested in soil characteristics that determine load-carrying capacity, angle of repose, and type of earth-moving equipment needed. Other cases involve locating deposits of construction gravel. For agriculture, soil surveys range from the very general to highly detailed maps showing boundaries of soil types in great detail. For the latter, most data are obtained on the ground and the photo is used primarily as a map. Often, however, it appears that reports of soil survey use involved the development of broad soil classes for specific purposes. It is probable that some farmers, realtors, and appraisers reporting this use made only general soil judgments based on topography and type of landcover. ASCS airphotos were used mostly for soil survey projects by the education and research customer category; a fifth reported this use, compared with only an eighth in the business and government categories.

Urban and rural planning as a use, reported by a fifth of all customers, was important to consulting planners and engineers, civic organizers, architects, surveyors, realtors, utility people, railmen, and bankers. Government customers included a wide variety at all levels in such fields as planning and development, water resources and conservation, regional planning, urban renewal, zoning, or parks. A third of the customers in the government category reported urban and rural planning uses, compared with less than a fifth in the business and education and research categories.

Right-of-way planning as a use was reported by 16 percent of all respondents. Practically all of them were either in the business category involved in pipe-, power-, or telephone-line projects, or in the governmental unit category engaged in highway, water, or sewerline projects.

3/ Manual of Photographic Interpretation, American Society of Photogrammetry, Washington, D.C., 1960, p. 343.

Airphotos are used for planning new highway routes or alterations in old highways. Preliminary work involves the consideration of alternative routes to determine the best road for the money. Possible routes are interpreted from the synoptic coverage of the photo mosaics, considering terrain, built-up areas, and existing roads. The contact prints are then used in stereo for more detailed feasibility analysis. Some of the factors analyzed are amount of clearing, landslide susceptibility, carrying capacity of soil, and location of sub-base aggregate. Besides these construction cost factors, the route impact in terms of service or disruption, or both, can be considered by observing property lines, field configurations, and characteristics of built-up areas. Airphotos are also used to plot and present final findings of field explorations.

A similar procedure is followed when airphotos are used in right-of-way planning for powerline and pipeline projects, but the specific cost factors vary. Grade is less of a problem so more emphasis is put on the most direct route. For powerlines, important considerations which can be interpreted to some degree from airphotos include amount of clearing required, cost of right-of-way as indicated by type of land use, accessibility for maintenance, danger of lightning, and soundness of soil for adequate tower support. For urban pipelines, sewer and water, enlargements are often used to plan detailed lay-outs, considering both prospective developments and current needs. For long pipelines, however, the same general procedure applies as that for highways. It is important to avoid bedrock, boulders, and corrosive soils. Concern with land use is less than with most construction because pipeline installations usually do not conflict with land uses.

Assessment or census projects aided by airphoto use were reported by only 4 percent of all customers. Most such use occurred within the government groups, which reported an incidence of 20 percent. Less important users were professional appraisers, valuation engineers, and attorneys. For taxation, photos are used not only to help determine valuation, but also to check whether all land is entered on the tax rolls. The latter is particularly useful in extensive rural forest and range areas. For censuses, photos are used to map field visits or to count specific items such as structures.

More than a third of all customers, and almost half of the business category, reported using airphotos in farm management. Besides farmers themselves, users in farm-related activities were attorneys, bankers, railmen, agricultural suppliers, and government people responsible for public farms, particularly county old-age or correctional institution farms. Farm uses included acreage measurement, field recordkeeping (by entering data directly on enlarged photos), and land planning (reclamation, irrigation, and drainage). Agricultural suppliers used photos to spot fields for direct application of seeds, fertilizer, pesticides, and herbicides by truck or air.

There were various "write-in" categories of use cited frequently, but these were somewhat specialized and tended to overlap with the above uses. Among business customers, 7 percent used enlargements as exhibits on which to show various development plans or to show customers a view of land, especially rural land, for sale. Use as a map (reported by 8 percent) was common in unmapped or roadless areas. Businesses using airphotos as maps included particularly mineral, forestry, or recreation concerns. Appraisal use, reported by 5 percent of the business customers, occurred among realtors, professional

appraisers, and the loaning personnel of banks and insurance companies. Four percent of the business-customer category listed market research, often to determine locations for such outlets as oil stations, branch banks, and supermarkets. Utility companies also reported market research on which to base expansion plans for telephone, gas, or electricity distribution.

Airphotos were used as legal evidence by both business and government, mainly in boundary line disputes. Other cases involved flood damage or zoning disputes. In some instances, old airphotos served as evidence of historic land use. Some 4 percent of both business and government purchasers indicated general use for developing industrial and commercial plans. Many of these customers were large corporations concerned with the location of both plants and retail outlets. Governmental customers particularly included those State and local agencies working with industry to promote industrial and commercial development.

Other airphoto uses in education or research were various projects in the physical, biological, and social sciences, and most other disciplines. Much use, of course, occurred in the fields of photogrammetry and photointerpretation. Many of the research and teaching applications covered all previously discussed uses in various degrees. Some uses not previously discussed were studies of village structure, ancient locations, historical patterns of cultural development, social structure, and population distribution, as well as delineation of sample survey segments. These examples give only a general idea of the use of airphotos in teaching and research. A 1966 survey at Cornell University listed 296 different general research areas in 39 different departments or organizational units. 4/

CUSTOMER OPINIONS OF AIRPHOTOS

Tone

Tone of ASCS photoprints purchased in fiscal 1966 was considered acceptable by 95 percent of the customers (table 9). It is important in black and white photography because, lacking distinguishing color differences, interpretation must be based on shades of gray. Tone is a function of the weather, the angle of light on an object, and the amount of light reflected by an object (which is not always proportional to its degree of darkness). It is also affected by the processing of the negative and print. Overall, only 4 percent 5/ of the customers felt that the tone was too light; however, among the education and research category, where interpretation problems are sometimes more detailed and difficult, 12 percent 6/ thought that the tone was too light. A few customers, 1 percent of the total, reported tone as too dark. 7/

4/ Uses of Air Photo Interpretation in the Social, Biological, and Physical Sciences. Center for Aerial Photographic Studies, Cornell University, 1966. (Mimeo.)

5/ Range is 3 to 5 percent at the 95-percent probability level.

6/ Range is 6 to 18 percent at the 95-percent probability level.

7/ Range is 0.4 to 1.6 percent at the 95-percent probability level.

Table 9.--Agricultural Stabilization and Conservation airphotos in 1966: Non-Federal customer opinion of tone 1/

Opinion of tone	Type of customer, year ended June 30					All
	Business	State and local government	Education, research	Personal	Other	
	Percent					
Acceptable	95	94	87	94	100	95
Too light	4	4	12	1	---	4
Too dark	1	2	1	5	---	1
Total	100	100	100	100	100	100

1/ Frequency distributions are statistically different at the 99-percent confidence level.

Resolution

Ground resolution of ASCS airphotos is generally from 2 to 3 feet. More than two-thirds of the customers were satisfied with this degree of visual detail, with little difference in this proportion among user groups. Of those who desired a different degree of detail, most preferred a film scale which would yield greater detail. This was particularly true of realtors, appraisers, and city land planners.

Characteristics discernible in an airphoto are determined by the degree of tone contrast between an object and its background, and by image sharpness. These qualities are functions of the equipment and techniques used to acquire the imagery, which for ASCS photography have become standardized and are prescribed by contract. Although tonal contrast and sharpness are fairly uniform, imagery acquired with identical equipment and techniques may vary in these qualities due to differences in object characteristics.

Tonal contrast and sharpness are difficult to index. Airphoto quality is first identified by scale, i.e., the number of inches per mile. As an indication of interpretability, however, it is more useful to use "ground resolution," which is a measure of the smallest object on the ground distinguishable from another nearby object. For example, with a resolution of 10 feet, a haystack 15 feet in diameter can be distinguished from an adjacent haystack of similar size. However, with imagery of 20-feet resolution, both haystacks would appear as a blob. Ground resolution, therefore, is an actual measure of the end product.

Most purchasers of ASCS airphotos reported interpretability as adequate but many desired greater detail -- a ground resolution less than 2 to 3 feet (table 10). Customer opinion favoring improved ground resolution ran as high as a fourth of the business category and a third of the education and research category.

Table 10.--Agricultural Stabilization and Conservation airphotos in 1966: Non-Federal customer opinion of detail interpretability 1/

Opinion of interpretability	Type of customer, year ended June 30					All
	Business	State and local government	Education, research	Personal	Other	
	Percent					
Adequate	71	64	62	62	50	69
Prefer:						
Larger detail (less coverage)	27	34	34	37	50	29
Smaller detail (greater coverage)	2	2	4	1	0	2
Total	100	100	100	100	100	100

1/ Frequency distributions are statistically different at the 80-percent confidence level.

Those in the business category desiring better ground resolution included realtors (appraisal and boundary determination), farmers and foresters (measurement and groundcover identification), engineers (more detailed terrain analysis), and city planners who wished relatively detailed data on dwellings by type. In government, need for greater detail was reported by highway engineers, city planners, tax appraisers, foresters, and zoning people. Educators and researchers wanted finer resolution for beach erosion studies, landcover studies, and soils mapping, besides the need for instruction and demonstration in photogrammetry and photointerpretation.

Age of Imagery

ASCS airphoto coverage is kept up-to-date by periodically contracting for airphoto flights to obtain new imagery. The airphotos are acquired to aid in administering those farm programs concerned with field acreages used for producing crops. Coverage is, therefore, designed to acquire airphotos for all areas which include cropland, and to acquire new airphotos often enough so that the imagery shows new cropland, abandoned cropland, as well as changes in field and farm boundaries, roads, irrigation, drainage, terraces, contours, and other characteristics. Although total land use in the country is shifting quite slowly, land-use changes are more pronounced in some States and in particular local areas. The most rapid of these changes occur in rural-urban fringes.

Table 11.--Agricultural Stabilization and Conservation airphotos in 1966: Non-Federal customer opinion of image age 1/

Would more recent coverage be more valuable	Type of customer, year ended June 30					All
	Business	State and local government	Education, research	Personal	Other	
	Percent					
No more	18	14	9	34	25	19
Slightly more	22	11	32	22	--	20
Moderately more	21	25	23	14	62	22
Much more	39	50	36	30	13	39
Total	100	100	100	100	100	100

1/ Frequency distributions are statistically different at the 99-percent confidence level.

To keep ASCS airphoto coverage up-to-date for the intended purpose, new photocoverage is acquired about every 5 to 8 years. This varies depending upon the proportion of acreage in cropland, the rate that land shifts in or out of crop production, and changes in land patterns. Although the age of the photography currently on hand ranges from less than 1 year up to 7 or more years, the average age is probably 3 or more years. For many purposes, this severely limits photo use. For instance, in a rural-urban fringe, whole subdivisions or extensive highway complexes are often constructed within a year or two.

Almost 40 percent of ASCS customers surveyed felt that more recent photo coverage would be "much more" valuable (table 11). The proportion was about the same in the business category of customers. However, of the business customers placing larger orders (15 or more prints), 53 percent said more recent coverage would be much more valuable. Almost all types of business customers preferred newer coverage -- foresters for mensuration estimates, reseeding plans, and property line determinations; utility people for long-line planning but more importantly for planning distribution lines and building in newly developing areas. Realtors (developers, sellers, and appraisers) also indicated the importance of current coverage. Others preferring newer airphotos included planners (both city and regional), market researchers, engineers, and mapmakers.

Of the governmental customers, a half definitely preferred newer coverage, in many cases for the same uses as the business category. Most commonly mentioned were city planning, appraising, surveying, highway planning, and construction and mapping.

Table 12.--Agricultural Stabilization and Conservation airphotos in 1966: Non-Federal customer opinion of economic benefits received 1/

Economic benefits	Type of customer, year ended June 30					All
	Business	State and local government	Education, research	Personal	Other	
	Percent					
Substantial	40	65	27	15	0	41
Moderate	33	23	21	22	17	30
Slight	19	8	8	11	17	17
None	8	4	44	52	66	12
Total	100	100	100	100	100	100

1/ Frequency distributions are statistically different at the 99-percent confidence level.

Only 19 percent of the non-Federal customers were satisfied with the age of ASCS coverage. Many of these were farmers in areas where field boundaries and land use are slowly changing or where available coverage served the purpose adequately. The satisfied group, of course, would also include those who received recent coverage as a result of the updating program.

Of all customers surveyed, 61 percent felt that more recent coverage would be more valuable in a degree ranging from "moderately more" to "much more."

Economic Benefits

Customer opinion of economic benefits received from ASCS airphotos ranged from none -- 12 percent -- to substantial -- 41 percent (table 12). Twenty-nine percent reported benefits as only slight or none, including a large number of those in education and research who reported no direct monetary returns and quite a few farmers who infrequently used the photographs for recordkeeping or field measurement. The large order (15 or more prints') group of the business customers, accounting for 45 percent of airphoto purchases, reported considerable airphoto value. More than half stated economic benefits were substantial, while a third benefited moderately.

In general, customers reporting the greatest economic benefit were those dealing with large areas. In these cases, airphotos acquired by private contract would have been very -- even prohibitively -- expensive.

Table 13.--Non-Federal customers of Agricultural Stabilization and Conservation Service airphotos: Number and percentage of prints acquired from all sources, 1966 1/

Type of customer, year ended June 30	Total airphoto prints acquired	Source of prints				
		ASCS	Non-ASCS			
			Total	Other Federal	Private	All other
	Thousands					
Business	428.9	262.3	166.6	47.1	104.8	14.7
Government (State and local)	250.6	173.9	76.7	10.1	62.5	4.1
Education and research	45.1	29.0	16.1	10.8	3.1	2.2
Personal	5.2	5.1	.1	----	.1	---
Other	.7	.7	----	----	----	---
Total	730.5	471.0	259.5	68.0	170.5	21.0
	Percent					
Business	100	61	39	11	25	3
Government (State and local)	100	69	31	4	25	2
Education and research	100	64	36	24	7	5
Personal	100	98	2	--	2	-
Other	100	100	--	--	--	-
Total	100	64	36	9	24	3

1/ Frequency distributions, based on number of reports, are statistically different at the 99-percent confidence level.

OTHER AIRPHOTOS ACQUIRED

During 1966, ASCS customers acquired 260,000 prints from other sources besides the 471,000 ASCS prints (table 13). This is a total of 731,000 prints -- two-thirds from ASCS and a third from other sources. It was not the intent of this survey to determine how many airphoto users acquired all of their prints from other sources, and their reasons for not acquiring any ASCS prints.

Sources

Considering all airphotos acquired from all sources, the business category reportedly obtained the greatest proportion (39 percent) from sources other than the ASCS. This is in line with the extensive use of airphotos by this

category for geologic exploration and for forestry purposes in areas where ASCS coverage is lacking. Business customers often needed photography without delay for construction or real estate work, or to finer ground resolution. Private airphoto contractors provided customers in the business category with a fourth of their total acquisitions; other Federal agencies supplied 11 percent of their needs, while 3 percent were acquired from other sources such as the borrowing or purchasing of photos from other non-Federal groups (table 13).

Governmental units (State and local) also acquired a substantial proportion (31 percent) of their airphotos from sources other than ASCS, mostly from private contractors. Of those acquired from other sources, only about an eighth came from other Federal agencies. Most were obtained by contracting with private airphoto firms for special imagery. Even though ASCS prints were widely used for preliminary highway planning, special imagery yielding finer "ground resolution" was often required for detailed construction plans. Large numbers of airphotos were obtained for these purposes from the private airphoto firms. Governmental units also often needed updated coverage or coverage in greater detail than ASCS prints for urban development, zoning, and appraisal. This type of imagery also required special flights by private airphoto firms.

To complete their airphoto coverage of the Nation's land area, education and research customers obtained more than a third of their airphotos from other sources, mostly from other Federal agencies. They were not only interested in the Nation's farmland represented by ASCS coverage but also in the forest, range, and wilderness areas of the West, along with the stream and coastal areas covered by the imagery of the Coast and Geodetic Survey. Some airphotos for special purposes, however, were acquired by donation, by borrowing, or by contract with private firms.

Reasons for Acquisition

Of those acquiring photos from other sources, more than a third indicated that ASCS airphotos were not recent enough for their purposes, with the same proportion also reported by the business category (table 14). Those reporting this need included utility people who must know the current landcover and improvements to plan long-line transmission construction as well as the latest housing pattern for planning local distribution lines; foresters who needed recent imagery to estimate current volume of standing timber; a large group needing imagery of current residential, commercial, and industrial development including those concerned with real estate development and sales, urban and rural planning, zoning, and tax appraisals; and attorneys for evidence in zoning and boundary disputes.

A fourth of all customers, and of the business category, receiving airphotos from other sources indicated ASCS coverage was not available. Airphoto coverage is available for all areas from some sources, either public or private, and to various specifications. Coverage of cropland is available from the ASCS. The Forest Service has photography of the National Forest and National Grasslands areas. This coverage includes much of the western (Rocky Mountain and Pacific Northwest) lands not available from the ASCS. In the Department of the Interior, the U.S. Geological Survey has coverage of many parts of the Nation not available from the ASCS, particularly the southwestern wilderness and desert

Table 14.--Reasons why non-Federal customers of Agricultural Stabilization and Conservation Service airphotos obtained prints from other sources in 1966 1/

Reason given why ASCS photos were not used	Type of customer, year ended June 30					All
	Business	State and local government	Education, research	Personal	Other	
	Percent					
Not recent enough	37	35	27	-	-	35
Not available	26	20	53	-	-	26
Not proper resolution	22	29	2	-	-	23
Other 2/	15	16	18	-	-	16
Total	100	100	100	-	-	100

1/ Frequency distributions are statistically different at the 95-percent confidence level.

2/ Needed airphotos immediately, at oblique angle, in infrared, at a different season such as when vegetation is defoliated, or with snow cover.

areas. Other imagery is supplied by the Coast and Geodetic Survey, Department of Commerce (coastal areas and rivers and harbors), by the Soil Conservation Service, Department of Agriculture (various local areas where SCS projects are underway), by the Bureau of Land Management, Department of the Interior (public domain lands, particularly western grazing lands), and by a number of private airphoto firms who not only fly on contract but also have coverage on hand including areas in Vermont and Minnesota not covered by the ASCS. 8/

Users interested in airphoto coverage of areas not available from the ASCS included business groups who desired imagery of the Southwest for geologic interpretation, western forest areas for surveys, and urban areas for real estate and development use. Also, governmental and education and research groups needed Coast and Geodetic Survey imagery for lakes, rivers, and coasts, as well as imagery for western and urban areas from other sources.

Almost a fourth of the customers gave "inadequate resolution" as the reason for ordering from other sources. Those reporting a need for finer resolution included tax officials and realtors; zoning and planning officials; strip miners; and others employing precise photogrammetric techniques.

8/ Geological Survey: Status of Aerial Photography, U.S. Department of the Interior, June 1966.

About a sixth gave other reasons; in most cases, these required special flights by private contract. Some wanted airphotos without delay for such needs as court evidence, real estate sales, or construction projects. Others desired photography at an oblique angle so that, for instance, a real estate development would be in the foreground with a city in the background. A few desired color photography, particularly because for many purposes its interpretability is superior to black and white. Sometimes infrared was desired to improve vegetative cover distinctions, for example, to distinguish types of trees in forest surveys. For geologic interpretation, terrain analysis, and soil survey work, defoliated (winter) imagery was desired. To facilitate terrain analysis, a few purchasers preferred light snow cover because it tended to accentuate ground features.

APPENDIX

Questionnaire and Sampling Plan

Non-Federal users of ASCS airphotos were surveyed by use of a random mailed questionnaire with a second mailing to check nonresponse bias. The ASCS customers who placed a total of 40,141 orders for 470,984 airphotos in the year ending June 30, 1966, were considered to be the universe. As shown in table 1, the file of orders consisted of 36,184 small orders (1 to 14 prints) for 133,390 prints and of 3,957 large orders (15 or more prints) for 337,594 prints. The small order group accounted for 90 percent of the orders, but only 28 percent of the number of prints ordered. The large order group with only 10 percent of the orders accounted for 72 percent of the prints ordered. These proportions were the basis for weights in summarizing the sample returns of the two groups which were sampled at different rates. For the small order group, 1,000 names were drawn -- a 3-percent sample. This group, which accounted for only 28 percent of all photo purchases, had a high population and a relatively low variance. A 25-percent sample was drawn for the large order group because it had greater variance and lower population and because it accounted for 72 percent of all photos purchased. This group showed a 70-percent response in the first request and a 31-percent response on the follow-up to nonrespondents; the total group response was 80 percent of the sample list and 20 percent of the universe.

All questions were designed so that response was quantified, except for those comments which were incorporated in the text. Replies to questions on quantity of prints ordered by size or from other sources were in actual numbers. Qualitative questions, such as opinion or preference, were set up for a checkmark from a range of choices as shown on the tables. These answers were then summarized on a frequency basis.

Besides the number of prints ordered as found on the order forms used for the mailing list, each respondent was asked to report the total number of prints ordered from the ASCS during fiscal year 1966. In total, the two sample groups purchased 276,300 ASCS prints or 59 percent of the total sold to non-Federal customers that year. Since all except the type of customer questions were relative to total annual photo purchases, the sample coverage included 59 percent of the universe on a total fiscal year basis.

Because of the high proportion of coverage and because the indications from respondents to the second request were quite similar to those from the first request, an adjustment for nonresponse bias was considered unnecessary.

All frequency distribution tables were tested for significance of differences by chi square. The thesis tested, in each case, was that the distribution in each type of customer column is the same as in the "total" or "all" customer column. 9/ In all frequency distribution tables, this thesis was rejected at the 99.5-percent confidence level except table 10, which was rejected at the 80-percent level. This means that the opinions or preferences indicated by each type of customer differed so much from the total sample average that there was very little possibility that differences in distributions could be due to random variation. The standard error of each percentage was computed to evaluate those cellular chi square values which were relatively high. The coefficient of variation (standard error expressed as a percent) in most cases was less than 10. All distributions in the total (or "all") column had a coefficient of variation under 5 except several of the very small frequencies, which ranged up to 30 percent. In other words, the fiducial probability is that the true value of most values in the "all" column is between a range of plus or minus 10 percent -- well within this range are the major customer categories (business, government, and education and research). The remaining two categories (personal and other) accounted for less than 10 percent of the total number of customers. Of all percentages, only a few had a coefficient of variation exceeding 50 percent and these were in the frequency cells of the minor "personal" and "other" customer categories. When frequencies with a coefficient of variation exceeding 20 percent are mentioned in the text, the confidence range (plus or minus $2\sigma_{\bar{x}}$) as a measure of reliability is footnoted.

9/ For method used see: Snedecor, George W., Statistical Methods. Iowa State College Press, Ames, Iowa, 1956, pp. 24-30 and 225-227.

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