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An Image Analysis System to Develop Area Sampling Frames for Agricultural Surveys

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ABSTRACT: A computer system which integrates digital image analysis, digitization and some sampling procedures has been developed to create area sampling frames to collect agricultural data. The system, known as CASS - Computer Aided Stratification and Sampling, automates a procedure which reduces errors and labor costs in the previous manual system. Although material costs have increased and resolution is a problem, stratification has been enhanced and data utility increased.

1. INTRODUCTION

The National Agricultural Statistics Service (NASS) has been developing, using and analyzing area sampling frames since 1954 as a vehicle for conducting surveys to gather information regarding crop acreage, cost of production, farm expenditures, grain yield and production, livestock inventories and other agricultural items (Cotter and Nealon, 1987). An area frame for a land area, typically a state or county, consists of a collection or listing of all parcels of land for the area of interest. These land parcels can be delineated based on factors such as ownership or based simply on easily identifiable boundaries as is done by NASS. Area frames are critical to producing quality estimates, as they provide complete coverage with all land areas being represented in a probability survey with a known (not necessarily equal) chance of selection.

The previous manual procedure used to develop area frames was slower and more labor intensive. The development of an area frame for a single state on paper-based materials may require 11,000 hours and cost over $150,000.

This paper will briefly describe the materials and procedures used in developing a paper-based area frame. This will then be followed by a description of the new automated procedures for developing area frames using digital inputs, which is now operational. For more information on area frame development, consult the authors.

2. PAPER-BASED AREA SAMPLING FRAMES

2.1 Materials Used

Area frames are currently developed on a state by state basis. The materials used in the stratification process (see examples in Cotter and Nealon) include:

Satellite Imagery: Historically, a paper-based image product from the LANDSAT satellite was used. Two types of scanners are available: a multispectral scanner and a thematic mapper (TM).

TM is the preferred product for stratification, though TM is more costly due to its better resolution. The paper TM product is scaled at 1:250,000.

National Aerial Photography Program (NAPP): NAPP is the product of a consortium of federal agencies, each of whom need and use aerial photography. 1:40,000, 9-inch contact prints are used. NAPP is a primary stratification tool. Nearly all of the U.S. has been photographed through the NAPP program.

Topographic Quadrangle Map: These maps are produced by the United States Geological Survey (USGS) and the preferred scale is 1:24,000 (7.5 minute series) which makes them useful for urban and ag-urban stratification and sampling.

Bureau of Land Management Map: These maps, scaled at 1:100,000, show the distribution of the federal and state land. They were useful in western states for delineating (public/private) range strata.

USGS 1:100,000 Topographic Map: These high quality maps provide NASS with an accurate map base on which to work.

2.2 Stratification

Satellite photo products and black and white aerial photography are used to identify land-use strata on the 1:100,000 map base. Table 1 displays the set of land-use categories which were used in the development of Missouri's area frame in 1987. This table also shows the target size range of first-stage sampling units called Primary Sampling Units (PSUs, discussed in section 2.3). The purpose of stratification is to reduce the sampling variability by creating homogeneous groups of sampling units. Although certain parts of the process are subjective, precision work is required of the personnel stratifying the land to ensure that overlaps and omissions of land area do not occur and that land is correctly assigned to land-use categories.

Table 1. Land-Use Strata Codes, Definitions, and Primary Sampling Unit Sizes

STRATUM CODE	DEFINITION	PSU SIZE (miles²) min	target	max
11	General Cropland, 75% or more cultivated.	1	6-8	12
12	General Cropland, 50-74% cultivated.	1	6-8	12
20	General Cropland, 15-49% cultivated.	1	6-8	12
31	Ag-Urban, less than 15% cultivated, more than 100 dwellings per square mile, residential mixed with agriculture.	0.25	1-2	3
32	Residential/Commercial, no cultivation, more than 100 dwellings per square mile.	0.1	0.5-1	1
40	Range and Pasture, less than 15% cultivated.	2	12-16	24
50	Non-agricultural, variable size.	1	n/a	n/a
62	Water	1	n/a	n/a

Initial training of personnel stresses the need to use quality boundaries. A quality boundary is a permanent or, at least, long-lasting geographic feature easily located on the ground by a field interviewer. If an interviewer cannot accurately locate the sampled area, or does not collect data associated with all of the land inside the sampled area or collects data for an area outside of that selected, then nonsampling errors will occur.

When the objective of using permanent boundaries conflicts in actual practice with the objective of obtaining homogeneous sampling units, permanent boundaries take precedence. Roads and rivers make good strata boundaries, while intermittent streams and field edges do not and should rarely be used. The following list shows geographic features most frequently used for strata boundaries ranked from highest to lowest quality:

- Paved highways.
- Secondary all-weather roads.
- Local farm to market roads.
- Railroads.
- Permanent rivers and streams.

The stratification is performed on a county by county basis for administrative purposes. Each stratification analyst works a county until its completion. Stratification generally begins with determining the urban and ag-urban strata for the county. The agricultural areas are then stratified using TM satellite imagery. The imagery is used primarily to ascertain where the cultivated areas and the non-cultivated areas are present in a county. Aerial photography may be one to five years old while TM data imagery usually covers the most recent growing season. Using TM data for locating crops and pasture and photography for boundaries, the analyst must make subjective decisions on placing areas in appropriate strata.

After stratification on photography has been reviewed and approved, strata boundaries are transferred to a map base (also called the frame maps). The map is later digitized to determine the areas of the PSUs. Once this transfer is completed, the next phase of stratification is begun - construction of primary sampling units.

2.3 Construction of Primary Sampling Units

Rather than dividing an entire frame into final sampling units, called segments, strata are divided into PSUs. Segments are areas of land visited by an interviewer. A random sample of PSUs are further divided into segments, resulting in a tremendous savings in labor costs.

The desired size of the PSU varies by strata, but averages six to eight segments. The minimum PSU size is one segment (see Table 1). In delineating PSUs, the main focus is not homogeneity of land-use, that has already been accomplished with land-use stratification. The main concern is to achieve a desired size with good boundaries while trying to maintain that each PSU is a smaller representation of the stratum as a whole.

Completed frame maps are reviewed as a final check. The polygons created by drawing each PSU are examined for closure. The numbering system is checked for strata identification accuracy and sequential accuracy. Frame maps are further checked to ensure that omissions and overlaps do not exist. Once these checks have been accomplished, frame maps are ready for the next step in the process - measuring the size of the PSUs.

2.4 Digitization

The 1:100,000 PSU base maps are digitized in order to:

- measure PSUs accurately,
- ensure quality, and
- retain a digital backup copy of the frame map in the unlikely event that a frame map is lost.

Using the map scale, the area of each PSU in a county is calculated in terms of square miles and stored in a file for that county.

PSU areas for each county are summed and compared against the official county size. The same procedure is done for the state area. County areas are allowed to vary 3.0 percent from the published area. The accumulated state area is only allowed to vary 0.5 percent from the published area. County area is allowed more variance because of the smaller area involved and because PSUs are allowed to cross county boundaries. Since stratification is never allowed to cross state boundary lines, only a small amount of error is allowed.

PSU areas are then accumulated for each stratum at the state level. The PSU area (e.g. 10.5 miles) divided by the target segment size for the stratum (e.g. 2.0 miles) is equal to the total number of segments in that PSU rounded to the nearest integer (e.g. 5). Summing the number of segments will yield the total number of segments in the stratum. This information will be used in determining the number of segments to be sampled for the entire state.

2.5 Sample Selection

After the total number of sample segments to be used in a state has been determined, a separate program is run to select PSUs which will be further broken down into sample segments. The PSUs are selected with probability proportional to their size. This is the first stage of sampling. Selected PSUs are located on the frame map and their boundaries transferred to photography. The selected PSU is then divided along identifiable boundaries into the required number of segments. Each segment has a specific target size (see Table 1) depending on the stratum it is associated with such that each individual segment closely resembles the full PSU (as much as possible) with the best physical boundaries available. Segments are manually numbered and a random number is chosen to select the sample segment with equal probability. This completes the second stage of sampling.

2.6 Sample Preparation

After the segment has been randomly chosen within the PSU, sample preparation (the last step) takes place. The sampled segment is located and identified on a map for use by the field enumerator. In addition, the most recent photo coverage of the segment is ordered as an enlargement from the Agricultural Stabilization and Conservation Service (ASCS), U.S. Department of Agriculture. The enlargement is obtained to facilitate data collection activities such as delineating crop fields and locating farmsteads. Identification information such as county name and segment number are scribed onto the enlargement prior to being mailed to the State Statistical Office.

3. DIGITAL-BASED AREA SAMPLING FRAMES

3.1 Research Background

NASS has been involved in a cooperative agreement with the National Aeronautics and Space Administration (NASA), the U.S. Space Agency, to develop area sampling frames using digital inputs. The project with NASA began in 1988 with a NASA Research Grant (87-OSSA-6). Although the initial research agreement with NASA expired in the fall of 1991, NASA continues to provide software support through a cooperative agreement with the Ecosystem Science and Technology Branch (ECOSAT), Ames Research Center, Moffett Field, California.

A new area frame system called the Computer Aided Stratification and Sampling (CASS) system will strengthen both the research and operational remote sensing programs at NASS and NASA and the development of area frames. One particular advantage to this approach will be the ability to use digital information relating to land use from previous years' surveys as an aid to the development or updating of area frames. Other benefits will be discussed later.

3.2 The CASS Workstation

The CASS Workstation (see Figure 1) includes several pieces of equipment. The display terminal (1) displays the color satellite image, and a menu screen (2) displays the text. The keyboard (3) is used to enter commands from the menu and the mouse (4) is used to interact with the display terminal. The button box (5) is also used in connection with the display terminal to handle the overlay planes (change the color of the overlay planes or turn them on and off) and to zoom the image.

Figure 1. CASS Workstation

At this time, a UNIX-based Hewlett-Packard (HP) workstation is being used to handle data processing and storage requirements. The HP workstations possess the minimum capabilities for area frame development, that is, three image planes, four overlay planes and a 1024 x 1280 display coordinate system. The configuration allows for three bands of satellite data in the image planes displayed using 24 bits while utilizing graphics planes for various purposes, such as displaying digital road, water and county boundary data, PSUs for a county and its neighbor and the command menu (small window overlaying the image on the display terminal).

A graphical user interface (GUI) has been written under the X Window System to make the software easier to use and to handle changing hardware and software technology. An image is reduced to 1024x1024, allowing the remaining area on the graphics terminal to display the menus.

3.3 The CASS System

CASS is an image analysis system that can read in and write out ArcInfo SVF (raster) and DLG (vector) format files, in addition to its own format files. CASS incorporates two types of digital inputs. TM data (1:100,000 scale, 30 meter resolution) from the EOSAT Corporation (see Fig. 2a) serves as a base to delineate land use according to the stratification scheme. U. S. Geological Survey's Digital Line Graph (DLG) data at a 1:100,000 scale is used for boundary identification, by overlaying onto the digital image using a graphics plane.

Displaying and coloring satellite data - TM bands two, three, and four were used for optimal agricultural land use classification. The digital nature of the data enables the user to create a color map which best distinguishes cultivation and boundaries.

Display and registration of DLG data - U. S. Geological Survey's transportation and hydrography DLG data (see roads in Fig. 2b) are used, as well as political boundary data from the Census Bureau's digital map data base, called TIGER. TIGER stands for Topologically Integrated Geographic Encoding and Referencing System. The 1:100,000 scale DLG boundary data are not complete, and 1:2 million scale DLG boundary data are too inaccurate for NASS's needs. Since the TM data is more recent than the DLG data, DLG data are used mainly as a reference. If the user can identify a physical boundary directly in the TM image, it is used. If a physical boundary can not be distinguished in the TM image, but a DLG boundary exists, it is used. The TM image (scene) is precisely overlayed with DLG, by registering the DLG data to the backdrop of satellite data. Several matching TM and DLG points are selected, and a least squares regression is run to fit the remainder of the data. These points and the regression are saved in a file and used each time a DLG file for that scene is displayed. This registration file also enables the user to determine latitude and longitude coordinates of a given point.

Figure 2

a) TM image-Macon county, Missouri **b) DLG road data**

Other inputs - Other reference materials include 1:100,000 U. S. Geological Survey maps, some small scale aerial photography, quadrangle maps for city areas, information from NASS State Offices, and information on planting and harvesting dates for the major crops in that state.

PSU delineation - In each county, polygons will be drawn and tagged with the appropriate PSU number, which consists of a stratum number and a sequence number (see Fig. 3a). This is done by determining the particular stratum in which to place a unit of land, by interpreting the color TM image. (The reason for using a visual approach, which is subjective, rather than a supervised classification approach, which is repeatable, is that good physical boundaries are required. Also, multitemporal and ground truth data are too expensive.) At the same time, a PSU within some specific size range is delineated (refer to Table 1), using physical boundaries identified by DLG and/or TM data. In CASS, this is done by keying in a PSU number, and then utilizing the mouse to pick points along desired boundaries. When a PSU (or polygon) is closed, the area is immediately calculated and displayed. This allows the user to determine if the PSU is within the target size for that stratum. If a polygon is too small or too large, polygons can be combined, split or reshaped. When a county is completed, the polygons are saved to a file to be reviewed by another experienced analyst. The user has the ability to check for overlapping polygons and holes (or missing land areas). At any time, the user may list PSUs that have been created, to check for proper PSU numbering and that PSU areas are within tolerance. Refer to Cheng, T., Angelici, G., et. al, 1989 and Cheng, T. Angelici, G., et. al, 1992 for further information.

PSU breakdown into segments - After the entire state has been stratified and the total area for each stratum has been calculated, a separate program is run to draw a sample of PSUs which will be further divided into segments. Only those PSUs which were chosen by the sample select program are divided. The user displays the file (saved in the previous step) and enters in the PSU number to be sampled. Software then erases all but the sample PSU from the screen. Many of the same functions which were involved in delineating PSUs during the stratification phase are used to divide the PSU into equal size segments. For example, the mouse is used to pick points along an identifiable boundary. When the segment (polygon) is closed, the size is immediately displayed, and segments can be merged, split, or boundaries reshaped. Similar quality control checks for overlaps and omissions are done. Since segment areas are much smaller, boundaries are harder to find. Occasionally, field edges, section lines, or point to point must be used. When the PSU has been completely divided into segments, one is selected randomly using the segment selection command (see segment number 01992 in Fig. 3b). Its latitude and longitude is then determined (for use in the NASS Geographic Information System), and a photo enlargement is ordered. Lastly, the boundaries for sample segments are transferred to enlarged photos by the Sample Preparation Unit (see Fig. 4) by displaying the segment, or utilizing a print of the digital image and segment boundary.

Figure 3

a) PSU delineation **b) PSU divided into segments**

Figure 4

3.4 Research

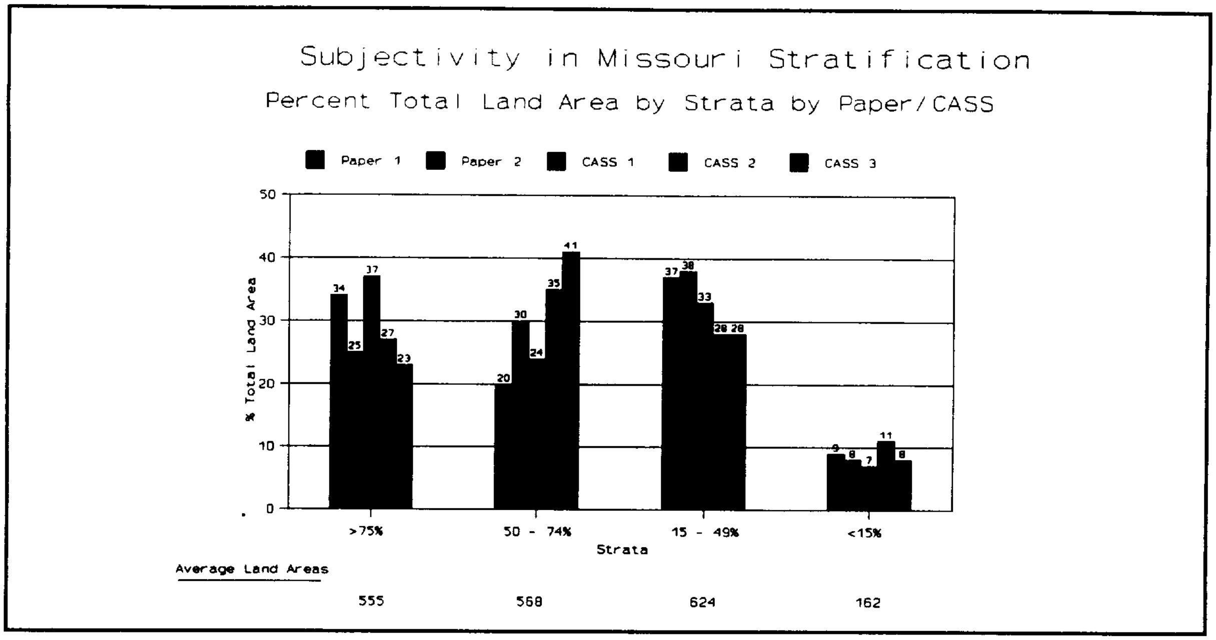
Missouri:

The purpose of the initial test (conducted in 1988-1989) was to gain basic experience with the software, compare CASS to the paper-based method, and determine the speed of frame construction. Digital data covering three north-central counties in Missouri (Linn, Livingston and Macon) were used. These counties were chosen partly because the Area Frame Section had developed a new area frame for Missouri in 1987 for use in 1988.

This test proved that stratification using CASS was possible. CASS proved to be faster, as 2.5 - 3 weeks were required for paper stratification and digitization, and 2 - 3 days for CASS. However, the subjective nature of the work must be stressed. In this test, 5 different people stratified each of the 3 counties. Two people used the paper method, and three used CASS. They are represented in Figure 5 as paper1, paper2, cass1, cass2, and cass3. The percent of the total 3-county area (excluding the urban, water, and non-cultivated strata) is given by strata, by person. That is, the percent land area in the >75% cultivated strata ranged from 23% (cass3) to 37% (cass1). The results illustrate the difficulty associated with the photointerpretation of cultivated areas and boundary selection using both small scale paper and digital image products.

Michigan:

A 21 county area in Michigan was selected to represent a pseudo-operational environment. At



the time of the study (1989-1990), the state had just received a new frame in 1989 (implemented

Figure 5 .

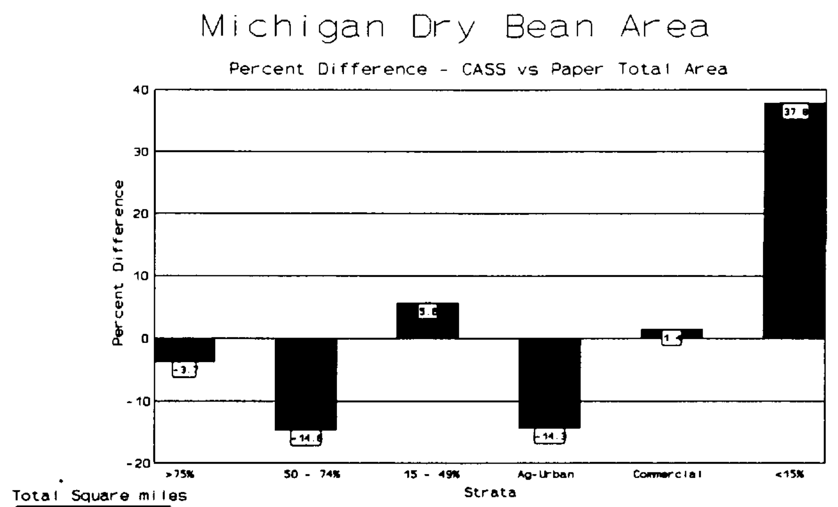
in 1990). Also, the Remote Sensing Section of NASS had recently completed work in the dry bean area of Michigan in regards to supervised classification (therefore TM data were available). In this test, only one person worked each county. Results of CASS stratification were influenced by the recency of the paper stratification, as an analyst doing CASS stratification might recall what occurred in the paper stratification.

An analysis was conducted on results in this 21 county area. Evaluations were both quantitative and qualitative. The total area in each land-use strata was measured, and the percentage difference between paper and CASS (given as CASS-paper/paper) calculated. This is shown in Fig. 6. As to the 14.6% difference in the 50-74% cultivated stratum, the users generally favored the CASS results, because they could better identify pasture, which was not considered cultivated land. As to the 37.8% difference in the <15% cultivated stratum, the users also favored the CASS results, because they felt they were better able to identify and include the woodland areas. Lastly, the 14.3% difference in Ag-Urban stratum is mostly due to the lower resolution of the TM data compared to aerial photography and quadrangle maps. The analysts could identify density of houses on the aerial photography (somewhat), and could easily locate road boundaries on the quadrangle maps. However, density of roads had to be used in some suburban areas on the TM, and the older age of the DLG compared to the TM, explained problems identifying road boundaries where new developments had been built. Also, the average PSU size in an Ag-Urban stratum was larger in CASS (1.6 square miles), than on paper (1.2 square miles).

In this operational test, no attempt was made to verify the results with ground truth data. Each of the 5 analysts visually compared the CASS and paper area frames for a given county, not to measure quantitative differences, but to see generally where differences occurred, and why. This qualitative aspect of the study is worth noting.

Figure 6

Although there is no quantitative way to prove it, the analysts generally felt that stratification of cultivated areas was better in CASS. This is due to the increased resolution of digital TM than paper TM imagery, and the dynamic rather than fixed colormapping abilities. As to stratification of urban areas, the paper was better, however this can be improved with better resolution imagery. As to the boundaries, the lower resolution of the TM data than the aerial



Total Square miles						
CASS	5225.8	2175.6	3448	555.3	170.7	1856.2
PAPER	5427.4	2547.8	3264	648	168.4	1347.3

photography made boundary selection more difficult. Also, the 1:100,000 maps provided the user with detailed information on boundary type, which was lost when displayed in an overlay plane using limited line types. Boundary selection in the sample selection process is even more important, as polygons are much smaller (typically one square mile).

In two cases, clouds were a problem. In one case, a cloud totally obscured a piece of land, resulting in its misclassification. In the second case, an island was obscured and missed by a wispy cloud.

It was at this time, that we first dealt with counties which crossed TM scenes and UTM (Universal Trans Mercator) zones. It was decided to convert the polygon files to UTM coordinates.

3.5 Operational Phase

Two states' area frames have been developed in CASS since it became operational: Oklahoma (the first) and California. Oklahoma's new area frame was first used for enumeration purposes in June 1993, and California's new area frame will be used for enumeration purposes in June 1994.

The most valuable lesson learned during this time was proper registration of the DLG to the TM scene. Initially, control points from the four scene corner points were used. These proved to be too inaccurate. The main problem occurred where TM scenes overlapped, that is, a given county is covered by 2 different scenes but not entirely by either one. Stratification is done at the county level. The difficulty is then in getting the two TM scene registrations to "agree", each with different number and spatial placement of control points. After much difficulty (such as occurs when a given county has a control point in one scene, but none in the other scene), the final solution was to place a substantial number of points, equally spaced, with points as close to the scene edge as possible. Problems with UTM zone changes within a TM scene were solved by locating control points throughout the entire scene (e.g. UTM zones 14 and 15), but reordering so that the first control point was in the zone of interest (e.g. zone 15). Thus, two registrations (one for each zone) would exist for that scene. At one point, Census TIGER data was used, as it was more recent than DLG data. It proved to be less geopositionally accurate in some areas (critical to our work), so we reverted to using DLG.

During the operational test, two problem areas were identified: clouds and urban areas. The most recent year's TM data is desired, but spring or fall months are necessary, when cultivation can best be identified (planting or harvesting has occurred, but trees are not at peak foliage). Therefore, some cloud coverage is accepted, though it is kept to a minimum. Aerial photography is ordered to supplement the TM data for problem areas (dense clouds). As to urban areas, aerial photography is also ordered to supplement the TM data for large cities. With segment sizes of one-tenth and one-quarter square miles, sample selection for Commercial and Ag-Urban strata is done on quadrangle maps, rather than in CASS.

For the first time, latitude and longitude coordinates were determined for each sample segment. Also, the Sample Preparation Unit had a few problems transferring segment boundaries onto photo enlargements. For the first time, the TM imagery was more recent than the enlargements. This more accurately reflects what exists on the ground, but the segment boundaries must be drawn on the older photo enlargements. In some cases, problem boundaries might have been selected due to the resolution of TM being lower than aerial photography. For example, intermittent streams were used as boundaries, which did not show up in the photos, and may or may not show up on the ground.

3.6 Resource Considerations

The resource considerations for CASS can be broken down into several categories: materials, labor/staffing, hardware and software.

Materials. Material costs are significantly higher using CASS. The cost of digital TM data are approximately four times greater per scene than the paper product. In the past, materials averaged 20% of the total cost of creating a new state frame. In Oklahoma, materials were 58%. See Table 3.

Labor/staffing.

a) Stratification using all paper products was very labor intensive. Users would analyze TM imagery, stratify land area, transfer boundaries twice, and then digitize the boundaries. With CASS, digitization is built in and boundary transfers eliminated resulting in excellent labor savings.

b) Not only are the total number of hours important, but also the personnel issues and changes are important. In the past, this work was accomplished by more part-time, lower paid staff. The staff are now fewer, full-time and higher graded. This results in a higher per-person cost, but total cost is still greatly reduced by the reduction in total hours. Having a full-time higher graded staff will result in less turnover, thereby reducing training costs for new employees.

c) In the past, labor was about 80% of the total cost of producing a new state frame. In Oklahoma, labor was 42%. See Table 3.

Table 3. Comparison of Cost and Hours for Recently Developed Area Sampling Frames

	year	% labor	% mater.	total cost	total hours	
OK	93	42	58	153,913	4,459	cass

AR	92	79	21	137,937	10,193	paper
GA	91	81	19	183,726	14,927	paper
AL	91	85	15	140,646	11,460	paper
MI	90	76	24	134,359	10,459	paper
LA	90	81	19	122,128	10,050	paper

Hardware. There are one-time and maintenance charges. Hardware start-up costs were partially offset by the NASA grant, and can be amortized over the life of the system. The systems will need to be upgraded or replaced over time, but the obvious trend in workstation prices is down while the amount of computing power per dollar is rising. At this time, a suitable HP workstation runs about $20,000 for the general public.

Software. The software was developed, corrected and enhanced with funds from the NASA grant, and NASS contributions. This funding should decrease in the very near future to an amount needed only to maintain the software. Changes in technology continue to have an affect on the software. Since the software was developed with government funding, it is public domain software. However, no software support mechanism is available.

3.7 Summary

Advantages of CASS

The users generally agree that stratification in CASS is better for several reasons. First, satellite data provides more recent data (potentially available every 16 days) than aerial photography (may be 5 years old). An area frame is used for about 15 years, therefore, the most recent imagery at the time of stratification is desired. Second, the land-use determination is more accurate, as the scale of TM data has gone from 1:250,000 on paper, to 1:100,000 digital data. Also, a dynamic color map is available to enhance the image, and bring out the cultivation.

The automation of this process has eliminated the tedious, error prone process of transferring from a satellite image print, to aerial photography, to a 1:100,000 scale USGS map, to a digital file. PSUs (and segments) can be more easily revised in CASS by moving digital boundaries, and since the size of the PSU (and segment) is known immediately, it can be resized if it does not fall within the suggested limits.

In CASS, the random numbers are unknown to the analysts. Some felt that in the paper process, an anaylst could find out which random number was next (from a paper table), which might influence their segment boundary selection.

The digital aspect of the frame will allow a frame to be updated rather than having to start from scratch (which is necessary with paper frames). Also, sample segment locations are being identified (latitude and longitude coordinates). The digital frame and these latitude and longitude coordinates can be input to a Geographic Information System.

Lastly, CASS allows easier exploration of specialized area frames. The Remote Sensing Section of NASS can provide crop-classified satellite imagery to assist in the development of specialized area frames.

Concerns

The disadvantages to using CASS are in conjunction with satellite digital imagery. Most users feel the job of identifying boundaries (which must be located on the ground by the enumerators) is more difficult, because the scale has gone from 1:40,000 on aerial photography to 1:100,000 on TM, and the resolution has decreased. Also, the DLG can be somewhat out of date. That is, it is only as good as the date created or revised.

Other concerns are urban stratification and cloud cover. Houses cannot be seen as well using TM data, so the analyst must resort to using such characteristics as density of roads. Aerial photography is being used to supplement TM data in urban and clouded areas.

4. FUTURE CONSIDERATIONS

SPOT data will be used in some of the larger city areas (e.g. New York City) to aid in urban stratification. It will enable the anaylst to identify houses and distinguish among physical boundaries. Digital orthophotography will be used (when available) to aid in identifying potential

segment boundaries. Also, edge enhancing filters will be tried to "bring out" boundaries in the

TM data.

Updated DLG would be a tremendous help. In one area in California the TM data was from 1991, the aerial photography was from 1987, and the DLG data was from 1983.

At this time, our primary output is the photo enlargement. The photo is ordered using microfiche, to locate the exact geographical area. In the near future, photos may be ordered using latitude and longitude coordinates, since segment latitude and longitude is calculated in CASS. Also, when the resolution of the imagery data improves, clear prints of the segment may be generated directly from digital data (e.g. possible with digital orthophotography).

5. CONCLUSION

All in all, the users feel CASS is a success. The stratification should be better, and the problems with determining boundaries will hopefully be solved in the near future. Progress continues to be made after each new state.

Although initial charges are high, all indications point in the direction of lower costs in the future, better land-use frames, and an increasing utility of the data. TM data costs should drop when the government takes control of LANDSAT 7, which would allow us to buy more data (panchromatic or multitemporal). DLG costs have already lowered, now that data is available on compact disc rather than 9-track tape. Also, the boom in Geographic Information Systems is causing a demand for updated (and affordable) digital data. Much will be determined by the direction things go in the next few years.

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