Area Estimates by LANDSAT: Arizona 1979

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ABSTRACT

This report describes how data from NASA earth resources monitoring satellites, LANDSAT II and III, were used in conjunction with conventionally gathered-ground data to estimate planted crop areas in the nine southern-most counties in Arizona. Estimates using LANDSAT and ground data jointly were more precise than those obtained utilizing ground information alone. The major emphasis of the project was to improve cotton, sorghum and localized corn area estimates. Availability of LANDSAT data and lack of sufficient ground data for classifier training hampered the complete success of the project.

Key words: LANDSAT, NASA, cloud cover, regression estimate, direct expansion.

CONTENTS

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INTRODUCTION

The objective of this project was to gain LANDSAT analysis experience pertaining to crops in Arizona. The primary emphasis was on improving cotton and sorghum area estimates. The target area was defined as the nine southernmost counties in Arizona. In addition to the previously outlined objectives, another goal was to make corn estimates in the eastern portion of Arizona, primarily Cochise County. In some counties, estimates were also made for alfalfa and minor crops. This paper covers the project in the following phases:

I. Ground Data Collection and Editing

II. LANDSAT Data Acquisition and Management

III. Analysis Procedures and Results

IV. Summary

Any questions on general analysis procedures, statistical theory, or current (non-research) ESCS procedures are referred to the paper by Hanuschak, et. al.[1/]

I. Ground Data Collection and Editing

Accurately located ground information on a probability basis is essential as data input to LANDSAT analysis. Field level data from the June Enumerative Survey (JES) were used to correlate crop and land-use with digital LANDSAT data and to evaluate the accuracy of the classification results.

Presurvey preparation for the JES included questionnaire modification, enumerator training, and testing of field level edit programs. The questionnaire for Arizona was altered from the normal JES design to allow for field level data entry. Additional information collected included the field number, waste area per field, and total field area. In order to extract as much information as possible for analysis, enumerators were instructed to record as separate field all continous waste, wooded, or water covered areas which exceeded 2.02 hectares (5 acres). Remote Sensing Branch (RSB) personnel provided assistance in the State JES training session for enumerators. Most phases of the field level edit programs and data transfer operations were tested prior to the survey to insure efficient data handling.

Data transfer procedures were established by RSB personnel to acquire the ground data in Arizona and subsequently transfer the information to the Bolt, Beranek and Newman, Inc. (BBN) computer system where the LANDSAT analysis work is done. These procedures involved three computer systems: 1) Computer Science Corporation (INFONET), 2) Washington Computer Center (WCC), and 3) the BBN system. Data was loaded as usual for the JES onto the INFONET system. Next the data set was stripped of all non-crop information (such as livestock and economic data). This abbreviated data set was written to a tape file at the Systems Branch RMT9 terminal. This tape was then used as input to the Generalized Edit System Reformat and String programs and to a SAS field level edit program.

During the actual survey period, assistance was provided to the Arizona SSO by RSB for questionnaire checking and to answer questions pertaining to the LANDSAT project. At this time the task was undertaken to copy the JES segment photos (8" = 1 mile). This was done by Phoenix Blueprint Company in Phoenix, Arizona using a process known as Photo Mechanical Transfer. The photos were copied as soon as they were returned by the enumerators in lots of 50-60 at a scale of 3 3/4" = 1 mile. Upon receipt of the original and photo copies the SSO staff transferred segment, tract and field boundaries to the copies with appropriate colors of ink and checked each field for reasonableness and consistency with the corresponding questionnaire. These copied photos were then mailed to RSB.

Upon completion of the JES by the Arizona SSO, the field level crop data were transferred to the WCC as described earlier. At WCC, the field level SAS edits were executed and error listings generated. Tract level updates made by the SSO during the survey were listed for comparison purposes. Using the copied photos, SAS error listings, and SSO updates; problems were rectified and batch jobs were submitted to update the SAS dataset at the field level.

A follow up survey was conducted for those fields which were not yet planted at the time of the JES visit (called intentions fields). Updates resulting from the survey were also made to the SAS dataset. When the editing and updating were completed, an output tape was created. This tape was mailed to BBN on August 27, 1979.

Segment, tract, and field boundaries were digitized from the segment photos to a map base by the RSB support staff after the editing process was complete. This process gave another check on the ground truth data set by locating inconsistencies in reported versus digitized areas. Any redigitizing or updating of ground truth needed was done at this point.

Methods Staff provided a master listing of segments for the Arizona JES which contained such information as JES District, county, and planimetered acreage for each segment. These data were incorporated at BBN to create a file called a segment catalog. Additional information for this file contained map type and map name from digitization and was added by the RSB support staff.

The Fairfax Sampling Unit provided files containing area sampling frame boundaries for the nine Arizona counties (called county network files). In addition to these files, they compiled a listing of the total number of frame units by county by strata. Using this listing, a frame unit file was created at BBN. This concluded the ground data phase of the project.

II. LANDSAT Data Acquisition and Management

In order to cover completely the 9 Arizona counties with LANDSAT data, 13 scene locations were required. A standing order for all cloud free (less than 20%) imagery over this area during the period July 1, 1979 through September 1, 1979 was sent to the EROS Data Center (Distribution of U.S. LANDSAT Data) and a copy to the manager of Earth Resources Program at NASA/Johnson Space Center in Texas. This standing order requested the CCT's (Computer Compatible Tapes) and 1:1;000,000 black and white positive film transparencies for three multispectral scanner bands be sent to us automatically.

Counting passes by both LANDSAT II and LANDSAT III, we should have had available seven dates of imagery for each of the thirteen locations, giving a total of 91 scenes to choose from before checking cloud cover. By mid-December only 16 of the 91 possibilities had been received by EROS Data Center from NASA Goddard (the actual supplier). These 16 scenes covered 11 locations with five locations duplicated on two dates. One of the locations covered by only one date had a defective tape plus cloud cover problems, leaving effectively ten of our original 13 locations covered by LANDSAT imagery. Of the 15 scenes covering the ten areas, three had 70 percent or more cloud cover. Appendix A, Table A1 lists scene identifiers and specific dates of acquisition for the ten chosen scenes. Figure 1 shows approximate scene locations by path and row.

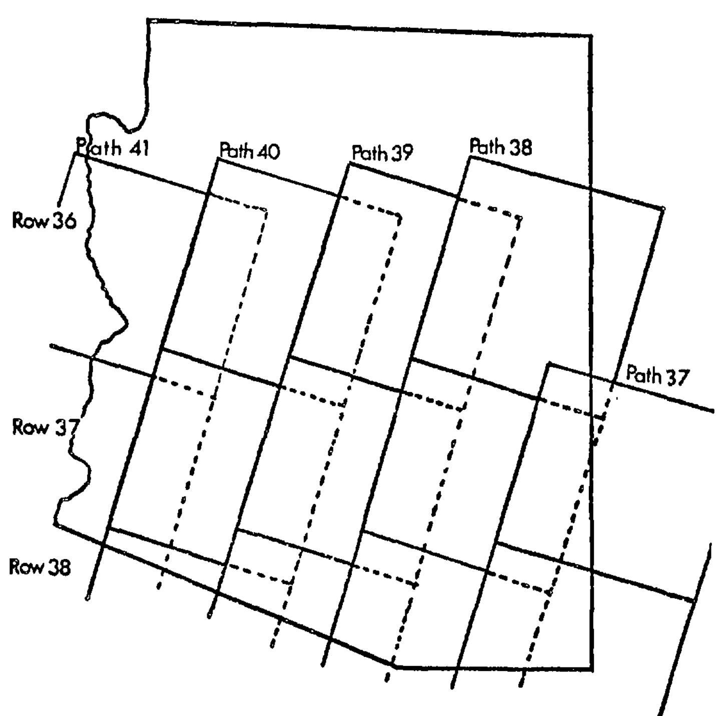

Figure 1. Approximate scene locations.

Included in the area not covered by LANDSAT were the entire counties of Greenlee, Cochise and Santa Cruz, plus parts (county mapsheets 9, 11, and 12) of Pima County. One additional scene was received December 26, 1979 at EROS but arrived too late to be analyzed. The scene covered only Greenlee County. Sources at NASA Goddard explained the missing data as a throughput problem at their Image Processing Facility (IPF). At last report, data shipped to EROS are approximately 60 percent of the data acquired.[2] NASA also felt that in addition to backlog, some of the scenes were permanently lost due to data retrieval problems associated with high density tapes at NASA Goddard.

Upon receipt of the raw data CCT's from EROS, several tasks were initiated. The raw data tapes were received in the EROS BIL (Band Interleave by Line) format and reformatted to the EDITOR system format (Band Interleave by pixel). Parameters were calculated for the amount of filler added to the scanner data for processing by EROS. Reformatting was done at the WCC and a copy of each EDITOR Format output tape was sent to BBN by mail. The first EROS copy arrived at RSB on July 26, 1979 and the last EDITOR reformat was mailed to BBN on August 27, 1979.

Reformat programs were also initiated to take the EDITOR format tapes and output tapes acceptable to the ILLIAC IV computer in California. These tapes were mailed in one group on November 9, 1979.

Using the 1:1,000,000 scale transparencies for each scene, the registration of LANDSAT data to a map base was begun. As an added aid to the registration process; 1:500,000 scale paper products were ordered for Band 5. Initial points corresponding to known map points were selected on the LANDSAT paper products. Grayscale printouts of the area surrounding the initial points were made. Comparisons of the map points and grayscale prints allowed more exact location of the corresponding points. For each scene, relationship between row-column and latitude-longitude was then estimated using a third order polynomial. These polynomials were used to create precision calibration files for each scene.

The precision calibration files in conjunction with the digitized segment files were then used to predict the segment locations in the LANDSAT data. Grayscales of the predicted locations of segments were produced and checked against plotter output at the same scale showing segment and field boundaries. A local calibration was done for each discrepancy between the predicted and actual location of a segment. Seldom were shifts larger than 2 pixels needed, with the vast majority of shifts needing only an approximately one pixel shift. When the segment shifting was completed we were ready to proceed with analysis.

III. Analysis Procedures and Results

The first step in analysis was to define the areas to be estimated within the individual scenes. Images from the same date (same path) were analyzed together and overlapping area designated into a specific scene. An analysis district was then defined for each path using county mapsheet boundaries when overlap area splitting was necessary. The four analysis districts were labeled: AZ38L, AZ39LM, AZ40KLM, and AZ41KL. Table A2 contains descriptions of the analysis districts, counties contained, and the number of segments contained in each.

Each of the four analysis districts was analyzed separately. Non-Agriculture strata areas were eliminated from the analysis. Within a specific analysis district, all segment data were "packed" together into one file and tabulated to determine the number of pixels present of different cover types. The unequal prior probabilities used in later analysis came from this tabulation, and were labelled PUR priors (for priors Proportional to Unexpanded Reported Area). Signature information was computed for any cover type having approximately 100 pixels available after boundary pixels and pixels in questionable fields were eliminated. Table A3 gives the tabulation of all available segment data by cover types for all analysis districts.

Several approaches were evaluated in order to create the final set of statistics (signatures) needed for pixel classification. Use of PUR prior probabilities versus using no or Equal Priors (EP) gave two possible options. Also considered was using a single category per cover (SCPC) versus multiple categories per cover (MCPC) to determine signatures. Thus four different statistics files were evaluated for each analysis district. Table A4 gives the number of training pixels available after elimination of boundary and questionable field pixels. Also in Table A4 are the number of categories used to describe signatures under the MCPC option as determined by our clustering methods. Notice from Table A4 that very little training data were available for sorghum and Pima cotton as compared to upland cotton and alfalfa (except for Pima cotton in AZ38L). Also notice that analysis districts A239LM and AZ40KLM cover parts of Maricopa county and when making a cover type estimate for this area, the cover type must be present in both analysis districts (Pima cotton is present in AZ39LM but not in AZ40KLM).

After creating the various statistics needed for each classification approach, all pixels interior to the segment boundaries were classified using the corresponding signatures. These categorizations would be used for evaluating each classifier and calculating regression parameters for estimation, called the small scale analysis.

The most important evaluator of classifier performance is not necessarily the percent of pixels correctly classified, but it is how well crop area is estimated for the area of interest. We use a regression estimator with JES data as the dependent variable and LANDSAT classified pixels as the independent variable. Maximization of the R-square values minimizes the variance of the regression estimates resulting from a classification. Thus, the major criterion used to compare classifier performance was the respective R-squares. Another measure of classifier performance is to measure how much better the regression estimator is than the corresponding direct expansion estimator for the same area. This measure can be expressed by the relative efficiency (RE) and is defined as the ratio of the variance of the direct expansion to the variance of the regression estimator. Tables A5, A6, A7, and A8 give R-squares, RE, and percent correct measures for the major crops by analysis district.

Using the indicators mentioned above, one set of signatures was chosen for further analysis in each analysis district. In district AZ38L, the multiple category per crop, equal prior probabilities (MCPC-EP) classifier was judged "best". In the other three districts, the MCPC-PUR classifier was chosen, although the distinction between MCPC and SCPC using PUR priors was very small. The chosen classifier was then transferred to the ILLIAC IV computer in Ames, California where a full frame classification was done for each corresponding scene.

Pixels from the full frame classifications were then aggregated by county, area frame strata, and category. The aggregations for agriculture strata were then used with regression parameters from the small scale analysis to produce large scale estimates (analysis district and county level). Table A9 gives the large scale regression estimates versus their corresponding direct expansion estimates by crop and by analysis district. Notice that these estimates represent agriculture strata only. Table A10 gives estimates by crop at the county level where data for non-agriculture strata was prorated in from the JES expansion. In this table a direct expansion was used for the area in Pima County not covered by LANDSAT data.

IV. SUMMARY

The major emphasis of this project was to improve cotton and sorghum estimates in Arizona. Lack of training data for sorghum was a major problem, with 213 pixels being the most available in any one analysis district. One analysis district (covering Yuma County) contained no segments with sorghum.

In contrast to sorghum, large amounts of training data were available for upland cotton (ranging from 971 pixels in Graham County to 25,564 pixels in Maricopa). In addition, 1154 pixels were available for Pima cotton in Graham County. Both upland cotton and all cotton estimates were made for each analysis district, plus a Pima cotton estimate for Graham county. Classification accuracy was very good for all cotton, ranging from 66 to 89 percent correct over the four analysis districts. The relative efficiencies with respect to direct expansion were also very good, ranging from 2.02 to 6.07. R-squares for all cotton ranged from .53 to .84.

Comparison of the regression estimates for cotton with 1978 SSO estimates shows a substantial difference in level; with the regression estimates being lower. Comparing cotton regression estimates versus direct expansion (ground data only) for agricultural strata, the regression comes out larger than direct expansion but the direct expansion is within two standards errors of the regression.

LANDSAT coverage was not available for Cochise, Greenlee, and Santa Cruz counties; plus part of Pima County. Since Cochise is the largest corn producing county in Arizona, no corn estimates were available using LANDSAT data.

Estimates were made for minor crops in some counties. Alfalfa estimates in four counties followed a pattern similar to cotton, with regression estimates lower than 1978 SSO figures but higher than corresponding direct expansions. R-squares for alfalfa ranged from .02 to .66. Maricopa county had training data for three other crops: citrus, safflower, and sugarbeets. Of these, only the safflower estimate had a reasonable CV (at 11.8 percent).

Based on usual criteria of success, the R-square and relative efficiency, LANDSAT regression estimates for cotton were very good. In order to determine if the level of the estimates was correct, comparisons were made with 1978 cotton data. Regression estimates show cotton at a lower level than the 1978 figure, while 1979 preliminary cotton estimates at the state level show a significant increase.

REFERENCES

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2. LANDSAT Newsletter. National Aeronautics and Space Administration Bulletin No. 27, Goddard Space Flight Center, November 15, 1979.

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APPENDIX A

Table A1. LANDSAT Acquisitions Over Arizona

Scene Identifier	Image Date (1979)	Cloud Cover(%)	Band Quality	Path	Row
21646-17085	July 26	10	8888	38	36
21646-17092	July 26	10	8888	38	37
21629-17142	July 9	20	5555	39	36
21629-17145	July 9	10	8888	39	37
21629-17151	July 9	10	8888	39	38
21630-17201	July 10	0	8885	40	36
21630-17203	July 10	10	8888	40	37
21630-17210	July 10	10	8888	40	38
30484-17321	July 2	10	5888	41	36
30484-17323	July 2	10	5555	41	37

Table A2. Analysis District Descriptions

Label*	Counties Contained	Agric. Strata	Number of Segments
AZ38L	Graham	35	9
AZ39LM	Maricopa**	15	38
	Pima***	30	5
	Pinal	20	52
AZ40KLM	Maricopa**	15	52
AZ41KL	Yuma	25	24

*The label was formed using this format: AZXXYYY
AZ - State Abbreviation for Arizona
XX - Path Number
YYY - Letters Describing row(s) used (K=36, L-37, M=38)
**Path 39 contained county map sheets 1, 2, and 7; Path 40 the rest of Maricopa
***No LANDSAT coverage available for county map sheets 9, 11, and 12

Table A3: Tabulation of Segment Data By Cover Type and Analysis District (Values Shown are Reported Area in Pixels)

Cover Type	AZ38L	AZ39LM	AZ40KLM	AZ41KL
Alfalfa	539	3387	2556	3941
Barley	116	925	594	-
Citrus	-	1433	488	569
Corn	-	495	186	-
Durum Wheat	-	1098	106	443
Hay	-	513	402	17
Other Crops	36	2439	970	1157
Pasture	217	902	673	930
Pima Cotton	1844	1093	41	38
Potatoes	-	446	-	-
Safflower	-	1184	513	-
Sorghum	144	478	227	-
Sugar Beets	-	475	218	-
Summer Fallow	70	1785	2333	417
Unknown	6	466	4	29
Upland Cotton	1391	21357	16938	5279
Waste Land	1689	32125	11379	3995
Winter Wheat	-	1144	792	2832
Woodland	-	29	21	5
Total	6052	71774	38441	19652

Table A4: Tabulation of Usable Training Data and Corresponding MCPC Categories by Cover Type

Cover Type	AZ38L		AZ39LM		AZ40KLM		AZ41KL	
	Training Pixels	Number of Categories	Training Pixels	Number of Categories	Training Pixels	Number of Categories	Training Pixels	Number of Categories
Alfalfa	346	4	1813	3	1727	6	2281	5
Barley	77	3	432	3	368	4	-	-
Citrus	-	-	1045	8	252	2	34	-
Corn	-	-	89	-	143	3	-	-
Durham Wheat	-	-	652	2	-	-	149	3
Hay	-	-	61	-	299	4	-	-
Other Crops	12	-	1143	2	540	4	634	3
Pasture	142	4	547	4	191	4	2	
Pima Cotton	1154	8	559	2	26	-	-	-
Potatoes	-	-	302	2	-	-	-	-
Safflower	-	-	732	3	319	3	-	-
Sorghum	114	2	213	5	111	1	-	-
Sugar Beets	-	-	275	2	162	2	-	-
Summer Fallow	4	-	1130	3	1478	6	-	-
Unknown	2	-	321	-	-	-	16	-
Upland Cotton	971	8	13430	5	12134	8	2907	8
Urban*	-	-	105	1	76	2	273	2
Waste Land	473	4	12217	6	6001	6	2219	7
Water*	588	1	588	1	763	1	2311	5
Winter Wheat	-	-	517	3	611	4	1647	8
Woodland	-	-	19	-	7	-	1	-

*Added, not found in segment data

Table A5: Classifier Evaluation - AZ38L

Cover Type	Classifier	Percent Correct	R^2	RE
Cotton Upland	MCPC, PUR	45.58	.6735	2.68
	MCPC, EP	53.13	.6281	2.35
	SCPC, PUR	32.71	.5758	2.06
	SCPC, EP	42.34	.5911	2.14
Cotton Pima	MCPC, PUR	58.51	.7463	3.49
	MCPC, EP	45.44	.7701	3.81
	SCPC, PUR	66.54	.5296	1.86
	SCPC, EP	26.68	.7057	2.97
All Cotton	MCPC, PUR	82.07	.7457	3.44
	MCPC, EP	77.25	.7906	4.19
	SCPC, PUR	83.77	.7236	3.17
	SCPC, EP	58.42	.8977	8.55
Alfalfa	MCPC, PUR	33.40	.6737	2.68
	MCPC, EP	28.57	.6635	2.60
	SCPC, PUR	19.11	.5379	1.89
	SCPC, EP	29.50	.3178	1.28
Sorghum	MCPC, EP	72.22	.8274	5.07
Overall	MCPC, PUR	51.28	-	-
	MCPC, EP	44.73	-	-
	SCPC, PUR	50.29	-	-
	SCPC, EP	37.15	-	-

Table A6: Classifier Evaluation - AZ39LM

Cover Type	Classifier	Percent Correct	R^2 by Strata 15	20	30	20, 30*	RE**
Cotton Upland	MCPC, PUR	77.92	.8179	.7701	.8316	.7737	4.52
	MCPC, EP	40.72	.8531	-	-	.7368	4.28
	SCPC, PUR	81.05	.8318	-	-	.7669	4.61
	SCPC, EP	36.31	.8777	-	-	.6821	3.72
Alfalfa	MCPC, PUR	25.57	.5459	.0225	.0000	.0244	1.55
	MCPC, EP	29.02	.6079	-	-	.0084	1.67
	SCPC, PUR	27.16	.6324	-	-	.0607	1.77
	SCPC, EP	28.40	.5508	-	-	.0221	1.58
Safflower	MCPC, PUR	40.03	.6200	.8081	-	.8081	4.93
	MCPC, EP	47.80	.2819	-	-	.7158	4.14
	SCPC, PUR	33.38	.9028	-	-	.7241	3.71
	SCPC, EP	58.19	.1946	-	-	.8205	4.97
Sorghum	MCPC, PUR	4.81	.0047	-	-	.0430	1.00
	MCPC, EP	34.31	.0081	-	-	.0231	1.00
	SCPC, PUR	0.21	.0031	-	-	.0314	1.00
	SCPC, EP	14.64	.0012	-	-	.0134	1.00
All Cotton	MCPC, PUR	78.33	.8266	.8097	.8102	.8020	5.03
Pima Cotton	MCPC, PUR	4.94	.0986	.0672	.0000	.0634	1.11
Citrus	MCPC, PUR	14.52	.6026	.0000	-	-	2.45
Sugar Beets	MCPC, PUR	12.42	.5812	-	-	.0139	1.97
Overall	MCPC, PUR	64.69	-	-	-	-	-
	MCPC, EP	35.55	-	-	-	-	-
	SCPC, PUR	67.82	-	-	-	-	-
	SCPC, EP	25.10	-	-	-	-	-

*Combined Regression
**Using Separate Regression Where Available

Table A7: Classifier Evaluation - AZ40KLM

Cover Type	Classifier	Percent Correct	R^2	RE
Upland Cotton	MCPC, PUR	88.68	.8377	6.04
	MCPC, EP	57.06	.8636	7.19
	SCPC, PUR	90.64	.8102	5.17
	SCPC, EP	45.01	.8087	5.12
Alfalfa	MCPC, PUR	35.76	.6600	2.88
	MCPC, EP	48.55	.5057	1.98
	SCPC, PUR	23.98	.6394	2.72
	SCPC, EP	30.05	.2519	1.31
Safflower	MCPC, PUR	57.89	.9562	22.38
	MCPC, EP	69.20	.8712	7.61
	SCPC, PUR	49.51	.9231	12.75
	SCPC, EP	58.87	.6952	3.22
Sorghum	MCPC, PUR	44.93	.7991	4.88
	MCPC, EP	46.26	.7854	4.57
	SCPC, PUR	44.93	.7913	4.70
	SCPC, EP	48.02	.6385	2.71
All Cotton	MCPC, PUR	88.62	.8385	6.07
Sugar Beets	MCPC, PUR	1.83	.1663	1.18
Citrus	MCPC, PUR	23.98	.7500	3.92
Overall	MCPC, PUR	65.22	-	-
	MCPC, EP	44.74	-	-
	SCPC, PUR	65.78	-	-
	SCPC, EP	34.56	-	-

Table A8: Classifier Evaluation - AZ41KL

Cover Type	Classifier	Percent Correct	R^2	RE
Upland Cotton	MCPC, PUR	65.79	.5343	2.05
	MCPC, EP	57.13	.4496	1.74
	SCPC, PUR	73.16	.5123	1.96
	SCPC, EP	44.52	.5181	1.98
Alfalfa	MCPC, PUR	48.16	.5617	2.18
	MCPC, EP	42.25	.5449	2.10
	SCPC, PUR	35.22	.5790	2.27
	SCPC, EP	52.07	.4702	1.81
Durham Wheat	MCPC, PUR	26.64	.6001	2.39
	MCPC, EP	41.99	.3662	1.51
	SCPC, PUR	4.74	.1764	1.16
	SCPC, EP	29.12	.3029	1.37
All Cotton	MCPC, PUR	65.79	.5321	2.04
Overall	MCPC, PUR	48.16	-	-
	MCPC, EP	52.17	-	-
	SCPC, PUR	56.30	-	-
	SCPC, EP	49.95	-	-

Table A9: Regression Versus Direct Expansion - Agriculture Strata Only

Analysis District	LANDSAT Regression Estimate (ha)	LANDSAT Regression CV(%)	Direct Expansion Estimate (ha)	Direct Expansion CV(%)
All Cotton				
AZ38L	9600	8.2	8400	19.3
AZ39LM	90900	4.2	88400	9.6
AZ40KLM	53300	4.1	51800	10.4
AZ41KL	33800	10.4	30200	16.6
Overall	187600	3.0	178700	6.4
Upland Cotton				
AZ38L	4100	16.6	3700	28.4
AZ39LM	86300	4.4	84200	9.6
AZ40KLM	53200	4.1	51600	10.4
AZ41KL	33500	10.4	299000	16.7
Overall	177000	3.2	169400	6.6
Alfalfa				
AZ38L	1800	21.2	1400	43.3
AZ39LM	17500	12.4	12200	21.4
AZ40KLM	10000	12.4	7900	26.4
AZ41KL	24100	15.0	23700	22.5
Overall	53400	8.3	44900	14.1
Pima Cotton				
AZ38L	5900	10.7	4700	26.2
AZ39LM	-	-	4200	30.6
AZ40KLM	-	-	100	95.0
AZ41KL	-	-	200	97.4
Overall	-	-	9300	19.5
Safflower				
AZ39LM	2200	35.5	5100	35.5
AZ40KLM	2300	8.1	1600	54.6
Durum Wheat				
AZ39LM*	4400	32.2	5100	33.9
AZ41KL	2400	45.5	2500	68.9

*Pinal County Only

Table A9 Continued

Analysis District	LANDSAT Regression		Direct Expansion	
	Estimate (ha)	CV(%)	Estimate (ha)	CV(%)
Sugar Beets				
AZ39LM**	1200	43.9	1200	64.1
AZ40KLM	400	97.1	700	66.6
Citrus				
AZ39LM**	2700	54.0	5000	45.2
AZ40KLM	1600	26.3	1600	55.3
Sorghum				
AZ38L	900	23.5	500	94.2
AZ39LM	-	-	2100	49.7
AZ40KLM	500	39.4	700	65.9
AZ41KL	-	-	0	0
Overall	-	-	3300	37.3

**Maricopa County Only

Table A10: County Level Estimates

	1978 SSO[3/] Estimate	1979 LANDSAT Regression (ha)	Regression CV (%)
All Cotton			
Graham	11700	9600	8.2
Maricopa	95500	85100	7.0
Pima	11300	9600	22.3
Pinal	59600	56700	5.2
Yuma	36500	33800	10.4
Upland Cotton			
Graham	8100	4100	16.6
Maricopa	92500	83800	7.1
Pima	10100	8900	22.2
Pinal	56700	53900	5.7
Yuma	34400	33500	10.4
Pima Cotton			
Graham	3600	5900	10.7
Alfalfa			
Graham	3600	2400	24.5
Maricopa	34400	24200	7.9
Pinal	6500	3000	51.1
Yuma	26700	24100	15.0
Safflower			
Maricopa	1000	2300	11.8
Pinal	1400	2200	35.4
Durham Wheat			
Pinal	15800	4400	32.2
Yuma	5700	2400	45.5
Sugar Beets			
Maricopa	3400	1600	41.2
Citrus			
Maricopa	*8600	4300	34.9

Table A10 Continued

	1978 SSO[3/] Estimate	1979 LANDSAT Regression (ha)	Regression CV (%)
Sorghum			
Graham	3200	900	22.9

*1978 Bearing Area