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Multitemporal vs. Unitemporal Analysis of
MSS Landsat Data on a Full State Basis

by

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1985

INTRODUCTION

The Statistical Reporting Service (SRS) in its Domestic Crops and Land Cover (DCLC) project is currently using Landsat data combined with ground truth data to provide acreage estimates in seven mid-western states. The ground truth data are collected during the June Enumerative Survey (JES) conducted by SRS in early June. As a part of the DCLC project, Landsat regression acreage estimates for corn, cotton, rice, sorghum, and soybeans in Missouri were presented to the Crop Reporting Board of the Statistical Reporting Service, United States Department of Agriculture on December 15, 1984. Similar estimates for planted and harvested winter wheat acreages were presented on December 5, 1984 to the same board.

Use of Landsat data to produce these estimates implied that both spring (April-May) and summer (July-August) Landsat MSS scenes be analyzed to produce estimates for winter wheat and spring planted crops. A unitemporal approach requires two full analyses; one on the spring data to produce Landsat estimates for fall planted crops and a second on the summer data for spring planted crops. A multitemporal analysis allows a single analysis on the combined spring and summer data. A combination of unitemporal and multitemporal analysis was used for the 1984 crop year because of the earlier due date for the winter wheat estimates, some doubts as to the software efficiency for multitemporal processing, and a desire to make a comparison between unitemporal and multitemporal processing. Unitemporal analysis for winter wheat estimates could be started much earlier than a multitemporal analysis since analysis could begin as soon as the spring Landsat scenes were acquired and the ground truth data were edited in late June. Multitemporal analysis requires that scenes for both dates be in-house before processing can begin. Since many of the spring planted crops were not planted at the time of the primary ground data collection effort in June, an intentions follow-up survey must also be conducted and edited before analysis can proceed to assure accurate ground truth data for estimating acreages of spring planted crops.

The 1984 analysis was done as follows:

1. Unitemporal analysis for winter wheat
2. Multitemporal analysis for all crops
3. Unitemporal analysis for all spring planted crops

The third analysis was done in January after the Crop Reporting Board request was met. Except for registration of scenes and the number of data channels, the analysis procedures for unitemporal and multitemporal data were the same.(1)

REGISTRATION OF LANDSAT DATA

Scene to Map. The spring scenes were designated as the primary scenes and were registered in the usual unitemporal manner.(2) This method has been presented many times and will not be discussed here.

Scene to Scene. When the summer scenes were acquired, 12 to 24 corresponding points were digitized on each scene using features clearly identifiable on both scenes. Using these points, blocks of pixels from each scene were correlated on the CRAY computer at NASA-Ames. Two channels from each scene were used. This procedure is fully explained by Ozga and Sigman.(3) The output was then used to create an eight channel data set. The coordinates of the pixels in this data set were the same as for the primary scene.

Underscored numbers in parenthesis refer to literature cited at the end of this report.

Multitemporal Data Set. The eight channel data set, for use in the multitemporal analysis, was generated by combining the spring and summer scenes using the coordinates of the spring scenes. Data channels 1, 2, 3, and 4 were created from the spring scene and data channels 5, 6, 7, and 8 from the summer scene. Therefore, it was not necessary to recalibrate the ground truth data to the summer scenes when doing the unitemporal analysis of the summer data. By picking channels 5, 6, 7, and 8 to be read from the eight channel data set, four channel output for a unitemporal data set were obtained representing the summer data.

SOME COST CONSIDERATIONS

Because of time and money constraints, it was not possible to completely separate the unitemporal and multitemporal processing to evaluate the cost for each analysis. However, we did observe that processing the generated eight channel data through the clustering and classification algorithms used approximately four times the computer resources that four channel data used. SRS uses a supervised clustering algorithm which clusters Landsat pixels within known crop covers. It is assumed that pixels from a given cover type come from a number of multivariate normals. The clustering algorithm is designed to find the means and covariances of the matrices representing these normals. The classification procedure used to assign a category to each pixel in the data set uses the statistics developed in clustering and a maximum likelihood algorithm to make the category to pixel assignment. Processing that reads and/or writes the eight channel data (window creation, packing, greyscales, and scattergramming) used twice the resources as the corresponding four channel data. Window creation is the extraction of Landsat data around each sample unit. Packing is the assignment of the window data (pixels) from all training units within the analysis area to the covers identified to be in the training area. Greyscales are black and white representations of a window for a single channel. Scattergramming is the process of displaying a packed file by plotting two channels; one on the horizontal axis and one on the vertical axis. Processing that did not involve raw Landsat MSS data was not impacted. Affected costs of scene-to-scene registration and creating the eight channel data set were offset somewhat by eliminating registration and calibration procedures for the secondary scene. We estimate that multitemporal analysis processing would cost about 125 percent of a single unitemporal analysis. However, the reduced professional labor in developing the classifier would offset part of this increased cost.

In states like Missouri, where both fall and spring planted crops are to be estimated, multitemporal analysis has a cost advantage since two unitemporal analyses are otherwise required.

RESULTS

For all crops, multitemporal analysis reduced the standard error of the estimate from the standard error of the unitemporal estimate. Standard errors of the unitemporal and multitemporal estimates are shown in Table 1. Unitemporal analysis achieved the greatest reduction in standard errors for rice, with a 47 percent reduction over the standard error of the JES direct expansion estimate. Additional reductions in standard errors of multitemporal over unitemporal analysis were greatest for sorghum with a 27 percent decrease. The overall reduction of standard errors for multitemporal analysis over the standard errors for the JES direct expansion were greatest for rice with a 49 percent reduction. The smaller standard errors for multitemporal verses unitemporal analysis for corn, sorghum, and soybeans, translates into a 30 to 40 thousand acre reduction. For winter wheat, this reduction was in the 10 to 12 thousand acre range. It was expected that the improvement for winter wheat might be minimal since a preferred pairing of scenes for winter wheat multitemporal analysis would be previous fall and spring scenes.

TABLE 1.
Comparison of Results of Multitemporal vs.
Unitemporal Analysis - in Missouri 1984

CROP	Direct Expansion[1/] TOTAL (000)Ac.	S.E.	C.V. (%)	Unitemporal TOTAL (000)Ac.	S.E.	C.V. (%)	R.E.	Multitemporal TOTAL (000)Ac.	S.E.	C.V. (%)	R.E.
CORN	2,107	183	8.7	1,782	148	8.2	1.5	2,019	110	5.5	2.8
COTTON	122	45	37.1	115	30	26.0	2.2	204	28	13.8	2.6
RICE	140	47	48.5	105	25	23.3	3.5	63	24	38.7	6.8
SORGHUM	1,552	175	11.3	1,364	147	10.8	1.4	1,361	108	7.9	2.6
SOYBEANS	6,006	298	5.0	5,395	195	3.6	2.3	5,655	165	2.9	3.2
WW-PL	2,403	172	7.2	2,137	129	6.0	1.8	2,348	118	5.0	2.1
WW-HV	2,246	165	7.3	2,045	126	6.2	1.7	2,024	114	5.6	2.1

1/ The JES Direct Expansion (D.E.), Standard Error (S.E.), and Coefficient of Variation (C.V.), are before the DCLC Field Level Edit.

The attached charts by crop show the relationship of the estimates and their 95 percent confidence intervals. For soybeans, the unitemporal estimate was outside the 95 percent confidence limit of the direct expansion estimation. For cotton, the multitemporal estimate was outside the 95 percent confidence interval for the unitemporal estimate. With 21 comparisons between the seven crop estimates, this has a high likelihood of being due to chance.

1985 ANALYSIS PLANS

SRS plans to make further evaluations of the benefits of using multitemporal Landsat data for making crop acreage estimates. Oklahoma will be done with multitemporal scenes for winter wheat using 1984 fall scenes and 1985 spring scenes. Arkansas and Missouri will be done with the spring-summer pairs.

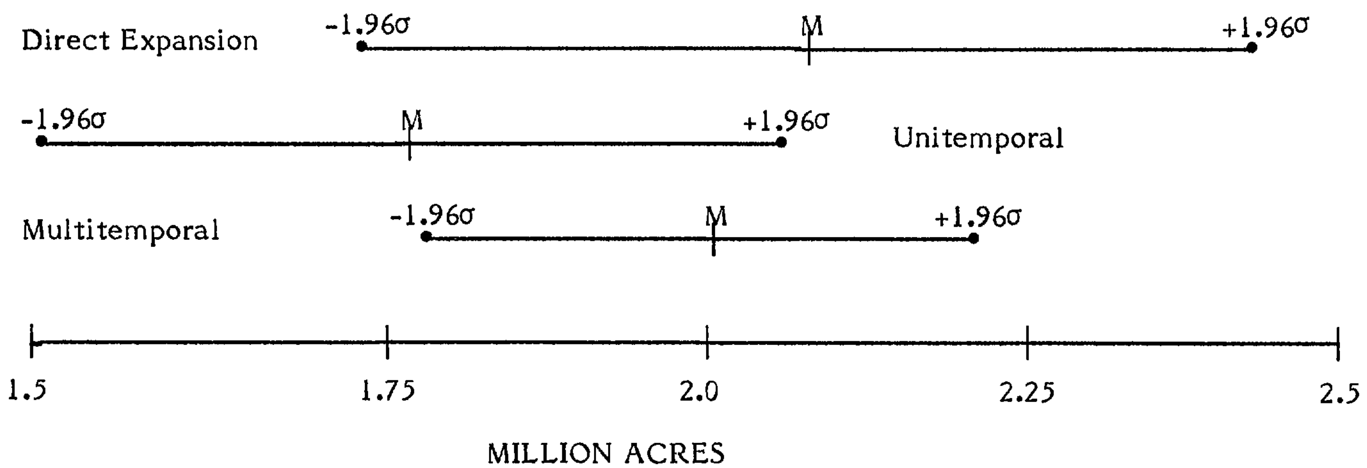
CONCLUSION

Multitemporal analysis saves both time and money over two separate unitemporal analyses when both spring and summer scenes are required for the same path-row combinations. The reduction in variance of the estimates, easier training of the classifier, and the shifting of workload to an earlier date make it attractive even where both spring and summer scenes are not required. However, if both spring and summer scenes are not required, there would be additional costs over a unitemporal analysis. Cloud cover can be more of a problem in multitemporal analysis, especially if only one satellite is operational since it may be difficult to obtain complete cloud free coverage for both dates chosen for the multitemporal analysis.(4)

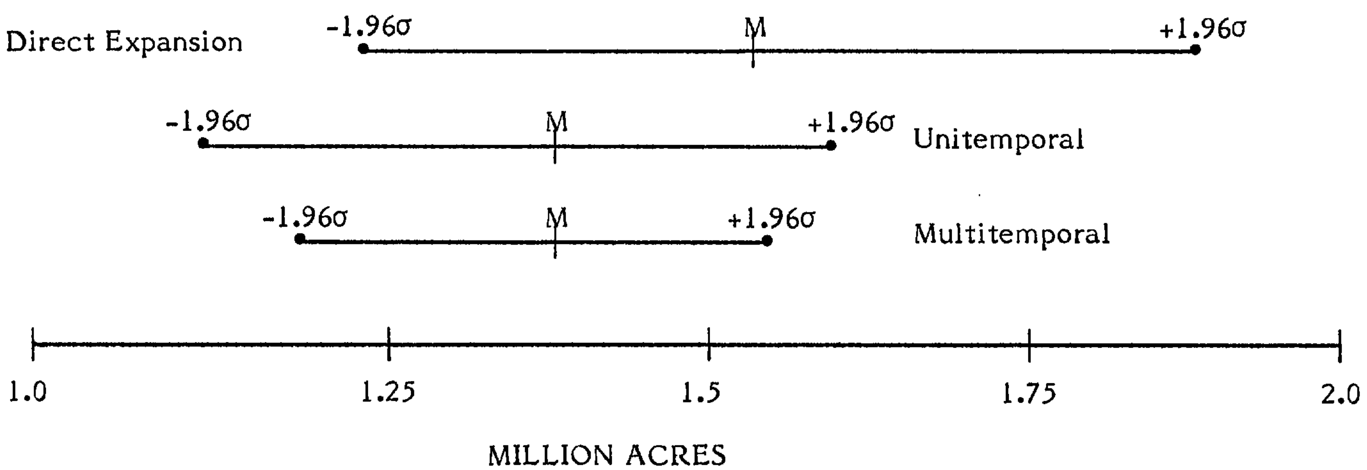
Confidence Intervals at the 95 Percent Level of Estimates by Direct Expansion, Unitemporal, and Multitemporal Analysis

Missouri 1984

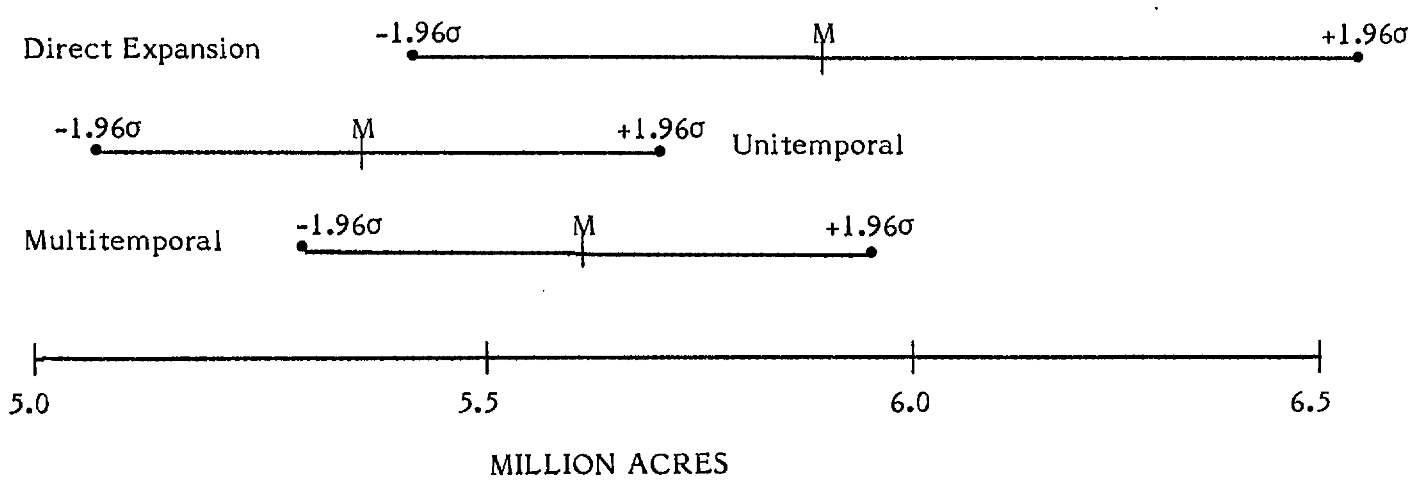
CORN



SORGHUM



SOYBEANS

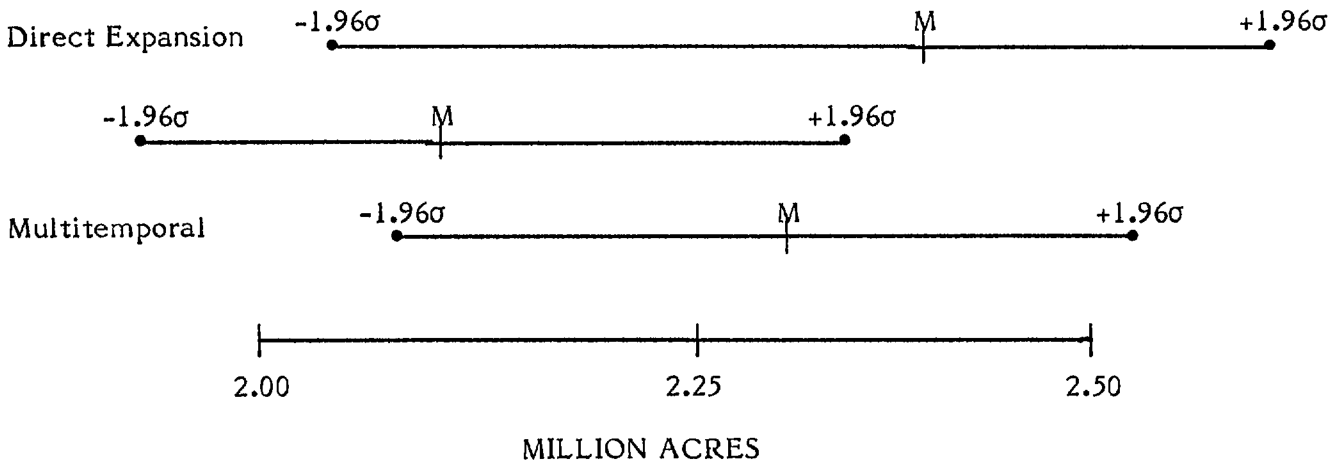


M = Mean

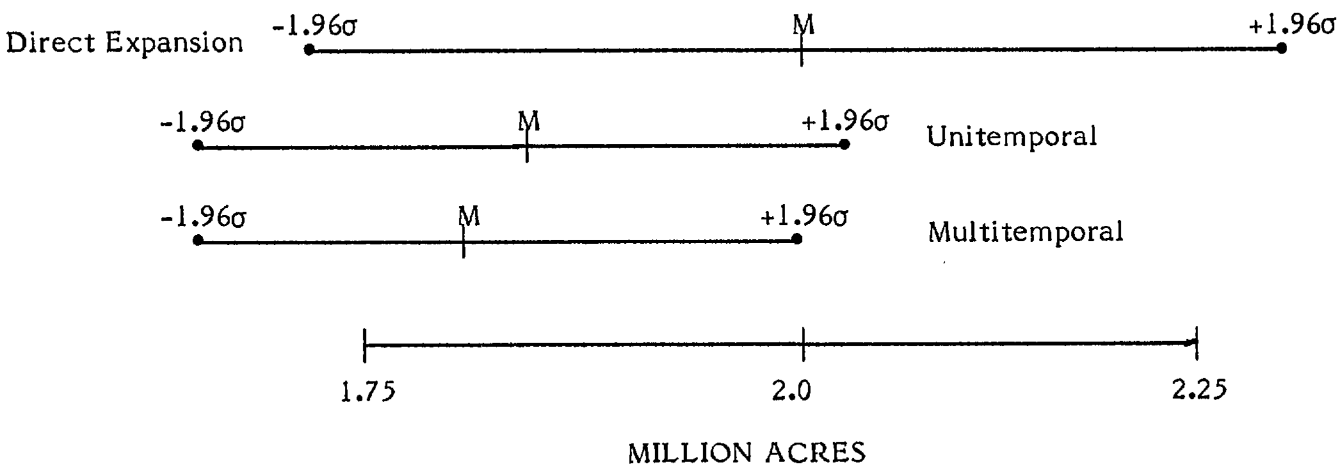
Confidence Intervals at the 95 Percent Level of Estimates by Direct Expansion, Unitemporal, and Multitemporal Analysis

Missouri 1984

WINTER WHEAT PLANTED ACREAGE



WINTER WHEAT HARVESTED

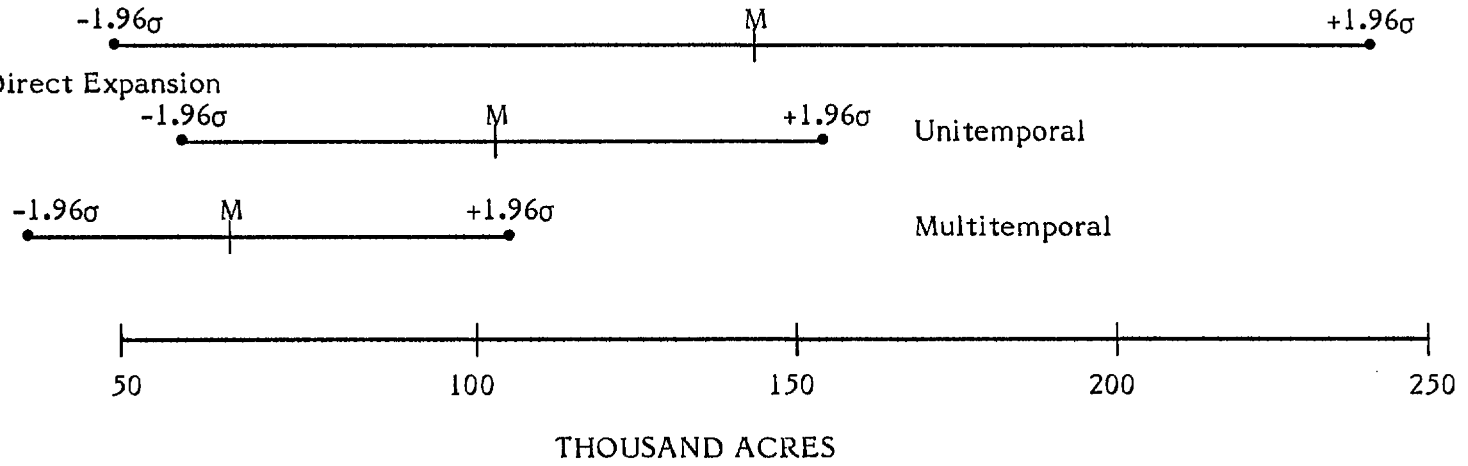


M = Mean

Confidence Intervals at the 95 Percent Level of Estimates by Direct Expansion, Unitemporal, and Multitemporal Analysis

Missouri 1984

RICE



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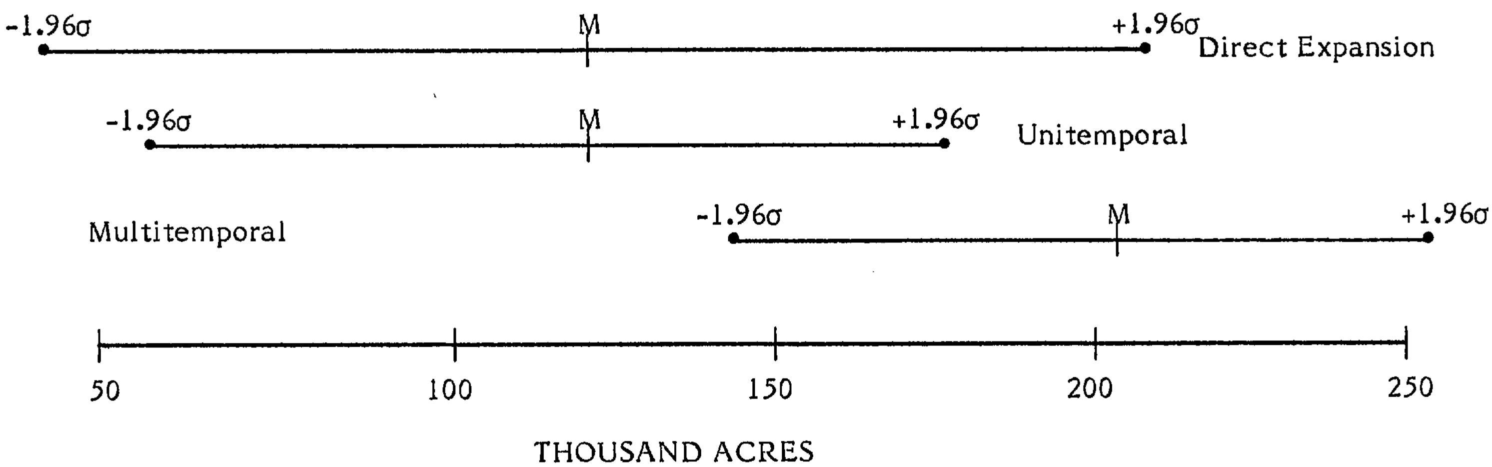
COTTON



M = Mean

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(2) Cook, Paul W., Landsat Registration Methodology Used by U.S. Department of Agriculture's Statistical Reporting Service, U.S. Department of Agriculture, May 1982.

(3) Ozga, M., and Sigman, R.S., Editor Multitemporal System, Statistical Reporting Service, U.S. Department of Agriculture, November 1979.

(4) Winings, S.B., Landsat Image Availability for Crop Area Estimation, Statistical Reporting Service, U.S Department of Agriculture, July 1982.