EVALUATING THE ACCURACY OF 2005 MULTITEMPORAL TM AND AWiFS IMAGERY FOR CROPLAND CLASSIFICATION OF NEBRASKA

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ABSTRACT

Since 1997, the USDA/National Agricultural Statistics Service (NASS) created an annual cropland classification known as the Cropland Data Layer (CDL) using thirty meter Landsat TM and since 1999, the ETM+. Historically, the Landsat 5 and 7 satellites provided adequate temporal coverage to create the CDL products with a high degree of reliability and statistical accuracy. Due to the uncertainty of the availability of TM 5 data for the 2006 crop growing season, USDA and NASS have been using AWiFS as a primary imagery source. In 2005**,** there was sufficient cloud-free imagery to cover most of Nebraska with multitemporal TM**,** using 31 scenes forming 7 analysis districts and multitemporal AWiFS**,** using 7 scenes forming 3 analysis districts. Both sets of data were processed separately using the same methodology that was used to create the NASS CDL. The CDL is created by ISODATA clustering of known cover types by analysis district from a statewide coverage of 470 segments representing 650 square miles and applying a maximum likelihood classifier. Crop coverage estimates are generated by analysis district using in order of preference: regression, pixel ratio or direct expansion. Analysis districts are mosaiced and clipped to minimize clouds and maximize higher quality classification. This analysis will compare the percent correct, Kappa accuracies, and regression estimates by analysis district and at the state level. Preliminary results show that although the quality of the AWiFS estimates are not as high as TM they will still provide valuable statistics to the NASS estimation program and warrants continued investigation into this sensor.

INTRODUCTION

The Cropland Data Layer (CDL) provides internal county and state acreage estimates which supplement other survey indications for major crops for the estimation program of the National Agricultural Statistics Service (NASS). The CDL also provides a geo-referenced, categorized land cover product to the public after county estimates have been released. From 1997 through 2005, the basis of the CDL has been Landsat 5 and 7 imagery coupled with ground truth from the June Agricultural Survey (JAS). The Landsat sensors have provided ideal imagery with 30 meter pixels, spectral bands sufficient for categorizing agriculture, and repeat coverage throughout the growing season.

Due to the age and recent problems with Landsat 5, and the scanline issue with Landsat 7, the availability of useful imagery across the growing season from the current Landsat system has been uncertain. The Indian Remote Sensing's (IRS) Resourcesat-1 Advanced Wide Field Sensor (AWiFS) sensor has some characteristics in common with Thematic Mapper (TM) that make it a potential substitute for creating the CDL. Four spectral bands are collected and are equivalent to bands 2, 3, 4, 5 of the Landsat TM. Although the AWiFS sensor has a pixel size of 56 meters compared to 30 meters for the TM, this should not be a problem since the field sizes for primary crops in Nebraska and other CDL states are relatively large. While the spatial and spectral resolution are decreased for the AWiFS compared to the TM, the wide swath of 737 kilometers for the AWiFS versus 185 kilometers for the TM provides a much wider coverage and a greater opportunity for multiple cloud free imagery during the growing season. A path is repeated every 24 days although with a sidelap of about 40 percent at a latitude of 40 degrees, coverage for any point on the ground is repeated every 5 days (NRSA, 2003).

Peditor, the in-house classification and editing software used for this comparison can use one (unitemporal) or two dates (multitemporal) of imagery to process an area. An area covered by a unique date or dates is referred to as an analysis district. Multitemporal imagery provides superior discrimination and classification of land covers and is used whenever possible. This research expands on a unitemporal AWiFS classification of Nebraska for 2004 (Boryan and Craig, 2005) that demonstrated the potential usefulness of AWiFS for the CDL program.

NASS collects the remote sensing field level training data during the June Agricultural Survey. This is a national survey based on a stratified random sample of land areas selected from each state's area frame. An area frame is a land use stratification based on percent cultivation. Nebraska has three agricultural strata; stratum 11 is more than 80 percent cultivated, stratum 12 is 51 to 80 percent cultivated, and stratum 20 is 15 to 50 percent cultivated. The enumerators are given questionnaires and a 1:8,000 scale aerial photo to ask the farmers what, where, when and how much are they planting. The survey focuses on cropland, but the enumerators record all land covers within the sampled area of land whether it is cropland or not. NASS uses broad land use categories to define land that is not under cultivation, including; non-agricultural, pasture/rangeland, waste, woods, and farmstead. The aerial photos are digitized and become the ground truth for classification.

METHODOLOGY

To design the analysis districts, scenes are selected to minimize clouds and to maximize the spectral distinction between crops. If only one date of observation is available a mid summer date is preferred. If only a unitemporal early spring date, from March to May or a unitemporal fall date from September to October is available during the growing season, then it is best to not use that scene or analysis district for estimation, as bare soil in the spring and fully senesced crops in the fall will create confusion between crops. Figure 1 shows the cumulative crop progress and condition of corn in Nebraska in 2005. This chart is based on data from the NASS crop progress and condition survey which is a non-probability subjective survey conducted for states with major crops (http://www.nass.usda.gov/research/CropProgress/cpindex.htm). The analyst can match the date of available imagery with the progress of the crop to find the optimal dates.

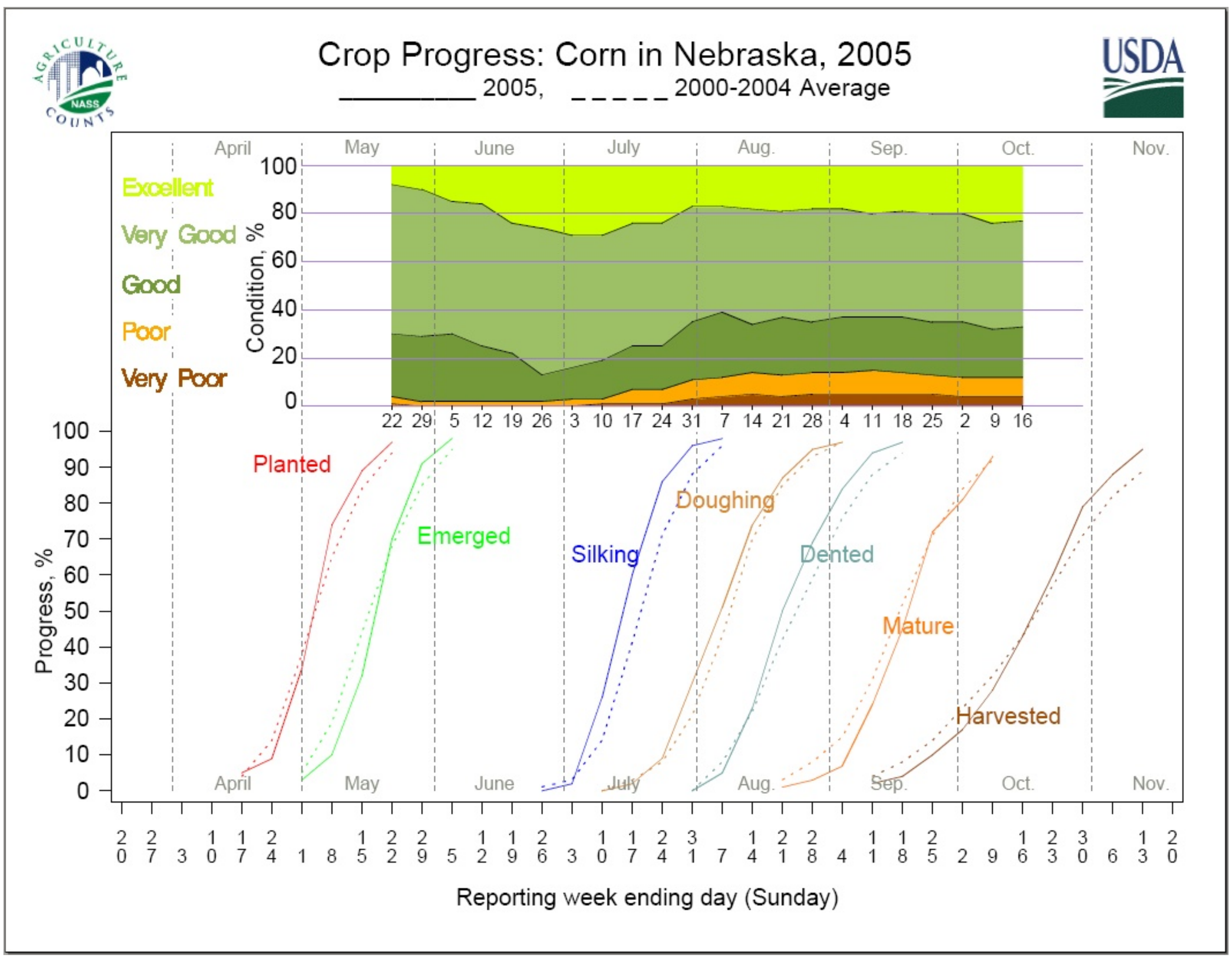

Figure 1. Knowing each crop's progress helps to select optimal imagery when multiple dates are available.

Figure 2 shows the results of the selection process for TM imagery. Nebraska was covered by 31 scenes making up 7 analysis districts. Some of the dates are not ideal due to the limited availability of cloud free imagery on Landsat's 16 day repeat cycle. Analysis districts AD03 and AD07 had only single date cloud-free imagery. Most of the imagery was acquired after corn and soybeans have emerged and before senescence. The exceptions are the early dates of 5/15/06 for AD01 and 4/06/05 for AD02 where the soil would still be visible for corn and soybeans. On the other hand, these dates would be good for winter wheat while anything after mid-June would be poorer for winter wheat.

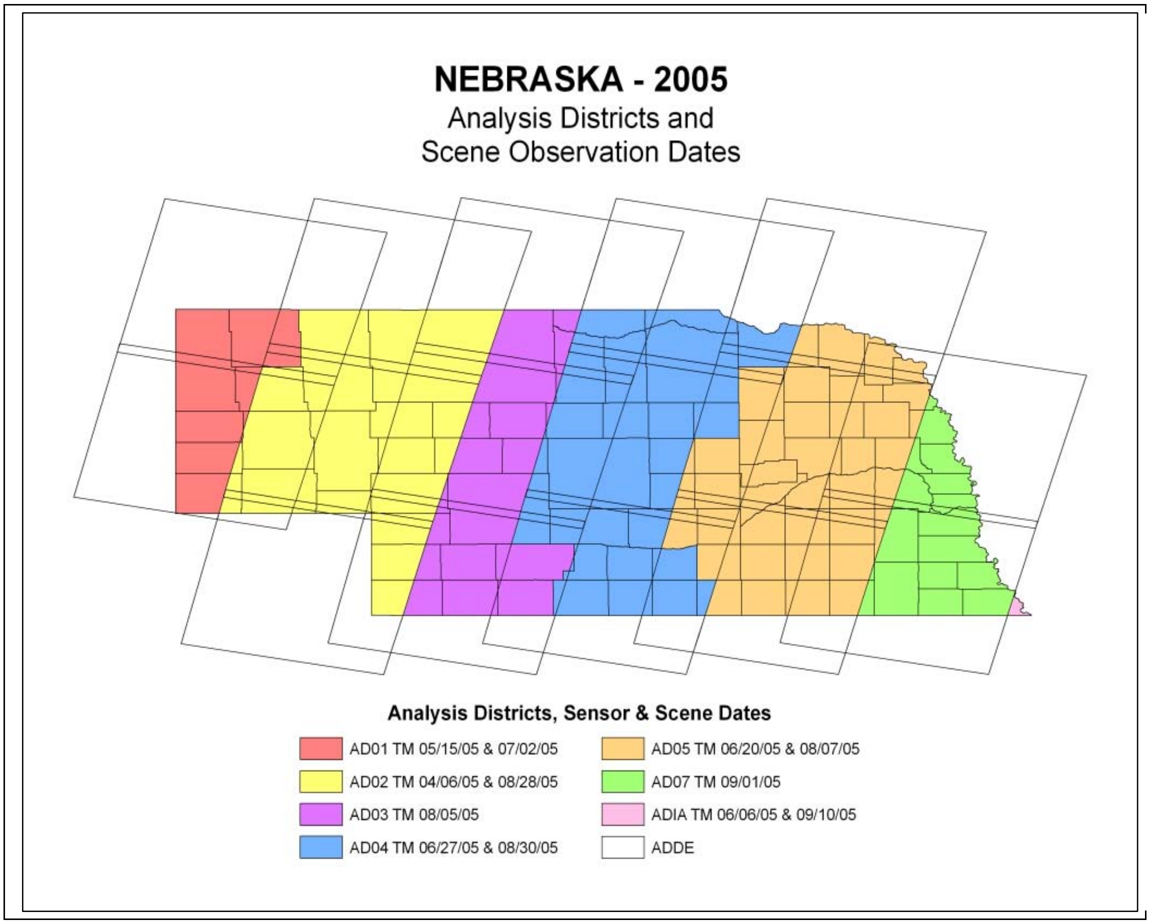

Figure 2. TM analysis districts having mostly cloud free imagery.

In 2005 a limited quantity of AWiFS imagery was collected during the growing season. The AWiFS analysis districts in Figure 3 were constructed with imagery that was mostly cloud-free and the most optimal dates for the spectral separation of crops. Due to the wide swath of the AWiFS compared to the TM, Nebraska was covered by 3 analysis districts made up of 9 scenes and 4 unique dates. When compared to the crop progress and condition charts, the June and August dates are good choices for corn and soybean but a poor choice for winter wheat.

The clustering/classification is an iterative process, as fields get misclassified, they can be fixed or marked as bad for training and reprocessed. Known pixels are separated by cover type and clustered, within cover type using a modified ISODATA clustering algorithm, as it allows for merging and splitting of clusters (Bellow and Ozga, 1991). Modified implies that the output clusters are not labeled (other than as coming from the input cover type) as they can be reassigned later if desired. Clustering is done separately for each cover type (or specified combination of cover types, such as all small grains). The clustered cover types are then assembled together into one signature file, where entire scenes are classified using the maximum likelihood algorithm (Craig, 2001).

Clustering is based on the LARSYS (Purdue University) ISODATA algorithm. It performs an iterative process to divide pixels into groups based on minimum variance. The pairs of clusters in close proximity (based on Swain-Fu distance) are merged. High variance clusters can be split into two clusters (variance of first principal component is used as a measure). The output of any clustering program is a statistics file which stores mean vectors and covariance matrices of final set of clusters.

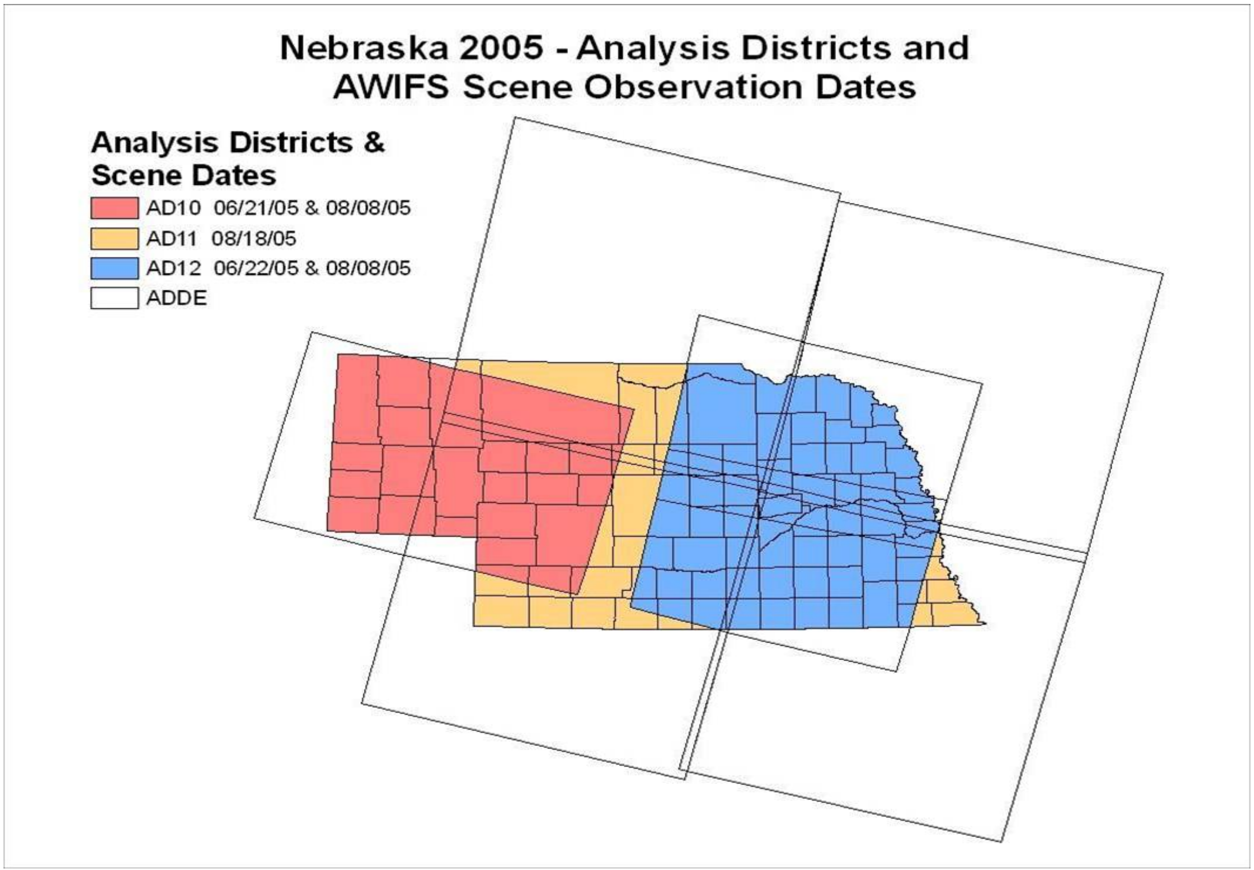

Figure 3. AWiFS with its much wider swath required few scenes to cover the state of Nebraska.

The outputs are a categorized or classified image in PEDITOR format and the associated accuracy statistics for each cover type. The maximum likelihood classifier performs a pixel-by-pixel classification based on the final, combined statistics file. It calculates the probability of each pixel being from each signature; then classifies a pixel to the category with highest probability. The processing time depends on size of file to be classified (i.e. number of pixels), number of categories in the statistics file and number of input dimensions (number of bands/pixel).

Three estimation methods are available for each analysis district: regression, pixel ratio and direct expansion. Where available, regression is chosen as the preferred type of estimation (Day, 2001). This approach essentially corrects the area sample (ground only) estimate based on the relationship found between reported data and classified pixels in each stratum where it is used. A regression relationship should be based on 10 or more segments for any stratum used. Where there are not enough segments in each stratum, a pixel based ratio estimator may be used which essentially combines data across stratum to get the relationship. Finally, the direct expansion (total number of possible segments times the average for sampled segment) may be used in the absence of pixel based methods. Regression adjusts the direct expansion estimate based on pixel information. It usually leads to an estimate with a much lower variance than direct expansion alone. Segments, called outliers, which do not fit the linear relationship estimated by the regression are reviewed; if errors are found, they are corrected or that segment may be removed from consideration in the analysis.

Full scene classifications (large scale) are run wherever the regression or pixel ratio estimates are usable. Estimates derived from the classification are compared to the ground data to make one final check. State estimates are made by summing pixel based estimators where available and ground data only estimators everywhere else. County estimates are then derived from the state estimates using a similar approach (Bellow, 1993).

RESULTS

Table 1 breaks out for corn and soybeans the Kappas and number of training pixels used for training in each analysis district for each type of imagery. Although it is difficult to make direct comparisons between TM and AWiFS due to the different size and location of the analysis districts, the AWiFS classification performed similarly to the TM classification. For the two analysis districts that were most similar in location, AD05 with imagery dates of 6/20/05 and 8/07/05 for TM and AD12 with almost identical imagery dates of 6/22/05 and 8/08/05 for AWiFS, TM performed better for corn and slightly worse for soybeans.

Table 1. Kappa statistics and pixel counts for Nebraska 2005 classifier accuracy.

Analysis District	Kappa		Training Pixels*	
	Corn	Soybeans	Corn	Soybeans
	Landsat TM			
AD01	97.5	.	2,014	.
AD02	89.7	99.9	9,635	888
AD03	75.7	81.4	18,440	2,814
AD04	88.5	95.7	39,219	19,693
AD05	92.3	90.4	81,409	50,103
AD07	70.3	91.1	30,181	20,769
	AWiFS			
AD10	95.3	98.3	3,510	347
AD11	83.7	87.7	36,959	19,703
AD12	87.5	91.3	27,786	17,247

*Training pixels may be used in multiple analysis districts and will not add to a state total.

Figure 4 is an example of the regression analysis at the analysis district level for corn in Nebraska. Each letter in the plots represents one or more segments occurring in the analysis district. Letter A represents segments that come from areas stratified to having more than 80 percent cultivation (stratum 11), letter B from areas with 51 to 80 percent cultivation (stratum 12), letter C 15 to 50 percent cultivation (stratum 20), and letter M for multiple segments. The segments with the highest cultivation, A and B are about one square mile while the lowest cultivation segments, C are about two square miles in size. Both analysis districts, AD05 for TM in Figure 2 and AD12 in Figure 3 for AWiFS come from the same agriculturally intensive area of Nebraska.

The horizontal axis is count of pixels in each segment from the classification while the vertical axis is the sum of the corn acres reported in the ground truth. With perfect ground truth and accurate classification the segments would line along a line of slope=0.2224 for the TM data and a slope=0.7749 for the AWiFS data. The AWiFS regression is based on a larger data set which contains the segments in the TM regression so a little more variability is expected. In this comparison, the TM data has a better R2 in both strata 11 and 12. The TM slopes are a little higher than ideal while the AWiFS slopes are lower than the ideal slope.

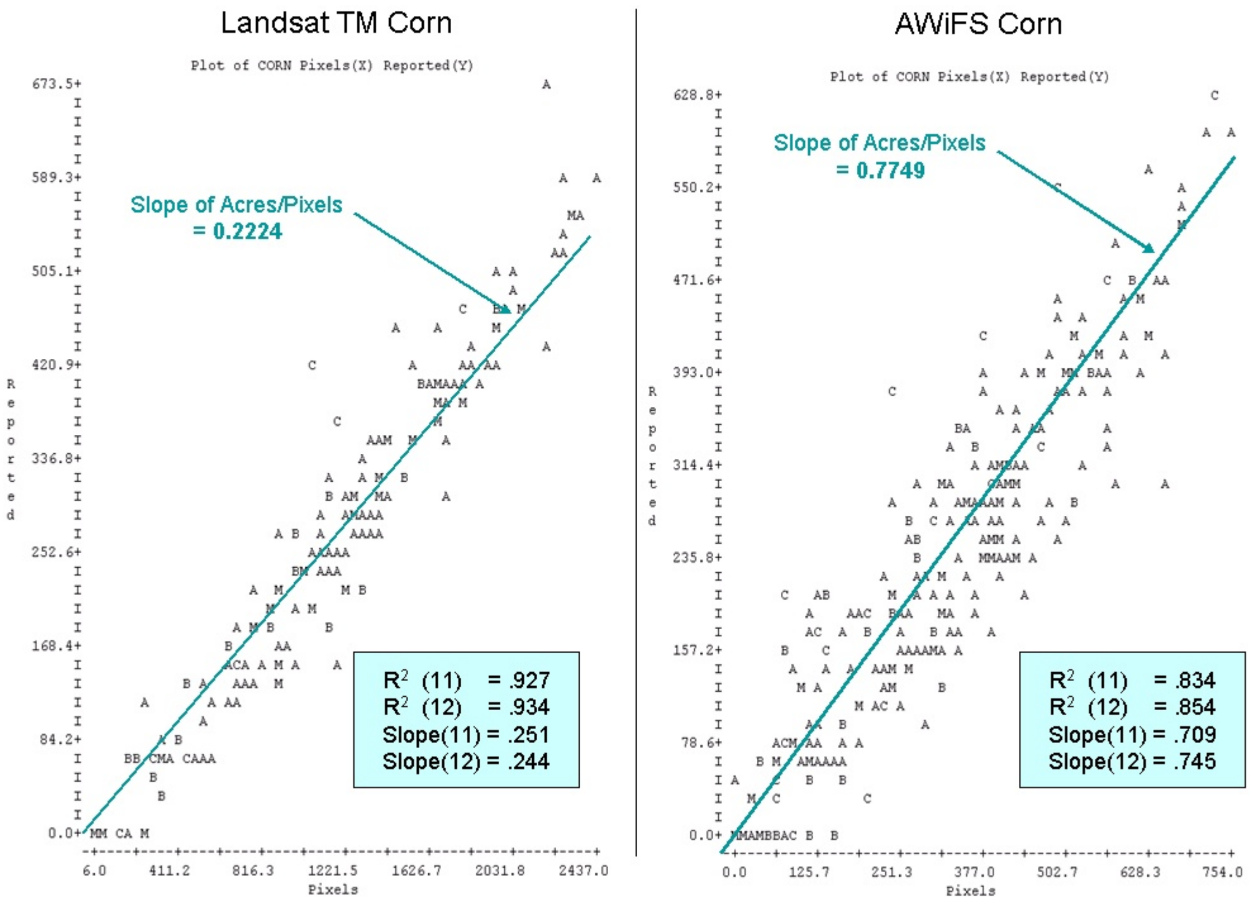

Figure 4. Comparison of TM and AWiFS regression analysis for a crop intensive area of Nebraska.

A better comparison is the overall accuracy at the state level. After regressions and pixel counts are performed for each analysis district, estimates are accumulated to the state level. In NASS, the Agricultural Statistics Board (ASB) published number for a crop acreage is the reference number. This number is the zero or reference line in Figure 5. For each of the crops in Figure 5 the black line represents the percentage difference the estimate is from the published number. For corn and soybeans, the June Agricultural Survey estimated on the high side, the TM estimate was slightly lower while the AWiFS estimate was lower for corn and higher for soybeans. The bars which are centered at the black line represent the range of the estimate encompassed by 2 coefficients of variation (CV). The TM had the best CV for corn and soybeans while the AWiFS had a wider range but still much better than the June Ag. estimate. The AWiFS estimate for wheat was better in accuracy and variability than TM and the June Ag.

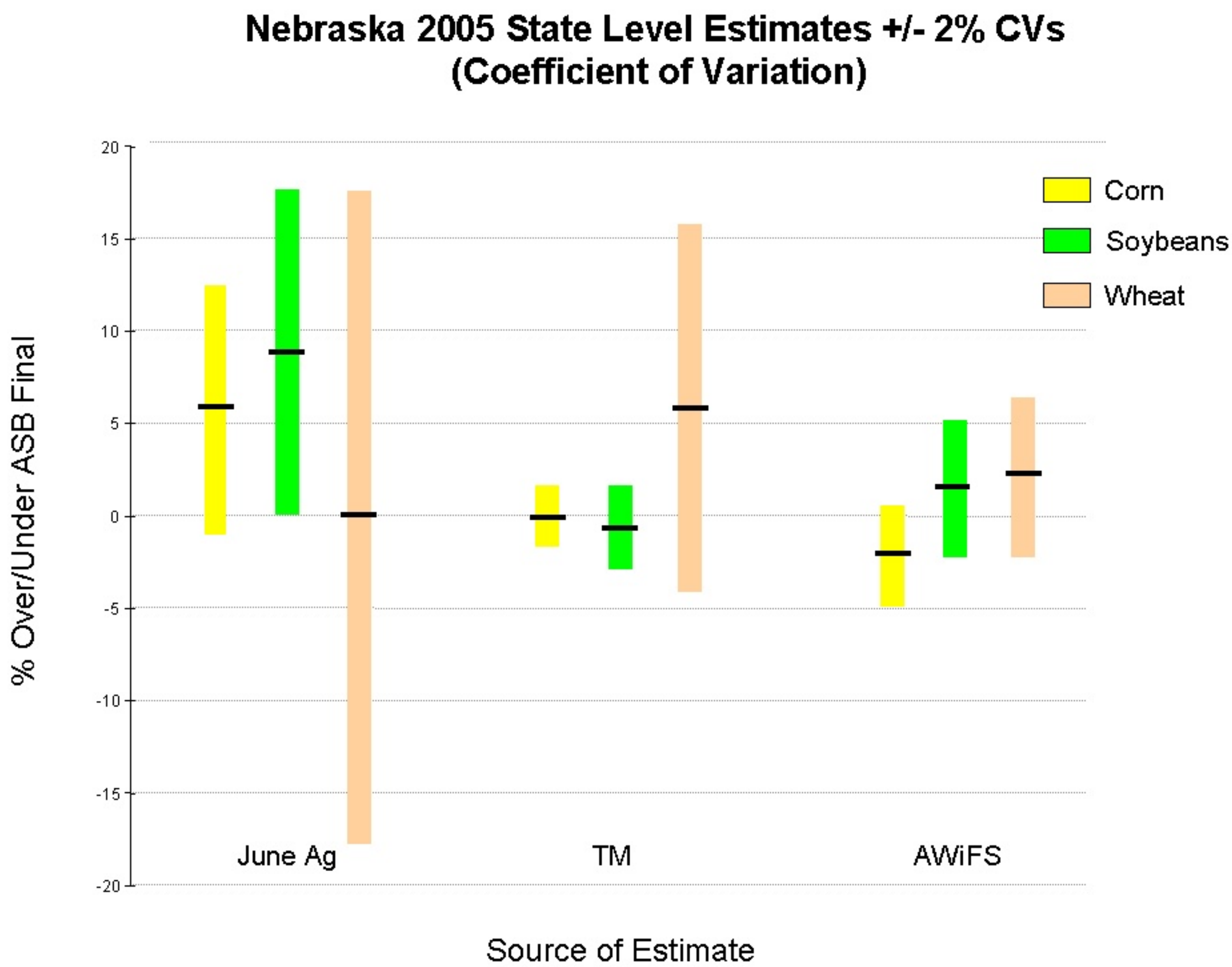

Figure 5. A comparison of the June Agricultural survey, TM and AWiFS estimates for Nebraska crop acreage.

CONCLUSIONS

Due to the uncertainty of the availability of Landsat imagery, NASS has begun using the AWiFS imagery operationally in 2006 for its CDL products. With its larger footprint AWiFS can provide more frequent cloud-free coverage. This increased coverage allows for better selection of optimal dates based on the progress and condition chart for each crop. The large footprint reduces the number of analysis districts and thus the amount of processing. With more segments per analysis district, regression estimates for all strata are more robust. Computer processing is also more efficient with the larger AWiFS pixel size and the reduced number of bands without a significant drop in the quality of the output.

This example for Nebraska in 2005 demonstrated good classification Kappas can be obtained from AWiFS data and the state level accuracy for corn and soybeans as measured by the difference from the ASB can be just as high for AWiFS as for a TM derived classification. While state level CVs are slightly larger for corn and soybeans for AWiFS than for TM, they are still tighter than from the JAS and will provided useful estimates to the overall NASS crop acreage estimation program, especially at the county level.

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