EFFECT OF RESOLUTION ON INFORMATION CONTENT OF TEMPORAL PROFILES OF VEGETATION

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ABSTRACT

Landsat has provided the capability to track vegetation development in acre-sized pixels. As this resolution is sub-field sized for most crops of interest, pure pixels of a single crop are not uncommon. Frequency of Landsat acquisition, however, is not adequate to provide a reliable estimate of the crop condition without supplemental information. The NOAA-6 and -7 AVHRR system can provide daily tracking of vegetation over limited areas, at a resolution of one kilometer, and worldwide, at a sampled pixel resolution of four kilometers. These data are further smoothed by some users to fit a 25-kilometer grid data base. Pure pixels do not exist at this coarser scale and questions arise as to the vegetation information retrievable.

Using field inventory data taken in support of the LACIE and AgRISTARS programs, simulation of these coarser resolution data have been made for twelve widely scattered test sites in the central United States. Indications to date are that significant information concerning vegetation condition remain at even the coarsest resolution considered, but, it is highly sensitive to location if used alone. Further, the vegetation information recoverable from combining Landsat and NOAA satellite data is significantly increased over that of using the two sources separately.

INTRODUCTION

In many applications of remotely acquired spectral data "high" spatial resolution is considered desirable. This has been particularly true in the use of satellite acquired spectral data to classify or inventory crop type where one of the limiting factors on accuracy in classification has been occurrence of pixels in which more than one field, or class of targets, is in the instantaneous field of view (mixed pixels). Higher resolution would reduce the percent of occurrence of these mixed pixels, hence, improve upon the accuracy of classification. Reason dictates there must exist some "most useful" resolution for a specific problem. If in the case of a nation-wide inventory of crop type, resolution were increased to the point that the components of the field (rows of plants or leaves) were discernible, horrendous data throughput problems would be experienced, with very little, if any, benefits to compensate for the added effort. Further increase in resolution to the point of microscoptic observation would make the problem insolvable. The point to be made is that, depending on the problem to be addressed, there is a limit to the spatial resolution desired. Just as there is a most desirable spatial resolution, there is a most desirable temporal resolution or frequency of view. Again, the value of this is highly problem dependent.

In practice, in the design of observational systems, a trade off occurs between spatial and temporal resolution which occurs as a result of limitations on sensor response time, data throughput constraints, power, money, etc. As an example, Landsat MSS provides one acre resolution at a frequency of once every 18 days. Had a 1/4 acre resolution been specified as a requirement, and the data rate held constantly, the frequency would be once every 36 days. Determining the optimum system characteristics for a multiple user system is not a simple or an appreciated undertaking, for often as one user is helped, another is hurt.

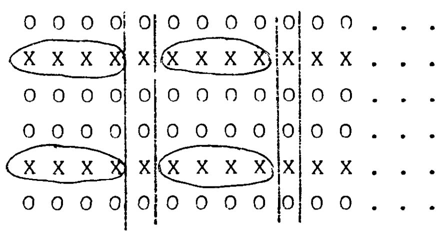
Within the AgRISTARS Early Warning Crop Condition Assessment project, the requirement of a technology to identify crop stress, degree of stress and the bounds of stressed areas, over broad areas, is well recognized. To meet this requirement frequent (of the order of 5 days or a week) updates in information are needed during critical parts of the growing season. The need for high resolution, however, is questionable. The existing user for the output is only able to track crop condition in time on a 25 mi. square grid (400,000 landsat pixels).

The NOAA AVHRR system appears to provide many of the characteristics required of the data. Vegetative Indices can be constructed from Channel 1 and 2 of this system. Dependent on the scan angle constraints imposed by the analyst, acquisition can be obtained more than once daily at full $\pm 56^{\circ}$ scan angle, every other day at $\pm 28^{\circ}$ scan angle; every fifth day at $\pm 14^{\circ}$ scan angle. This compares to each 18 day for the $\pm 5^{\circ}$ scan angle of Landsat. The resolution of the AVHRR system is at best $(1km)^2$ at nadir (available on a limited basis) and $(4km)^2$ (sampled) at nadir on a world wide basis. This resolution certainly will provide few pure crop pixels but may be adequate to provide a description of general pattern of crop stress. The objective of the work described here is to determine the most effective scale of input to the analysis of broad scale crop condition and to determine what information is lost in going from Landsat sized pixels to the 25 km mile grid. This work is still in progress but some results to date are informative.

APPROACH

During the course of the LACIE (Large Area Crop Inventory Experiment) scattered sites (5x6 n. mi. in size) were selected as Intensive Test Sites. For these sites inventory of scene content were performed and every effort was made to acquire all possible Landsat data. These sites were scattered over the Great Plains and Midwest from Canada to the Gulf, hence a wide variety of crops, cropping practices, and soils were included (Fig. 1). Each Landsat pixel was classified using the ground truth inventory. Registration between acquisitions were performed. In some cases multiple years of data were acquired. With the extensive ground truth available and much of the preprocessing of satellite data already performed, this was deemed an ideal data set to use in considering the effect of scale on information content.

Software was developed (METSIM, Austin 1982) to go from the data to simulation of the scale of output of AVHRR Local Area Coverage (LAC) and Global Area Coverage (GAC) which have $(1\ Km)^2$ and $(4\ Km)^2$ resolution respectively. The relative scale of these Landsat pixels and the 5x6 n. mi. sample segments are shown in Figure 2. It should be noted that while the simulated GAC data is an average over all Landsat pixels contained, the operational GAC data is a sample from the full resolution AVHRR data. GAC sampling provides a data value which is the average of four contiguous pixels. On every third scan, four pixels are averaged for a data value, the fifth pixel is skipped, and then four more pixels are averaged. This is repeated for the scan. Consequently, on a sampled scan line, 409 data points are recorded for the 2048 pixels. The sampling technique for six lines is:



with the mean value of the four sampled pixels recorded. The four encircled full-resolution points (X) represent one GAC value.

For our purposes, LAC was simulated by a cell: 221 Landsat pixels grouped 13 lines by 17 columns on the LACIE segment. GAC was simulated by a block: a grouping of 16 cells, 4 cells by 4 cells, or 68 Landsat columns by 52 Landsat lines. The software program provided flexibility in positioning the blocks. There is no suitable procedure for simulating the high frequency AVHRR data using the low frequency Landsat data, although Badhwar (1982) has devised a curve fitting technique that can support some comparisons.

Subtle change in temporal profile can be important indicators of anomalies in crop condition. This can only be tracked with the higher frequency data. The temporal plots shown here are the best that could be acquired using both Landsat 2 and 3. The vertical coordinate is proportioned to the ratio of Landsat MSS Channel 4 to Channel 2. The horizontal coordinate is day of the year.

RESULTS OF ANALYSIS

Only a small fraction of the results acquired to date can be shown here. More detailed description is in preparation as an AgRISTARS Technical Report.

In this discussion the term "cell" refers to a simulated AVHRR LAC pixel generated from approximately 250 Landsat pixels (See figure 2). A "block" is 16 cells. Crop profiles are for individual fields within the Intensive Test sties. The amount and/or vigor of vegetation is assumed to increase with the ratio of MSS Channel 4 to MSS Channel 2.

In Figure 3 the temporal profiles for major components of the Hines County Mississippi Site are shown. For each of the crop categories shown, a general pattern is discernable, although there is considerable difference between the profile of different fields of the same crop. The largest difference in patterns occurs in corn. This may be due to the different ways corn can be used, abandoment, or mislabeling of the inventory. In Figure 4, the temporal profile for major components of the Traverse County, Minnesota test sites are shown. Again, some definite patterns exist for each crop. The differences between fields is somewhat less than that shown for the Mississippi crops due in part to the dictates of a shorter growing season. Pasture again shows a great deal of difference in fields due to different management practices.

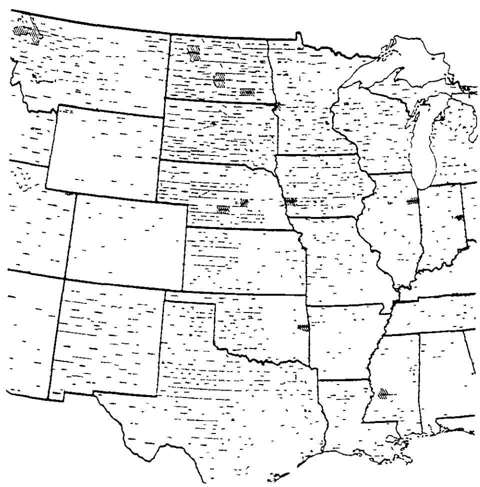


Fig 1. Geographical Distribution of Sites

In Figure 6 a comparison is made between the 4 blocks contained in the test site segment. The composition of each block is given in the insert. While some modest differences occur in composition the difference between block profiles is considerably less than that between cell profiles. The significant point to be made in Figures 5 and 6 is that in this case:

1) Restricting consideration to vegetation only can make significant differences at the cell level but at the Block level its impact is small.

2) Differences between cells are considerably greater than differences between blocks.

The reason for this is built into the practical scale of agriculture as performed in this region. Each farm has its homestead, its woodlot, pond etc; there are roads, cross-roads, communities, schools. Each of these features which has little to do with crop condition can make significant impact on a cell, but for a block these features tend to settle down to a stable percentile. We have found that farther to the west were topographic features are more pronounced and cultural impact less apparent, more difference between blocks sometimes occurs.

The question remains, can the GAC simulated data which contains all the components of a scene show sufficient detail in temporal profile to infer general crop condition? Figure 7 compares profiles of fields of corn and fields of soybeans in 197Ø to the fields in 1978 for the Kankakee County, Illinois test site. Both crops show flatter, but prolonged profiles in 1979 than in 1978. Figure 8 compares the profiles for two of the cells in two of these blocks of this site between years. Again, the characteristic difference between years is a flatter but prolonged profile in 1979. It appears in this case (as in other cases studied) the simulated GAC profile does provide sufficient detail to track general crop condition.

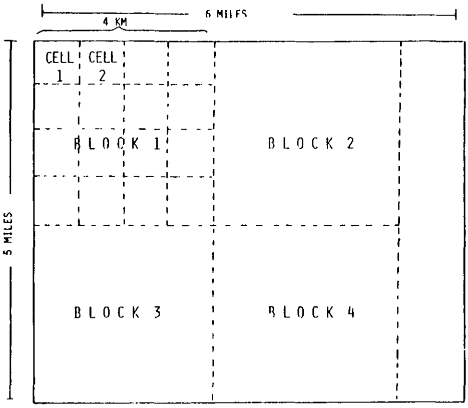
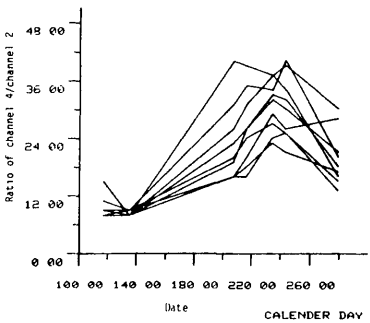
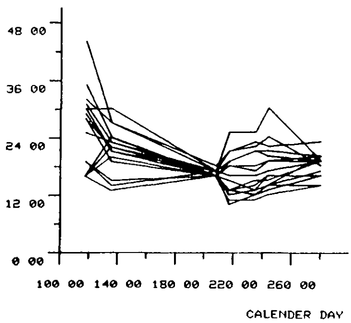


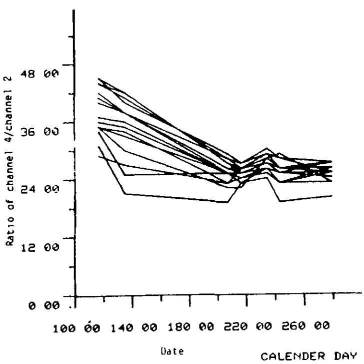
Figure 2. Simulation of Metsat Information Content Using LANDSAT and LACIE Ground Truth



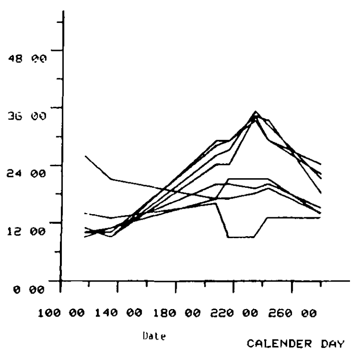
(a) Cotton



(b) Pasture



(c) Trees

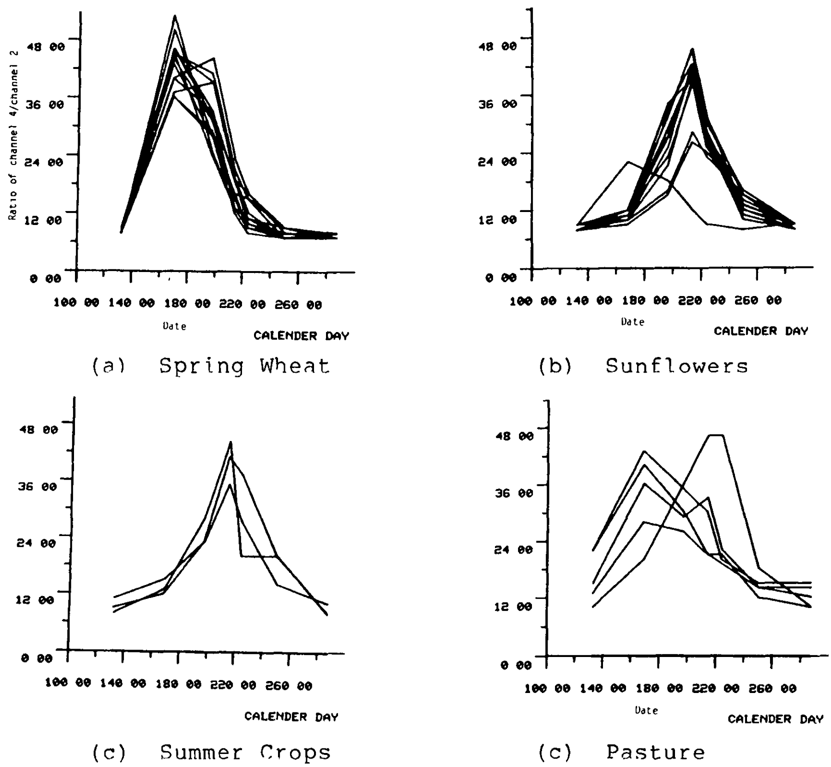


(d) Corn

Fig. 3. Hines County, Mississippi Site Temporal Profiles for Major Categories

In both Figures 3 and 4 some rather abrupt changes in profile slope occur due to the small number of Landsat data points upon which to base the curve. The important message in these figures is: For a given location-year, general patterns in temporal vegetation profiles appear for a specific crop, however significant differences occur between fields for a given crop.

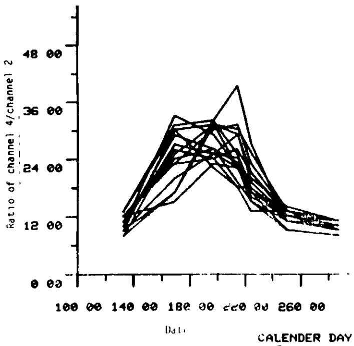
In Figure 5 (again Traverse County, Minnesota), the profiles are shown not by crop, but by cells in one block of the test site. Figure 5a shows a definite general pattern but with considerable difference between cells. In Figure 5b the envelope of standard deviation for those data are shown as solid lines with abrupt changes in slope. The block mean is shown as dots, and a smoothed depiction of block profile as determined using the Badhwar Technique is shown. All pixels in the block were used in arriving at Figures 5a&b. In Figure 5c only those pixels in each cell that were classified as vegetation were used. The overall pattern is very similar although some cells have changed considerably. The statistics and simulated curves for the two are almost identical.



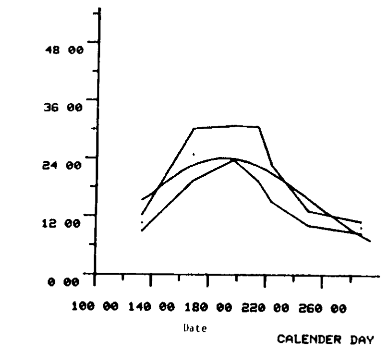
(a) Spring Wheat (b) Sunflowers

(c) Summer Crops (c) Pasture

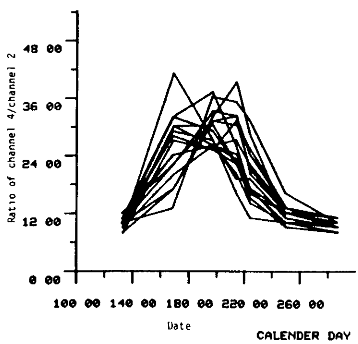
Fig. 4. Traverse County, Minnesota Site
Temporal Profiles for Major Categories



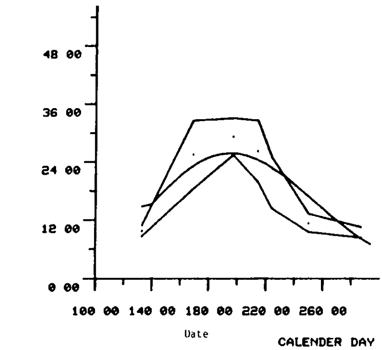
(a) Block 1 Cell Profiles



(b) Block 1 Statistics or Curve Fit



(c) Block 2 Cell Profiles



(d) Block 2 Statistics and Curve Fit

Fig. 5. All Pixel Input by Cell, Profile Statistics and Curve Fit Traverse County, Minnesota

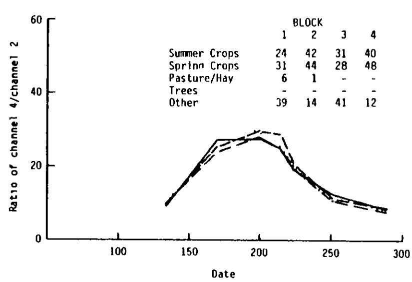
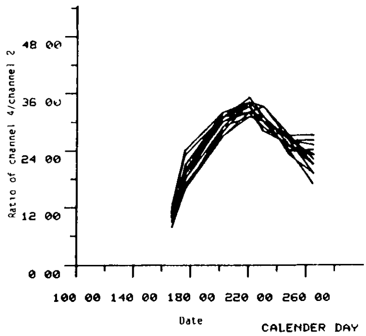
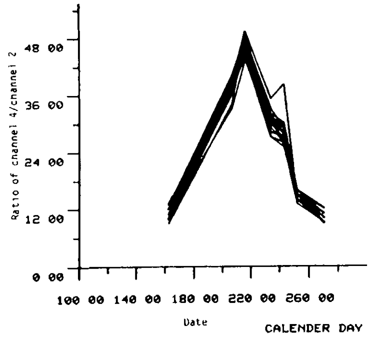


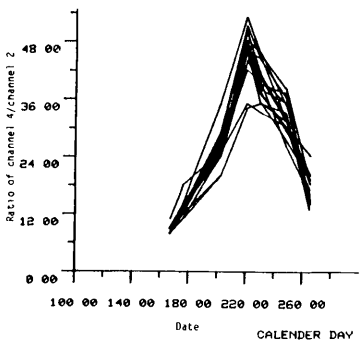
Figure 6. Comparison of Composition and Profile for the 4-Block in Traverse County, Minnesota Site



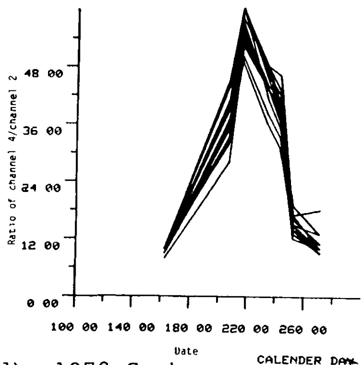
(a) 1979 Corn



(b) 1978 Corn

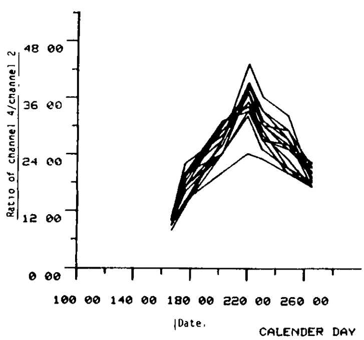


(c) 1979 Soybean

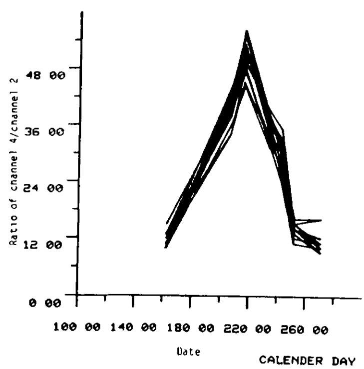


(d) 1978 Soybean

Fig. 7. Comparison of 1979 and 1978 Crop Profiles
Kankaku County, Illinois Site



(a) 1979



(b) 1978

Fig. 8. Comparison of 1979 and 1978 Profiles
for Block 1, Kankaku County, Illinois

CONCLUSION

With the study still in progress it is not possible to yet specify the most effective spectral scale for our purpose. It appears, based on the results shown here and other cases, considered in the parent study that little information is lost concerning the general vegetative condition for large areas if the pixel size is increased to the AVHRR/GAC scale. The cost in information content as larger pixels (up to 25 n. mi. on a side) are considered is yet to be determined. It also appears that because the topographic and demographic features and cropping practices vary from location to location the ability for the GAC scale to track general crop condition may be dependent on some means of identifying the percent of scene fitted by each component. This may be estimated by past record but in areas of dynamic agriculture change it may require once a year inventory taken by much higher resolution sensors.

REFERENCES

Austin, W. W., and W. E. Ryland, 1982, Simulation of Meteorological Satellite (Metsat) Data using LANDSAT Data., AgRISTARS EW/CCA Technical Report, in printing.

Badhwar, G. D., J. G. Carnes and W. W. Austin, 1982, Use of Landsat-Derived Temporal Profiles for Corn-Soybean Feature Extraction and Classification, Remote Sensing of Environment, 12-57-79.