Comparison of the Information Contents of Landsat TM and MSS Data*

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ABSTRACT: A communications-theory approach is taken to analyze the dispersion and concentration of signal values in various data spaces, irrespective of specific class membership. Entropy is used to quantify information, and mutual information is used to measure the information represented by subsets of spectral variables. Several different comparisons of information content are made. These include comparisons of system design capacities, of data volumes occupied by agricultural data in the spaces defined by original bands and by transformed spectral (Tasseled Cap) variables, of the information contents of original bands and Tasseled Cap variables, and of the information contents of TM and MSS for the given agricultural data sets. Also, the effects of sample size, scene content, and quantization level are examined.

INTRODUCTION

IN ANALYSES OF MULTISPECTRAL data sets produced by imaging remote sensing systems, needs arise for comparing the amounts of information provided by individual spectral bands, by various combinations of bands, and by different sensors. Measures based on classification performance or signal variance (e.g., principal component analysis) are commonly used for such comparisons. Classification procedures require knowledge of the identity of the scene elements being imaged and usually involve assumptions on the form of the signal distributions and parametric descriptors of those distributions. A class-independent and nonparametric measure of information content can be described in information-theoretic terms and is used here to analyze and compare digital image data from the Landsat Multispectral Scanner Subsystem (MSS) and from the Thematic Mapper (TM).

C. Shannon (1948) developed entropy measures of the information content of communications signals. Price (1984) and Bernstein, *et al.* (1984) made entropy calculations and comparisons of Landsat data on a band-by-band or component-by-component basis. Malila (1984) developed a procedure that takes into account dependencies among spectral bands and applied it to original and transformed versions of Landsat data; those results are summarized herein and extended to include additional data sets and other considerations.

METHOD

A communications-theory approach is taken to analyze the dispersion and concentration of signal values in various data spaces. Entropy, as defined by Shannon (1948), is used to quantify information. The process of selecting a subset of bands is viewed as the transmission of data through a communication channel in which loss of information may occur, and the mutual information between input and output is used to measure information transfer, i.e., the information represented by the subset.

Several different comparisons of information content are made. These include (1) comparison of TM and MSS system-design information capacities, (2) comparisons of the TM and MSS data-space volumes spanned by the agricultural data in the spaces defined by both original bands and transformed spectral (Tasseled Cap) variables, (3) comparison of the agricultural information content of original bands to that of transformed variables, and (4) comparison of the agricultural information content of TM data to that of MSS. The effects of sample size and varied scene content are examined, as is the effect of coarser quantization.

BASIC INFORMATION CONCEPTS

Shannon defined self information, $I(x_i)$, as a measure of the information associated with knowing the occurrence of a signal state x_i which occurs with probability $P(x_i)$:

$$I(x_i) = \log_2 \left(\frac{1}{P(x_i)}\right) = -\log_2 P(x_i) \quad \text{(bits)} \qquad (1)$$

The rarer the event, the greater is the uncertainty about when it will occur and, consequently, the

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* This research was sponsored by the U.S. National Aeronautics and Space Administration, Goddard Space Flight Center, Greenbelt, MD, under Contract NAS5-27346.

PHOTOGRAMMETRIC ENGINEERING AND REMOTE SENSING,
Vol. 51, No. 9, September 1985, pp. 1449-1457.

0099-1112/85/5109-1449$02.25/0
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greater is the information conveyed when it is observed. Entropy, given the symbol H, is the value of self information when averaged over all N possible states of x:

$$H(x) = \sum_{i=1}^{N} P(x_i) \log_2 \frac{1}{P(x_i)} \tag{2}$$

Entropy is at its maximum when all states or cells are equally likely. It can be reduced by decreasing the number of cells occupied, by having a nonuniform distribution or a concentration of observations in the occupied cells, or both.

With two variables, the use of joint and conditional probabilities is necessary:

$$H(x,y) = H(x) + H(y|x) \tag{3}$$

since

$$P(x,y) = P(x)P(y|x) \tag{4}$$

In computing the conditional entropy, the weighting assigned to each information term is the joint probability of the states involved, i.e.,

$$H(x|y) = \sum_{i=1}^{N_x} \sum_{j=1}^{N_y} P(x_i,y_j) \log_2 \frac{1}{P(x_i|y_j)} \tag{5}$$

If we consider x to be the input to a communication channel and y to be the output, we can define the mutual information transferred between them, i.e., $I_M(x;y)$, as

$$I_M(x;y) = H(x) - H(x|y) \tag{6}$$

This equation shows that the mutual information exchanged is the difference between $H(x)$, the information content of the input, and $H(x|y)$, the information loss or uncertainty about x when we are given the output y. When the total information is transferred, $H(x|y) = 0$ and $I_M(x;y) = H(x)$. At the other extreme, when y does not contain any information relatable to x, $H(x|y) = H(x)$ and therefore $I_M(x;y) = 0$, i.e., there is no mutual information. Figure 1 presents a concise graphical summary of these quantities and their interrelationships. Numerical examples are given by Malila (1984).

MULTISPECTRAL EXTENSION

The above concepts can be extended to multispectral situations by letting the variables x and y become multidimensional vectors X and Y, with $X = (X_1, X_2, \ldots, X_{N_x})$ and $Y = (Y_1, Y_2, \ldots, Y_{N_y})$. Usually, $N_y \leq N_x$. The information transfer achieved by the communication channel is used here in a general sense, to represent both simple selections of spectral band subsets and more complex transformations, such as the Tasseled Cap transformation.

ABSOLUTE VS. RELATIVE INFORMATION CONTENT

Multispectral sensors produce signals that have a fixed maximum number of signal levels in each spectral band, usually expressed as a number of bits, e.g., six bits for 64 levels in telemetered Landsat MSS bands and eight bits for 256 levels in Landsat TM bands. When the probabilities in the entropy equations are based on all possible combinations of those levels, absolute information measures will result. These would, for instance, be appropriate when absolute radiometric calibration of data is utilized.

Most current uses of multispectral data, however, employ techniques that utilize only relative amplitude information between signals from various scene elements. In these instances, the information resides in the number of spectral cells that are occupied and the distribution of spectral values within them. Malila (1984) developed an expression that gives a relative entropy value, H_R, for any given data set, in terms of counts of occurrences of observations in cells of the spectral space. It is repeated here (for six variables):

$$H_R(X) = \underbrace{\log_2 N_{\text{obs}}}_{\text{Information if each observation were in a unique cell}} - \underbrace{\left(\frac{1}{N_{\text{obs}}}\right)\sum_{ijklmn}\cdots\sum C_{ijklmn} \log_2 C_{ijklmn}}_{\text{Information loss due to concentration of the observations into a subset of cells}} \tag{7a}$$

where: C_{ijklmn} is the count of occurrences in the cell having Level i in X_1, Level j in X_2, etc.,

and: N_{obs} is the total number of observations in the data set being analyzed.

More briefly,

$$H_R(X) = H_{\max} - H_{\text{loss}} \tag{7b}$$

It also is informative to divide the total information loss due to spectroradiometric concentration of signals (from Equation 7) into two components, one due to the reduced number of spectral cells which are occupied (below the total possible) and the remainder which occurs when the duplicate observations are not uniformly distributed among those cells, i.e.,

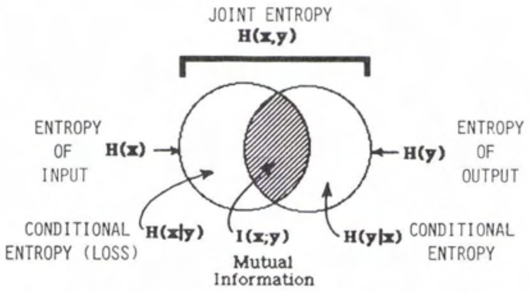

FIG. 1. Summary of Information Relationships.

$$H_{\text{loss}} = L_{\text{cell}} + L_{\text{unif}} \tag{8}$$

where: L_{cell} is the cell loss or loss in number of cells, i.e.,

$$L_{\text{cell}} = \log_2 N_{\text{obs}} - \log_2 N_{\text{cells}} = -\log_2 \left(\frac{N_{\text{cells}}}{N_{\text{obs}}}\right)$$

and: L_{unif} is the uniformity loss,

$$L_{\text{unif}} = H_{\text{loss}} - L_{\text{cell}}$$

SPECTRAL BAND SUBSETTING

The selection of subsets of spectral bands is a special case of the mutual information expression,

$$I_M(X;Y) = H(X) - H(X|Y)$$

where Y now is a subset, X', of the X variables, so

$$I_M(X;X') = H(X) - H(X|X')$$

Whenever a variable, say X_p, is retained, its conditional probability term becomes unity, its contribution to $H(X|X')$ is reduced to zero, and its information content is retained as mutual information. Whenever a variable, say X_q, is eliminated, there is a loss of mutual information. This loss is represented by the conditional entropy term through all conditional probability components in which X_q occurs on the left-hand side of the conditional probability indicator line but not on the right-hand (or given) side.

SPECTRAL TRANSFORMS

Spectral transformations were obtained by applying the linear-combination Tasseled Cap (TASCAP) transformations to MSS (Kauth and Thomas, 1976) and six-band TM (Crist and Cicone, 1984) data. The principal TASCAP variables are Brightness and Greenness. The Brightness variables are positively weighted sums of all bands and respond to general changes in overall scene reflectance. The Greenness variables are essentially contrasts between near-infrared wavelengths (where healthy vegetation is more highly reflecting than soil) and visible wavelengths (where healthy vegetation tends to be less reflecting than many soils) and respond to the amount of vegetation present. These two variables capture 95 to 98 percent of the variability in MSS data from typical U.S. agricultural scenes, while a third variable, called Wetness, has been found to be significant in similar TM data (Crist and Cicone, 1984). The Tasseled Cap variables, though related to principal-component variables, have advantages over them in that the Tasseled Cap directions do not vary with the scene content, and they have more consistent interpretability.

Also, principal-component analysis was utilized to obtain a different set of spectral variables for one comparison. All transformed values were rounded to the nearest integer before being analyzed.

QUANTIZATION EFFECTS

To explore the influence of quantization on the resultant information content, the amplitude values were requantized several times. At each step, the number of original digital counts per modified amplitude interval was doubled, thereby compressing the data and reducing the number of bits per channel by one for each step.

DATA SET

MSS and six-band TM data of two types were analyzed. These are (1) real Landsat-4 MSS and TM data acquired simultaneously from an agricultural scene in North Carolina and (2) data values synthesized from field-measured reflectance spectra of agricultural crops and soils using an atmospheric model. These data were used in prior comparisons of the spatial and spectral characteristics of Landsat TM and MSS data (Malila, *et al.*, 1984; Crist, 1984). In the synthetic data, samples are primarily from vegetation at a variety of ground cover percentages, with many fewer examples of bare soil. All analyses of TM data are limited to the six reflective bands; the thermal band was not analyzed in this effort due to its coarser spatial resolution, its dependence on emissive rather than reflective characteristics of scene materials, and lack of a comparable simulation data base. The TM frame was acquired on 24 September 1982 and included a wide range of agricultural crop conditions, ranging from bare soil to green and senescent vegetation to crop residues. It also included some samples from water and vegetation along the Atlantic Coast and from deciduous and coniferous trees.

RESULTS

SPECTRAL DATA VOLUMES

The diagram in Figure 2 helps describe the various terms used here to designate spectral data-space characteristics, while Table 1 quantifies many of the observed values. Figure 3 presents information measures for several of those quantities, as a function of the number of data variables. First, the

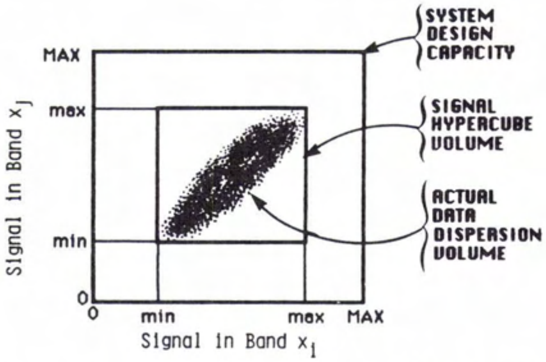

FIG. 2. Illustration of Various Spectral Data Volumes.

system-design capacities of the Landsat-4 TM and MSS are presented in terms of the number of bits transmitted to the ground and/or recorded on computer-compatible tapes (CCTs). For TM, the number of bits recorded on CCTs is the same as that transmitted (8 bits/channel). For MSS, however, the six-bit telemetered data are expanded to seven bits on the CCTs, with only an apparent gain of information. Nevertheless, many comparisons involving MSS will use seven-bit data since that is the form in which we received them. For some others, a degradation to six bits was performed before analysis. The greater information potential of the TM system design (reflective bands), as compared to the MSS system, is quantified as 48 vs. 24 bits in telemetered data.

Figure 3 also portrays the hypercube volume or data-space volume spanned by the TM and MSS data of Table 1a. These volumes are computed by summing the bit equivalents of the observed data-value ranges (max − min + 1) in each band being considered. Upon comparing the fractions of their total data-space volumes that are spanned by data from the agricultural scene, one observes that the TM data fall nine bits short of capacity while the MSS data fall approximately six bits short of capacity.

Actual data dispersion volumes or relative entro-

TABLE 1. INFORMATION COMPARISON FOR MSS AND SIX-BAND TM DATA SETS

		MSS		Six-Band TM		TM Gain
		number	bits	number	bits	bits
A. Values for Real Agricultural Data (A common area from the N. Carolina scene)						
System capacity: Sensor		0.17×10^8	24	0.28×10^{15}	48	24
CCT		0.27×10^9	28	0.28×10^{15}	48	20
Hypercube vol.: Sensor		0.44×10^6	18.7	0.43×10^{12}	38.6	20
CCT		0.32×10^7	21.6	0.43×10^{12}	38.6	17
Data dispersion pattern:						
	• # Observations; H_{max}	3,468	11.8	13,015	13.7	1.91 (Spatial)
MSS CCT: 7 bits per band	• #Unique cells	2,898	—	12,903	—	
	• Relative Entropy, H_R	—	11.4	—	13.7	2.27 (Total)
	• Entropy loss due to spectral concentration, H_{loss}	—	0.38	—	0.02	0.36 (Spectral)
MSS Sensor: 6 bits per band	• # Unique cells	1,730	—	12,903	—	
	• Relative Entropy, H_R	—	10.3	—	13.7	3.34 (Total)
	• Entropy loss due to spectral concentration, H_{loss}	—	1.45	—	0.02	1.43 (Spectral)
B. Values for Synthetic Agricultural Data (Assumes equal spatial resolution)						
"System" capacity (MSS: 6 bits/band)		0.17×10^8	24	0.28×10^{15}	48	24
Observed hypercube volume		0.10×10^7	20	0.99×10^{12}	40	20
Data dispersion pattern:						
	• # Observations; H_{max}	2,276	11.15	2,276	11.5	
	• # Unique cells	817	—	2,260	—	
	• Relative Entropy, H_R	—	8.94	—	11.14	2.20 (Spectral)*
	• Entropy loss due to spectral concentration, H_{loss}	—	2.21	—	0.01	

* (TM gain over seven-bit simulated MSS data was one bit.)

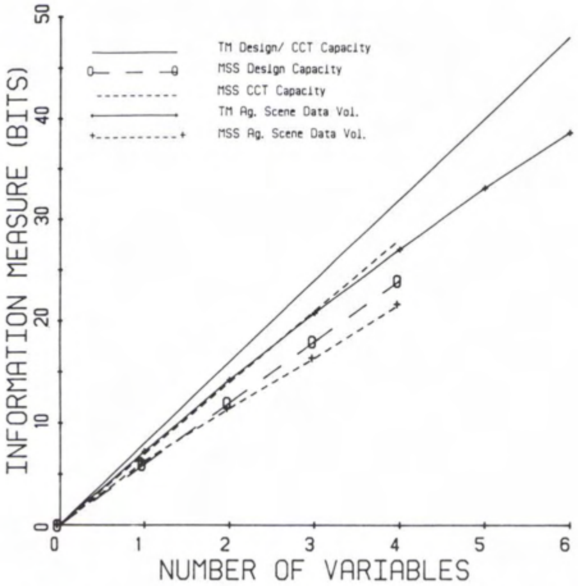

FIG. 3. Comparison of Landsat TM and MSS Information Capacities.

pies (see Figure 2 and Table 1) were found to be substantially smaller than the hypercube volumes, owing to correlations between bands and the limited numbers of observations. Results for the real TM data are shown in Figure 4 and for both TM and MSS (7 bits/band; CCT) in Figure 5. Note that these relative-entropy values for actual information are substantially smaller than those reported by Price (1984) for similar comparisons in which the sum of band values was treated as the joint information content. The data dispersion volumes in Figure 4 are measured by the relative entropies of the best variable combinations, and represent the relative information present in those sets. Most of the information is contained in the first two or three variables. Both the best and worst combinations are shown for each system in Figure 5. The number of observations analyzed establishes a maximum limit on each relative entropy value. As shown earlier in Equation (7), the concentration of multiple observations (pixels) into individual spectral cells reduces the information content below the potential maximum. Table 1 shows very little tendency for TM pixels to do this, owing to the very large system capacity, spectral diversity, and fine gradation of the TM bands. The MSS data show definite tendencies for multiple observations in spectral cells.

Table 1 shows that the TM data represent 3.3 bits more information than the MSS sensor data, with approximately two bits being associated with spatial resolution (pixel size and number) and the remainder with spectral bands and radiometric resolution. Since the synthetic data have the same number of observations for both TM and MSS, they can be considered to have equal spatial resolutions. Thus, the 2.2-bit difference must be solely due to their spectral and radiometric properties.

The above results were for a systematic sample from a larger area, 900 lines by 1300 TM pixels in size (450 × 650 MSS pixels). To explore the effects of sample size and scene content on the information measure, the area was divided into nine subareas, containing varied types and amounts of the scene classes. When all 1.17 million TM pixels were in-

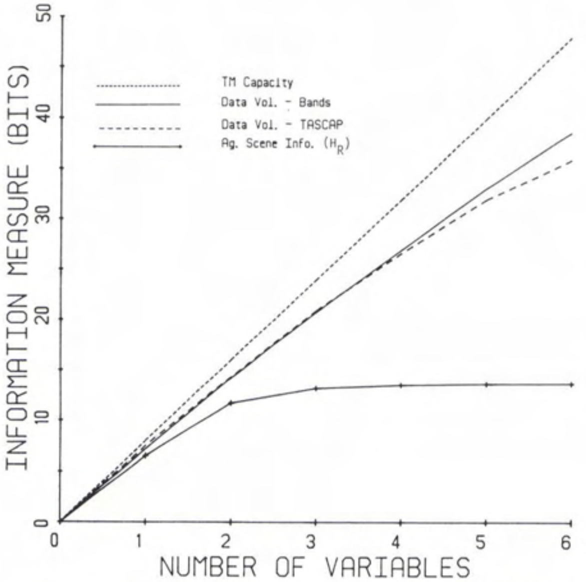

FIG. 4. Thematic Mapper's Utilization of Data Space.

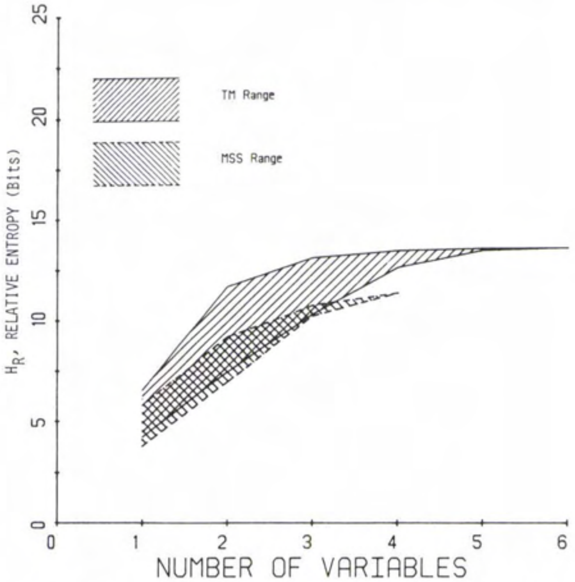

FIG. 5. Range of Information in Subsets of Bands.

cluded in the analysis (Data Set TM-C), an information content equal to 18.4 bits of the possible 20.2 bits was computed, as shown in Table 2. For the corresponding 0.29 million MSS pixels, 13.8 bits of the possible 18.2 bits were present as information. The two bits difference between maximum potentials is due to the greater number of TM pixels. Reductions below the maxima are due to reduced numbers of distinct spectral cells and nonuniformity of the cell populations. Bit equivalents of those losses are also indicated in Table 2. It can be seen that substantially greater losses occur for MSS data than for TM data, leading to a total difference of 4.6 bits between the two data sets.

Values also were computed using all pixels in each subarea. Mean values are given in Table 2 (Data Sets TM-B and MSS-B) along with standard deviations to indicate the amount of variability found among the different scene areas. On the average, both types of losses are reduced from those found in the total data set, but variability among subareas is substantial. Even smaller subsets of data were obtained for analysis by taking every tenth pixel in each subarea; the averages and standard deviations of those values also are listed in Table 2 (Data Sets TM-A and MSS-A). For these, the loss of information by TM is very minor (0.26 bit), but the losses for MSS remain greater (about one bit). Wharton (1984) simulated TM and MSS data sets, analyzed histograms of various sample sizes, and computed ratios of distinct to total number of samples. Comparable numbers were computed from the average cell loss values and are given in the last column of Table 2 as the percentage of cells which are distinct. The percentage for the largest real MSS data set is quite comparable to that for the largest set examined by Wharton, who found 27 percent distinct cells among 230,400 samples. His 59 percent for 28,800 samples and 85 percent for 3,600 samples are higher than the respective 34 percent in Table 2 for 32,500 samples and 66 percent for 3,300 samples. For TM, Wharton found nearly 100 percent distinct cases for even the 230,400-sample case, versus 61 percent here for 130,000 samples, but he considered seven rather than the six dimensions analyzed here and included only samples from nine scene classes. The TM data in Table 2 retain much more distinctness than MSS as the sample size is increased, with 89 percent distinct for 13,000 samples, 61 percent for 130,000 samples, and 58 percent distinct for 1,170,000 samples.

SPECTRAL TRANSFORMATIONS

Figure 4 also compares the data-space volumes spanned by original bands and Tasseled Cap transformed versions of signals from the agricultural scene (Table 1A sample). Three fewer bits per pixel are required to provide the same information using the transformed variables than would be required by the original bands. This effect potentially could be used to reduce telemetry requirements; differences might be even greater for data sets with a broader range of scene amplitudes.

For the synthetic MSS data set, a comparison was made of the information content of original band values and two types of transformed variables, TASCAP variables and principal-component variables. They were found to be essentially identical. The equality of the complete sets of variables is in keeping with theoretical considerations of linear transformations.

To compare with the original-band values of Figure 5, relative entropy values for the best and worst TASCAP subsets of each size are presented

TABLE 2. EFFECTS OF SAMPLE SIZE AND SCENE DIVERSITY ON INFORMATION CONTENT

Data Set	Number of Pixels	H_{max} Maximum Possible Relative Entropy (bits)	H_R Actual Relative Entropy (bits)	L_{cell} Loss in Number of Cells (bits)	L_{unif} Uniformity Loss (bits)	$\frac{N_{cells}}{N_{obs}} \times 100$ Percent Distinct Cells$^+$
TM-A	1.3×10^4	13.67	13.41* (0.21)	0.162* (0.136)	0.091* (0.078)	89.4 [75–99]
TM-B	1.3×10^5	16.99	15.66* (1.37)	0.711* (0.675)	0.615* (0.704)	61.1 [38–96]
TM-C	1.17×10^6	20.16	18.41	0.791	0.954	57.8
MSS-A	3.3×10^3	11.69	10.72* (0.47)	0.604* (0.331)	0.361* (0.148)	65.8 [44–88]
MSS-B	3.25×10^4	14.99	12.27* (1.04)	1.539* (0.693)	1.179* (0.380)	34.4 [16–61]
MSS-C	2.93×10^5	18.16	13.81	2.149	2.200	22.5

* Denotes mean of values from nine subareas.
( ) Denotes standard deviation of those values.
+ Computable from average bits of cell loss, i.e., 100 × 2 exp($-L_{cell}$).
[ ] Denotes range of values computed for individual samples.

in Figure 6. In this case, we find an even greater disparity between best and worst combinations, owing to the decreased information content of the last TASCAP variables. Here again, relatively little information is gained by the inclusion of more than three variables.

DIMENSIONALITY

Figure 7 displays relative entropy values computed for the first three Tasseled Cap components of TM and MSS data from the agricultural scene (Table 1A sample). (The MSS data were in CCT form at seven bits/band.) The first three components are individually quite similar for TM, but there is a substantial decrease (3.3 bits below Brightness) for the third component of MSS (Yellowness). This is consistent both with many investigators' experiences in finding MSS data of agricultural areas to be primarily two dimensional and with recent studies which have found a substantial amount of information in the TM Tasseled Cap Third Component (Crist and Cicone, 1984). Throughout this comparison, TM values are greater than the corresponding MSS values, for example the TM Brightness value is 6.7 bits compared to 5.8 bits for MSS.

When pairs of components are considered, we see substantial increases in total information, as would be expected with the addition of a second variable; the value for TM Brightness/Greenness is 4.8 bits greater than for Brightness alone, and the corresponding increase for MSS is 3.7 bits. However, differences do appear between MSS and TM. Whereas the value of the Brightness/Greenness pair for MSS is substantially greater than the other two (approximately two bits greater than Greenness/Third Component), there is relatively little difference (less than 0.4 bits) among the three pairings from TM data, pointing to a higher dimensionality in TM.

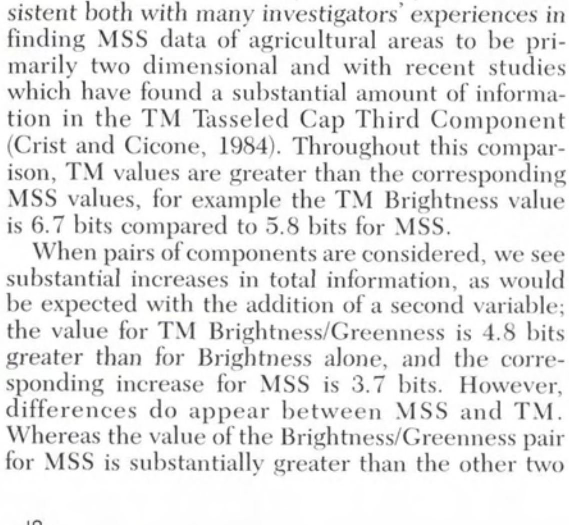

FIG. 6. Range of Information in Subsets of Tasseled Cap Variables.

Three components captured the vast majority of information for both systems. However, the fact that the gain in going from two to three components was nearly as large for MSS (1.25 bits) as for TM (1.70 bits) was somewhat surprising in view of the previously discussed two-dimensional character of MSS data. Furthermore, principal-component analysis of MSS data showed nearly total representation of variance by the first two components. The MSS gain likely is due to the Brightness/Greenness plane having a thickness of several counts in the third direction, even though this third component was uncorrelated with the others. The observed values also indicate that differences do exist among these various measures of multispectral signal properties. The TM data pattern also may be somewhat planar in three space, although not aligned as well with any component axis; correlations with the Third Component were -0.69 for Brightness and 0.36 for Greenness in this data set. None of these observations, however, should diminish the utility of Tasseled Cap transforms for physical interpretation of data values and agricultural scene characteristics.

NOISE

Noise in multispectral data was not considered explicitly in the results presented thus far. Sensor noise effects certainly were present in the real Landsat data, and natural variations of crop observations were present in both the real and synthetic data. Noise can add variance to signals and increase the number of spectral cells occupied (above that for no noise), thereby creating an apparent information content greater than the true information content of ideal, noiseless signals. To explore such effects, the number of discrete levels present in the data sets was reduced by applying several different quantization factors (greater than unity) to each band and computing the reduced information content. The results are summarized in Table 3 for three subareas which had (relatively) high, medium, and low information content, respectively. The TM still had more information when degraded to seven bits per band but, by the time the amplitude data were degraded to five bits per band, there was little difference between the corresponding TM and MSS data sets.

SUMMARY

An information-theoretic measure was defined and used to compare Landsat MSS and TM multispectral data. The measure quantifies signal dispersion patterns, independently of class membership and distributional assumptions. It provides an alter-

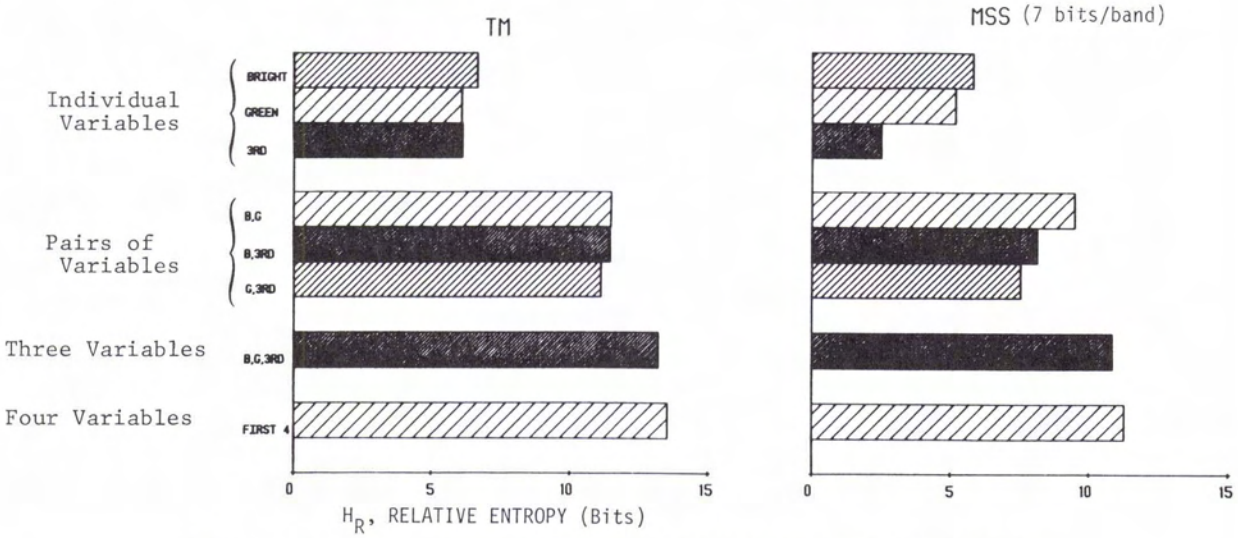

FIG. 7. Comparison of Information Contents of TM and MSS Tasseled Cap Variables.

nate method (to classification) of measuring the extent to which subsets of bands or transformed variables represent the total pattern. The relative entropy value is limited by the number of observations being analyzed. Since results do vary with scene content, analysts should insure that data sets being analyzed are representative of the problems under consideration.

A number of observations were made. The TM system-design information capacity is much greater than that of MSS. The potential information capacities and the signal hypercube volumes of agricultural data were much larger than the information actually represented by signal dispersion patterns in the sets of data values analyzed. Tasseled Cap transformations preserved the information in original bands and offered a modest savings in bits over those original bands, a fact which might be useful in data compression approaches. Relatively few multiple occurrences of spectral observations were found in the TM data sets compared to MSS, another indication of TM's finer partitioning of spectral space. For the best combinations of variables, relative entropy magnitudes were more a function of

TABLE 3. EFFECTS OF QUANTIZATION DETAIL ON INFORMATION CONTENT

Sensor	Number of Pixels	Relative Scene Complexity	Relative Entropy (bits) for Indicated Number of Bits per Band: 8	7	6	5	4	3
TM	1.3×10^5	High	16.9	15.6	12.3	9.0	6.2	4.6
	1.3×10^5	Medium	16.1	13.4	10.0	7.2	4.8	3.4
	1.3×10^5	Low	15.3	11.8	8.5	5.8	3.7	2.7
MSS	3.3×10^4	High	—	13.8	10.6	9.1	6.4	4.3
	3.3×10^4	Medium	—	12.0	9.9	7.2	4.9	3.3
	3.3×10^4	Low	—	11.0	8.7	6.1	3.8	2.5

Sensor	Relative Scene Complexity	Fraction of Maximum Relative Entropy for Indicated Bits/Band: 8	7	6	5	4	3
TM	High	1.00	0.93	0.73	0.53	0.37	0.27
	Medium	1.00	0.83	0.62	0.44	0.30	0.21
	Low	1.00	0.77	0.56	0.38	0.24	0.17
MSS	High	—	1.00	0.76	0.66	0.46	0.31
	Medium	—	1.00	0.83	0.60	0.41	0.28
	Low	—	1.00	0.79	0.55	0.35	0.22

the number of variables than of the type of variables (original bands or transformed). TM had greater relative entropy values for Brightness and Brightness/Greenness than did MSS. Information in the Tasseled Cap Third Component of TM was much greater than that of MSS, both by itself and in combination with Brightness or Greenness, confirming TM's greater dimensionality. Reductions in the number of bits used to encode data in each channel decreased the information content, affecting TM data proportionately more than MSS data so that, with five bits or less per band, the information in comparable sets was equal.

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