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Title: Spectral characteristics and the extent of paleosols of the Palouse formation

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Introduction

The second six month period of our work has been devoted to analysis of image data and verification with additional field sampling. We report work by objective as stated in our proposal.

Progress by Objective:

I.A. Develop spectral relationships from TM data that will define the spatial distribution of soil areas by levels of (1) organic matter in the surface soil , (2) iron oxide and clay in exposed paleosol B horizons, and (3) lime-silica accumulations in exposed paleosol B horizons.

B. Compare areas determined by the method outlined in A to patterns interpreted from color aerial photographs, and to ground observaions on bare-soil fields.

Spectral relationships have been investigated for several bare soil fields which were in summer fallow rotation on the date of the imagery. Techniques used were to examine printouts of each band and compare them to aerial photography. Bands with dissimilar reflectance patterns for known areas were then combined using ratio techniques which have been proven useful in other studies (Williams, 1983). Selected ratios were TM1/TM4, TM3/TM4 and TM5/TM4. Cluster analyses and Baysian and Fastclass classifier images were produced using the three ratio images. Plots of cluster analysis outputs revealed distinct groupings of reflectance data representing green crops, ripened crops, soil and green plants and bare soil (Figure 1). Bare soil was represented by a line of clusters on plots of the ratios TM5/TM4 and TM3/TM4.

The soil line was investigated further to determine factors involved in the distribution of clusters along the line. Each of the clusters was mapped out so that the landscape position could be studied and compared to aerial photographs. It was noted that any cluster which was not positioned exactly on the line was not bare soil. Clusters 46, 47 and 48 contained varying amounts of green plant material and cluster 16 contained dry plant material in addition to bare soil (Figure 1). It was also noted that cluster 17 had the lowest TM5/TM4 value and represented soils with the lowest carbon content. It represented paleosols with lime-silica horizons exposed on the surface. Cluster 18 was closely associated on the landscape, had little organic carbon and no lime-silica. It represented paleosols having exposed Bw horizons.

The clusters representing the bare soil line were also studied by plotting them to observe the TM5/TM4, TM1/TM4 dimension (Figure 2). From this view the line was spread out, forming a plane. The reasons for this remain unknown; however the plot was used to group clusters into adjacent blocks along the TM5/TM4-TM3/TM4 line. The landscape position of each cluster was studied to determine where breaks could logically be made. The blocks of clusters were then mapped using a Baysian classifer and field checked. Landscape units were found including convex knobs with both white paleosols with Bk horizons and light brown paleosols with Bw horizons exposed, steep south-facing straight slope positions, moderate convex south-facing slopes, summits and north-facing concave positions and low-lying, flat positions.

Soil samples were collected within 3 X 3 pixel squares within each mapped area. This size was chosen because it was large enough to be located easily without the use of surveying equipment. Smaller squares were used for units where exact location in the field was obvious because of exposed paleosols and mapped areas were smaller than 3 X 3 pixels.

A total of 76 samples were gathered and analyzed for organic carbon. Means were computed for each of five landscape classes which were derived from the blocks of clusters. The means of DN values of the ratio bands for each of the landscape classes were regressed against the means for organic carbon. Results show that the soil line is affected strongly by organic carbon (Table 1). Based on this analysis any of the ratio bands could be used to model organic carbon content of bare dry soil, but the best single ratio is TM5/TM4.

The organic carbon data (Table 2) were also analyzed by landscape categories using ANOVA and the LSD test to determine if they were significantly different from each other. Since the standard deviations of the carbon values increased as the means increased, we did the statistical analyse on log transformations of the means. These tests were used to determine whether the blocks of clusters, which were derived empirically and which looked separable on maps, were statistically separable. Carbon values explained 84% of the differences observed in the first ANOVA, but the LSD test showed two pairs of classes that were not separable (Table 3).

Reexamination of the original data showed that the two classes with low carbon values were paleosols which were closely associated on the landscape. These can be logically combined based on carbon values. The other pair which was not adequately separated had moderate levels of carbon. Since their means differ by less than 0.4% one could argue that they too could be combined and the map would still be useful; however, they represent distinctly different areas of the landscape.

We studied the original data again with the aerial photographs and found that three sample points in the moderately convex south-facing slope class had been taken from areas which were not recently cultivated prior to the image date. These samples had carbon values well above the mean of the next higher class. Lighter tones are shown on the aerial photographs in uncultivated vs recently cultivated areas. The soil surface would have been smoother in the uncultivated areas and probably was slaked (crusted). The remote sensing system accurately mapped the area based on reflectance; the surface layer was smoother and may have had less carbon than our sample showed. We have not yet attempted to sample a soil crust to determine if it has less carbon than the soil immediately below or if the increased reflectance that we see is due only to less roughness. If we remove the three samples gathered from the slaked areas from the analysis, the two classes are statistically separated (Table 4). The implications of this are that we have not removed surface roughness differences and differences due to slaking of the soil surface by using the ratio techniques.

We conclude from this that we can map organic carbon levels very well if the soils are bare and that the lime-silica paleosols are easily separated and mapped. We have not found evidence yet to show if or how iron enriched paleosols may be separated and mapped.

II. Using selected test sites, estimate the extent of eroded agricultural soils of the Palouse region and establish baseline information for comparison with future estimates.

Using the carbon class map from this test site and our knowledge of the soils derived from field sampling we found 1039 ha (2569 ac) of bare soil (Table 5). Paleosols which have been completely exposed by erosion occupy 2.7% of the area. Low carbon areas on steep south-facing slopes with soils 1 m (3.3 ft) or less in depth occupy 20% of the area. These have about 16 cm (6.3 in.) of epipedon remaining. The moderate carbon class covers 44% of the area, has soils with 30 cm (11.8 in.) epipedons, and has about 1.3 m (4.3 ft) of soil over a lime-silica paleosol. The high carbon area covers 28.8% of the site, has soils with 36 cm (14.2 in) to 46 cm (18.1 in) epipedons and averages 1.3 m (4.3 ft) to a paleosol. Low-lying areas with the highest carbon content are 4.4% of the area. This class should show much more area, but most of it has been covered with alluvial soil from upper slope positions and is accurately mapped into several of the other carbon classes.

Other sites will be looked at during the next two reporting periods.

Literature Cited

Williams, R. S.,Jr. ed. 1983. Geological Applications. In Manual of Remote Sensing, Second ed. Vol II. p. 1749. American Society of Photogrammetry, Falls Church, VA 22046

Table 1. Regression analysis of organic carbon and average DN value of TM band ratios

			Organic Carbon	Estimated Org. C
Regression Output:TM1/TM4				
Constant		-11.8656		
Std Err of Y Est		0.195542	0.48	0.54
R Squared		0.952995	1.00	0.87
No. of Observations		5	1.45	1.45
Degrees of Freedom		3	1.78	2.03
			2.54	2.36
X Coefficient(s)	0.082705			
Std Err of Coef.	0.010604			
Regression Output:TM3/TM4				
Constant		30.10176		
Std Err of Y Est		0.125760	0.48	0.39
R Squared		0.980557	1.00	1.18
No. of Observations		5	1.45	1.45
Degrees of Freedom		3	1.78	1.72
			2.54	2.51
X Coefficent(s)	-0.26529			
Std Err of Coef.	0.021567			
Regression Output:TM5/TM4				
Constant		- 4.08519		
Std Err of Y Est		0.041529	0.48	0.47
R Squared		0.997879	1.00	1.01
No. of Observations		5	1.45	1.42
Degrees of Freedom		3	1.78	1.84
			2.54	2.51
X Coefficient(s)	0.025865			
Std Err of Coef.	0.000688			
Regression Output:COMBINED				
Constant		- 9.83647		
Std Err of Y Est		0.048989	0.48	0.48
R Squared		0.999016	1.00	1.02
No. of Observations		5	1.45	1.41
Degrees of Freedom		1	1.78	1.80
			2.54	2.54
X Coefficient(s)	-0.02647	0.064705	0.04	
Std Err of Coef.	0.027115	0.109039	0.017888	

Table 2. Organic carbon sample data gathered from within map units derived from groups of DN data clusters. Each point represents a 3 x 3 pixel area.

Bk Paleosols	Bw Paleosols	Steep south slopes	Moderate south slopes	Summits and north slopes	Flat low-lying
			%		
0.51	0.32	0.77	1.34	1.69	2.42
0.44	0.63	0.88	1.58	1.37	2.67
0.60	0.66	0.88	1.94*	1.29	
0.24	0.61	0.65	1.74*	2.06	
0.34	0.45	1.19	1.33	2.00	
		0.79	1.62	1.65	
		1.06	1.36	1.63	
		0.95	1.40	1.54	
		1.23	1.74	1.76	
		1.51	1.31	1.97	
		0.85	1.84	1.66	
		0.81	0.67	1.85	
		0.97	1.79*	1.85	
		1.34	0.73	1.89	
		1.06	1.55	1.89	
		1.06	1.37	1.70	
		0.79	1.13	1.71	
		1.02	1.69	1.62	
		1.30		1.74	
				2.23	
				1.82	
				1.83	
				2.22	
				1.69	
				1.72	
				2.03	

* Samples known to have come from slaked areas

Table 3. T tests (LSD) for carbon value

Alpha = 0.05   DF = 70   MSE = 0.052
Critical value of T = 1.99
Least Significant Difference = 0.268
Means with the same letter are not significantly different

	Carbon	Transformed Mean	
	%		
Bk Paleosols	0.43	-0.9022	A
Bw Paleosols	0.53	-0.6620	A
Steep South Slopes	1.00	-0.0174	B
Moderate South Slopes	1.45	0.3377	C
Summits and North Slopes	1.78	0.5666	C
Flat, Low-Lying	2.54	0.9329	D

Table 4. T tests (LSD) for carbon value. Three samples from known slaked areas removed.

Alpha = 0.05 DF = 67 MSE = 0.50
Critical value of T = 1.996
Least Significant Difference = 0.266
Means with the same letter are not significantly different

	Carbon	Transformed Mean	
	%		
Bk Paleosols	0.43	-0.9022	A
Bw Paleosols	0.53	-0.6620	A
Steep South Slopes	1.00	-0.0174	B
Moderate South Slopes	1.38	0.2853	C
Summits and North Slopes	1.78	0.5666	D
Flat, Low-Lying	2.54	0.9329	E

Table 5. Area of exposed paleosols and organic carbon levels.

	Carbon Percent	Area		
		Percent	Acres	Hectares
Bk Paleosols	0.43	0.7	18	7
Bw Paleosols	0.53	2.0	52	21
Steep South Slopes	1.00	20.0	514	208
Moderate South Slopes	1.38	44.0	1131	458
Summits and North Slopes	1.78	28.8	740	299
Flat, Low-Lying	2.55	4.4	114	46
TOTAL			2569	1039

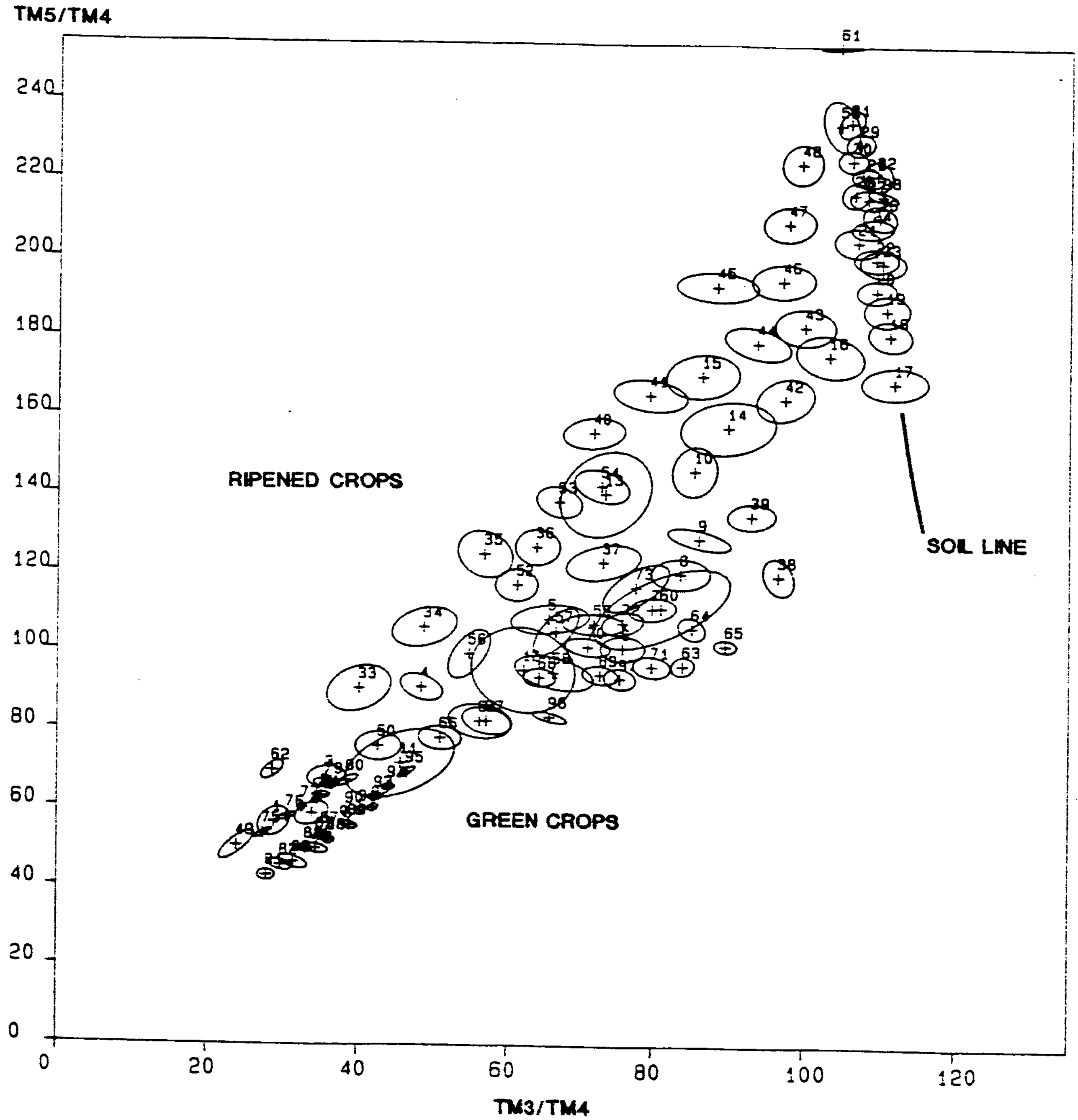

Figure 1. Plot of DN clusters for ratio bands TM5/TM4 and TM3/TM4. Carbon content ranges from 0.5% at cluster 17 to 2.5% at cluster 61.

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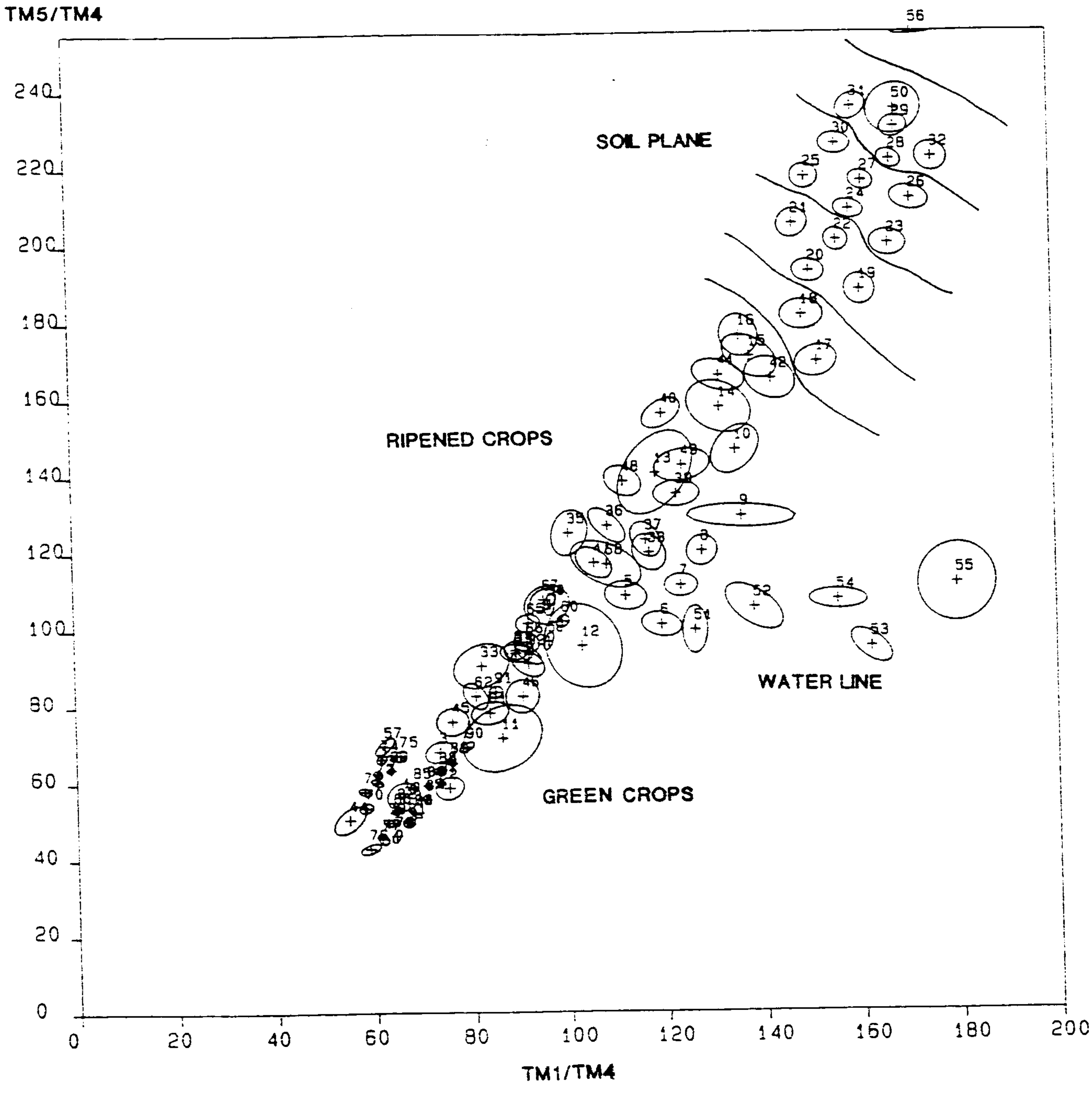

Figure 2. Plot of DN clusters for ratio bands TM5/TM4 and TM1/TM4. This plot shows the soil line as a plane. Lines have been drawn between clusters to show blocks representing levels of carbon. Some cluster numbers are changed from Figure 1 because clusters lying behind the soil plane have been deleted.