

**United States
Department of
Agriculture**

**Natural
Resources
Conservation
Service**

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Subject: ESAP & EMI Data
Collected at the Sparta National Guard Training Site

Date: 2 August 2011

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Sam, I want to thank you for getting the particle-size and soil moisture data to me for the 24 calibration sampling points that were identified by the ESAP (EC_e Sampling, Assessment, and Prediction) software's "Respond Surface Sampling Design" (RSSD) Program. The ESAP-RSSD program is a prediction-based sampling approach that is designed to reduce the number and optimize the location of calibration sampling points (either 6, 12, or 20 points) based on the observed magnitudes and spatial locations of the raw EC_a data. As you know we sampled the soil at 6 calibration sampling points in each of the four sites at the National Guard Training Facility in Sparta, Illinois. These points were sampled in 50 cm increments down to a depth of 150 cm. This resulted in 3 samples for each of the 24 RSSD defined sampling points (a total of 72 measurements of moisture (% weight), and percent clay, sand, and silt). I ran the data through the ESAP "Calibrate" program using "Stochastic Modeling" methods. The ESAP-Calibrate program is designed to estimate a predictive model for a specified soil physiochemical property based on the sampled soil and EC_a data. The ESAP-Calibrate program was used to convert raw EC_a data into estimates of % water, clay, silt, and sand. To do this, soil profile and raw EC_a data were used to estimate an appropriate stochastic-prediction model for each sampled depth interval and an aggregate for the total depth interval. The default settings of the ESAP-Calibrate program were used and all advanced modeling options ignored as recommended in the ESAP Programs Guide.

The attached documents summarize the analysis of the EC_a and soil profile data thru the ESAP Calibrate Program.

With kind regards,

Jim Doolittle
Research Soil Scientist
Investigation Staff
National Soil Survey Center

Electromagnetic induction works best in estimating a one soil property that significantly influences EC_a when other physiochemical properties that also influence EC_a remain relatively invariable, both laterally and with depth. Figures 1 to 4 are one dimensional (1D) plots of the soil data that were analyzed at each site. As evident in the plots shown in these figures, water, clay, sand, and silt contents are all, both highly spatially and vertically variable. The inherent variability in these and other soil properties were anticipated to lessen the predictability of water and clay contents across each site.

Sparta Site 1
1D Profile Plots of Raw Data

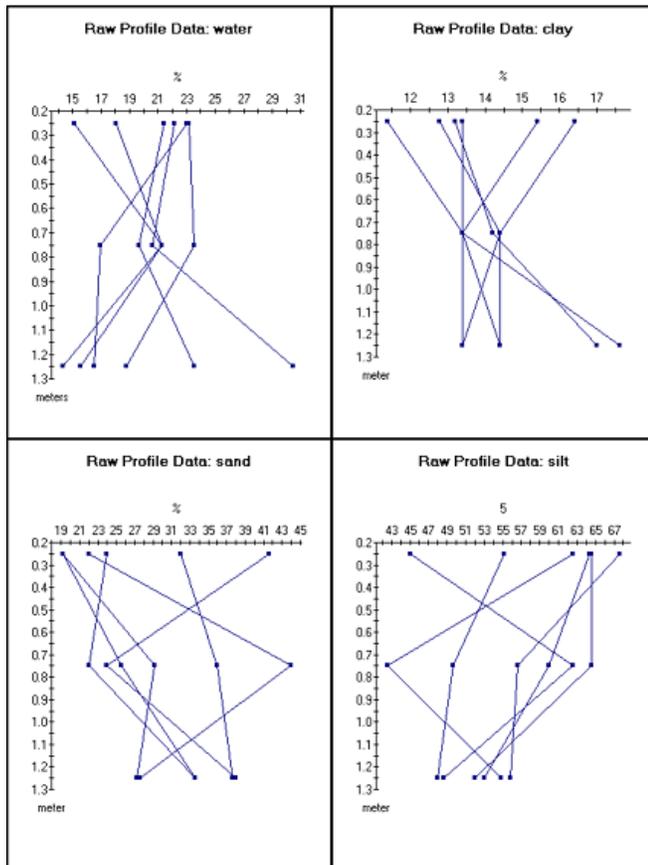


Figure 1. Sparta Site 1.

Sparta Site 2
1D Profile Plots of Raw Data

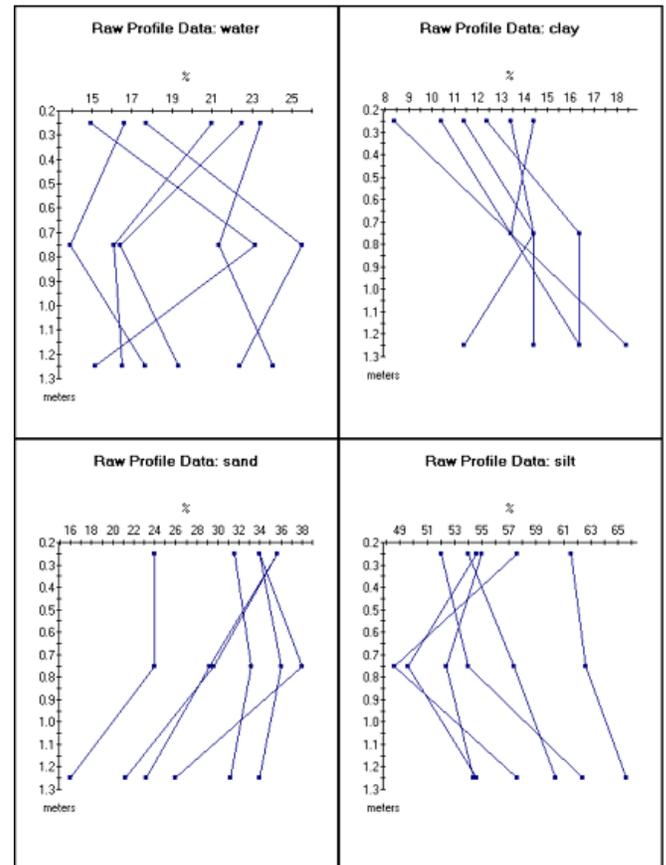


Figure 2. Sparta Site 2.

Sparta Site 3
1D Profile Plots of Raw Data

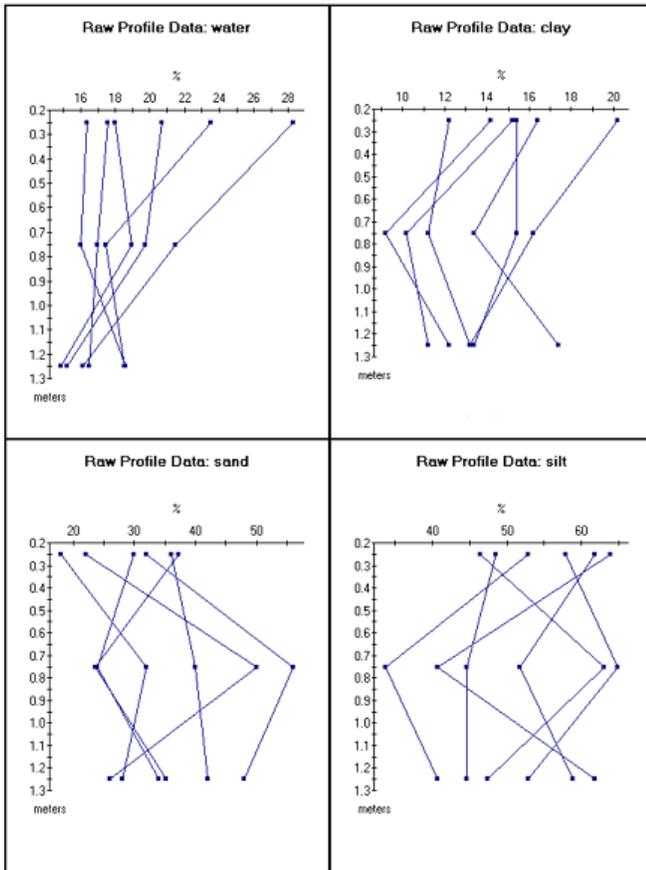


Figure 3. Sparta Site 3.

Sparta Site 4
1D Profile Plots of Raw Data

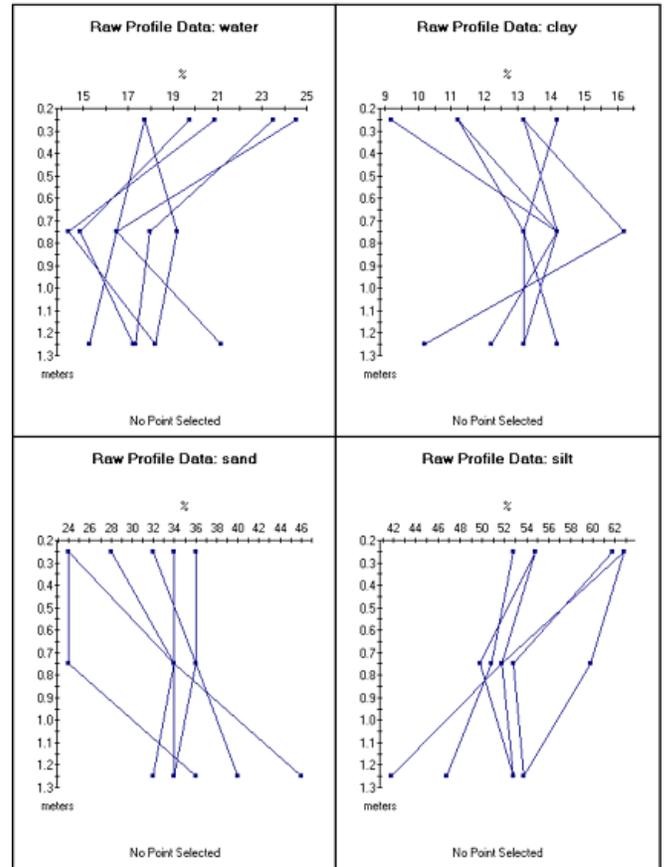


Figure 4. Sparta Site 4.

ESAP Calibrate:

The following tables show the results of processing the raw EC_a and soil profile data for each of the four Sparta sites through the ESAP Calibrate Program. Relationships are lower than anticipated, but reflect the inherent variability of each of these reclaimed mine spoil areas.

For each of the four sites, two separate table are provide for each of the four soil properties examined (% moisture, clay, sand, and silt). In each table, separate statistics are provided for each of the three depth intervals samples (0 to 50, 50 to 100, and 100 to 150 cm). These three depth intervals are identified by their mid-points (0.25, 0.75, and 1.25 cm). An “Average” or “bulk” row is for the 0 to 150 cm soil column. For each soil property, the first table provides the basic statistics (mean, variance and the 95% confidence interval for the mean). For each soil property, the second table provides the R² and the root mean square error of the predictive equation. The R² values are exceedingly low for most properties and depth intervals sampled. This is unfortunate, but perhaps should not have been unexpected based on our tacit knowledge of the sites and the variability in the soil physical properties shown in Figures 1 to 4.

Sparta Site 1:

Soil Moisture:

I. Field Average Point Estimates [Soil Moisture]

Depth	mean	variance	95% Confidence Interval
0.25	20.23720	2.32376	15.387 to 25.088
0.75	20.35894	0.85672	17.414 to 23.304
1.25	19.46949	2.96660	13.989 to 24.950
Average	20.02188	0.92035	16.969 to 23.075

Basic Regression Summary Statistics

Depth	R-square	Root MSE
0.25	0.2287	3.6416
0.75	0.3847	2.2111
1.25	0.7286	4.1146
bulk	0.5890	2.2918

Sparta Site 1:

Clay:

I. Field Average Point Estimates [clay]

Depth	mean	variance	95% Confidence Interval
0.25	14.04068	0.16792	12.737 to 15.345
0.75	13.86705	0.02684	13.346 to 14.388
1.25	15.00257	0.92262	11.946 to 18.059
Average	14.30343	0.17309	12.980 to 15.627

Basic Regression Summary Statistics

Depth	R-square	Root MSE
0.25	0.8267	0.9789
0.75	0.6554	0.3914
1.25	0.0481	2.2946
bulk	0.3078	0.9939

Sand:

I. Field Average Point Estimates [sand]

Depth	mean	variance	95% Confidence Interval
0.25	26.45388	22.03337	11.518 to 41.390
0.75	30.91103	14.42057	18.828 to 42.994
1.25	33.03109	6.32345	25.029 to 41.033
Average	30.13200	4.46801	23.406 to 36.858

Basic Regression Summary Statistics

Depth	R-square	Root MSE
0.25	0.0357	11.2134
0.75	0.2984	9.0717
1.25	0.0127	6.0072
bulk	0.2258	5.0496

Silt:

I. Field Average Point Estimates [silt]

Depth	mean	variance	95% Confidence Interval
0.25	59.50524	19.11665	45.593 to 73.418
0.75	55.22172	14.96261	42.913 to 67.530
1.25	51.96615	2.89768	46.550 to 57.383
Average	55.56437	3.79516	49.365 to 61.763

Basic Regression Summary Statistics

Depth	R-square	Root MSE
0.25	0.0729	10.4449
0.75	0.2772	9.2406
1.25	0.0241	4.0665
Bulk	0.3045	4.6538

**Sparta Site 2:
Soil Moisture:**

I. Field Average Point Estimates [Soil Moisture]

Depth	mean	variance	95% Confidence Interval
0.25	20.23720	2.32376	15.387 to 25.088
0.75	20.35894	0.85672	17.414 to 23.304
1.25	19.46949	2.96660	13.989 to 24.950
Average	20.02188	0.92035	16.969 to 23.075

Basic Regression Summary Statistics

Depth	R-square	Root MSE
0.25	0.7944	2.0133
0.75	0.2637	5.0904
1.25	0.2491	3.8785
Bulk	0.0908	3.2573

Clay:

I. Field Average Point Estimates [clay]

Depth	mean	variance	95% Confidence Interval
0.25	14.04068	0.16792	12.737 to 15.345
0.75	13.86705	0.02684	13.346 to 14.388
1.25	15.00257	0.92262	11.946 to 18.059
Average	14.30343	0.17309	12.980 to 15.627

Basic Regression Summary Statistics

Depth	R-square	Root MSE
0.25	0.2459	2.4218
0.75	0.7226	0.7950
1.25	0.1559	2.8483
Bulk	0.0168	1.5659

Sand:

I. Field Average Point Estimates [Soil Moisture]

Depth	mean	variance	95% Confidence Interval
0.25	19.43260	0.68025	16.808 to 22.057
0.75	19.34943	4.34878	12.714 to 25.985
1.25	19.21995	2.52451	14.164 to 24.276
Average	19.33399	1.78062	15.088 to 23.580

Basic Regression Summary Statistics (sand)

Depth	R-square	Root MSE
0.25	0.7243	2.9821
0.75	0.2016	5.8906
1.25	0.2593	7.3483
Bulk	0.3018	5.0515

Sparta Site 2:**Silt:**

I. Field Average Point Estimates [silt]

Depth	mean	variance	95% Confidence Interval
0.25	59.50524	19.11665	45.593 to 73.418
0.75	55.22172	14.96261	42.913 to 67.530
1.25	51.96615	2.89768	46.550 to 57.383
Average	55.56437	3.79516	49.365 to 61.763

Basic Regression Summary Statistics

Depth	R-square	Root MSE
0.25	0.7825	2.0265
0.75	0.3800	5.3119
1.25	0.3022	4.8082
Bulk	0.4702	3.4985

Sparta Site 3:**Soil Moisture:**

I. Field Average Point Estimates [Soil Moisture]

Depth	mean	variance	95% Confidence Interval
0.25	20.77080	5.08541	13.595 to 27.946
0.75	18.38741	0.71714	15.693 to 21.082
1.25	16.69660	0.02065	16.239 to 17.154
Average	18.61827	1.01206	15.417 to 21.819

Basic Regression Summary Statistics

Depth	R-square	Root MSE
0.25	0.1070	5.4877
0.75	0.3709	2.0608
1.25	0.9717	0.3497
Bulk	0.0884	2.4481

Clay:

I. Field Average Point Estimates [clay]

Depth	mean	variance	95% Confidence Interval
0.25	15.66405	0.93415	12.589 to 18.740
0.75	12.68794	0.91201	9.649 to 15.727
1.25	13.45853	1.14181	10.058 to 16.859
average	13.93684	0.50968	11.665 to 16.209

Basic Regression Summary Statistics

Depth	R-square	Root MSE
0.25	0.5328	2.3520
0.75	0.6021	2.3239
1.25	0.0925	2.6003
Bulk	0.5668	1.7373

Sparta Site 3:

Sand:

I. Field Average Point Estimates [sand]

Depth	mean	variance	95% Confidence Interval
0.25	29.06226	10.32692	18.837 to 39.288
0.75	37.24383	22.14837	22.269 to 52.219
1.25	35.35036	8.40671	26.124 to 44.576
Average	33.88548	4.67322	27.007 to 40.764

Basic Regression Summary Statistics

Depth	R-square	Root MSE
0.25	0.3802	7.8201
0.75	0.5678	11.4524
1.25	0.5700	7.0557
Bulk	0.6657	5.2606

Silt:

I. Field Average Point Estimates [silt]

Depth	mean	variance	95% Confidence Interval
0.25	55.27349	11.86115	44.315 to 66.232
0.75	50.06803	23.89325	34.514 to 65.622
1.25	51.19090	9.69532	41.283 to 61.099
Average	52.17747	6.88707	43.827 to 60.528

Basic Regression Summary Statistics

Depth	R-square	Root MSE
0.25	0.1606	8.3809
0.75	0.4468	11.8949
1.25	0.4914	7.5772
Bulk	0.4215	6.3862

A second run was conducted using only the clay and moisture content data collected for the 0 to 50 and 50 to 100 cm depth intervals. The following is a summary of the results:

Analysis of the 0 to 100 cm Data

Sparta Site 1

Soil Moisture:

I. Field Average Point Estimates [moisture]

Depth	mean	variance	95% Confidence Interval
0.25	20.23720	2.32376	15.387 to 25.088
0.75	20.35894	0.85672	17.414 to 23.304
Average	20.29807	0.49622	18.057 to 22.540

Basic Regression Summary Statistics

Depth	R-square	Root MSE
0.25	0.2287	3.6416
0.75	0.3847	2.2111
Bulk	0.4358	1.6828

Sparta Site 1

Clay:

I. Field Average Point Estimates [clay]

Depth	mean	variance	95% Confidence Interval
0.25	14.04068	0.16792	12.737 to 15.345
0.75	13.86705	0.02684	13.346 to 14.388
Average	13.95387	0.03787	13.335 to 14.573

Basic Regression Summary Statistics

Depth	R-square	Root MSE
0.25	0.8267	0.9789
0.75	0.6554	0.3914
Bulk	0.8726	0.4649

Sparta Site 2

Soil Moisture:

I. Field Average Point Estimates [moisture]

Depth	mean	variance	95% Confidence Interval
0.25	19.43260	0.68025	16.808 to 22.057
0.75	19.34943	4.34878	12.714 to 25.985
Average	19.39101	1.74374	15.189 to 23.593

Basic Regression Summary Statistics

Depth	R-square	Root MSE
0.25	0.7944	2.0133
0.75	0.2637	5.0904
Bulk	0.0198	3.2234

Clay:

I. Field Average Point Estimates [clay]

Depth	mean	variance	95% Confidence Interval
0.25	11.71461	0.98435	8.558 to 14.872
0.75	14.22298	0.10606	13.187 to 15.259
Average	12.96880	0.42024	10.906 to 15.032

Basic Regression Summary Statistics

Depth	R-square	Root MSE
0.25	0.2459	2.4218
0.75	0.7226	0.7950
Bulk	0.1842	1.5824

Sparta Site 3

Soil Moisture:

I. Field Average Point Estimates [moisture]

Depth	mean	variance	95% Confidence Interval
0.25	20.77080	5.08541	13.595 to 27.946
0.75	18.38741	0.71714	15.693 to 21.082
average	19.57911	2.40043	14.649 to 24.509

Sparta Site 3

Soil Moisture:

Basic Regression Summary Statistics

Depth	R-square	Root MSE
0.25	0.1070	5.4877
0.75	0.3709	2.0608
Bulk	0.1009	3.7702

Clay:

I. Field Average Point Estimates [clay]

Depth	mean	variance	95% Confidence Interval
0.25	15.66405	0.93415	12.589 to 18.740
0.75	12.68794	0.91201	9.649 to 15.727
Average	14.17600	0.72252	11.471 to 16.881

Basic Regression Summary Statistics

Depth	R-square	Root MSE
0.25	0.5328	2.3520
0.75	0.6021	2.3239
Bulk	0.6065	2.0685

Sparta Site 4

Soil Moisture:

I. Field Average Point Estimates [moisture]

Depth	mean	variance	95% Confidence Interval
0.25	20.68206	1.68290	16.554 to 24.810
0.75	16.50079	0.03781	15.882 to 17.119
Average	18.59142	0.35849	16.686 to 20.497

Basic Regression Summary Statistics

Depth	R-square	Root MSE
0.25	0.2614	3.1651
0.75	0.9601	0.4744
Bulk	0.5109	1.4608

Clay:

I. Field Average Point Estimates [clay]

depth	mean	variance	95% Confidence Interval
0.25	12.02884	0.83648	9.119 to 14.939
0.75	14.22140	0.09765	13.227 to 15.216
Average	13.12512	0.32064	11.323 to 14.927

Basic Regression Summary Statistics

Depth	R-square	Root MSE
0.25	0.1126	2.2315
0.75	0.7094	0.7624
Bulk	0.0777	1.3816

Summary:

Perhaps these lower than would-have-like correlations should have been expected. Depending on the physiochemical properties and their variability within sites, EMI, soil sampling and the ESAP program may or may not be successful. A stochastic model predicted the soil moisture content (weight) for the 0 to 100 cm depth interval at Sparta Site 1 with an R2 of 0.44. The spatial distribution of soil moisture content based on the stochastic model and the raw EC_a data is shown in Figure 5.

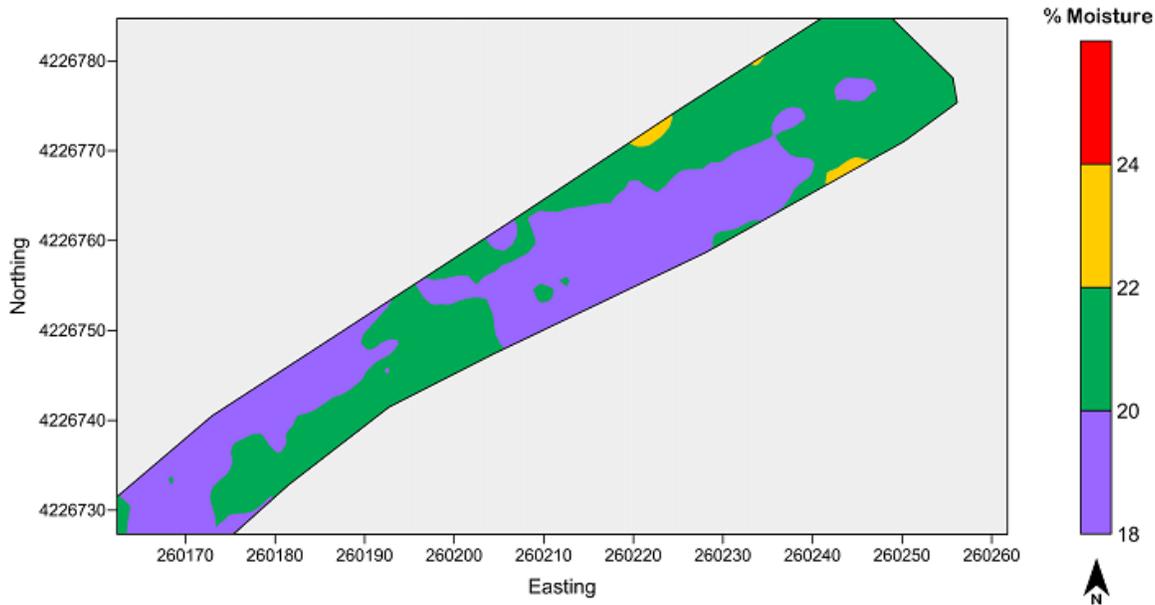


Figure 5. The ESAP predicted (R₂ of 0.4358) soil moisture contents for the 0 to 100 cm depth interval at Sparta Site 1 is shown in this plot.

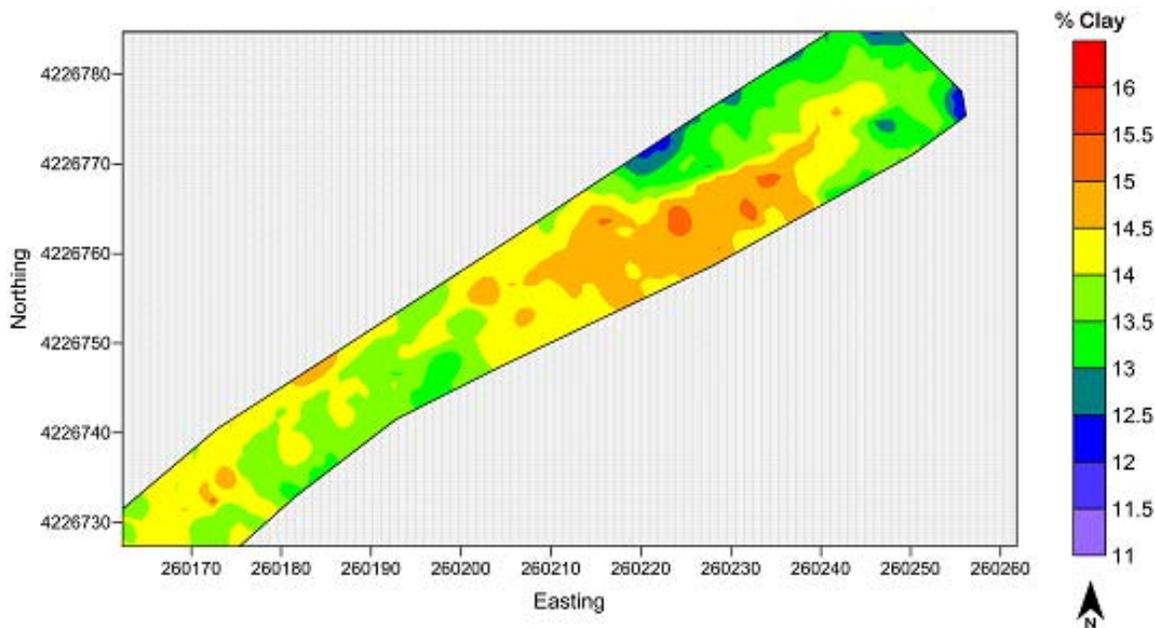


Figure 6. The ESAP predicted (R₂ of 0.8726) clay contents for the 0 to 100 cm depth interval at Sparta Site 1 is shown in this plot.

A stochastic model predicted the clay content for the 0 to 100 cm depth interval at Sparta Site 1 with an R2 of 0.87. The spatial distribution of clay content based on the stochastic model and the raw EC_a data is shown in Figure 6. A

relatively high predictive value ($R_2 = 0.7944$) was also achieved using stochastic models to predict the soil water content of the 0 to 50 cm depth interval across Sparta Site 2 (Figure 7).

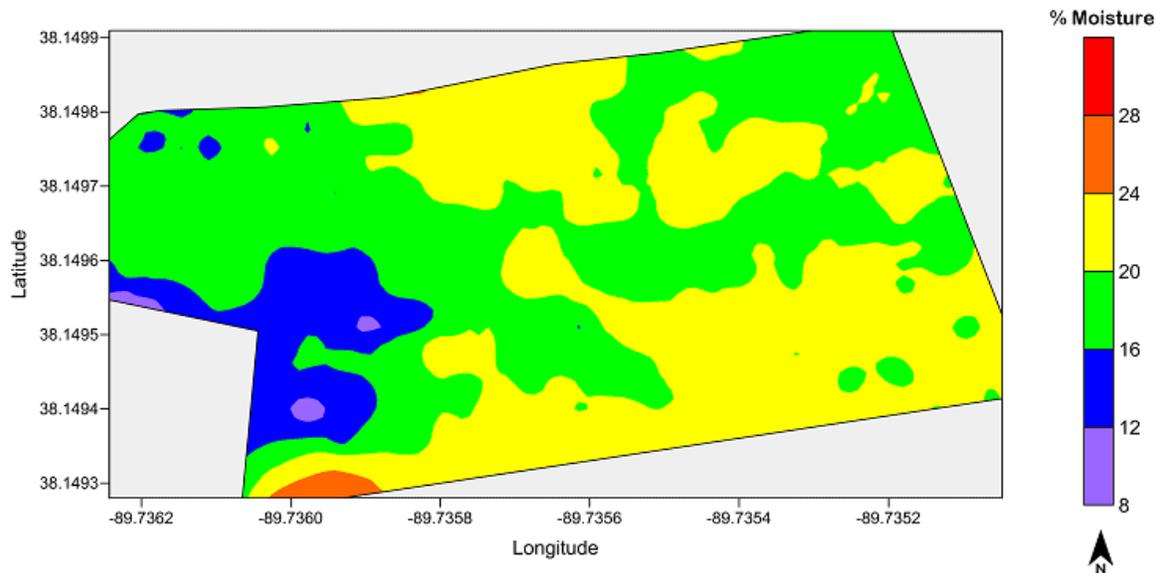


Figure 7. The ESAP predicted (R_2 of 0.7944) soil moisture contents for the 0 to 50 cm depth interval at Sparta Site 2 is shown in this plot.

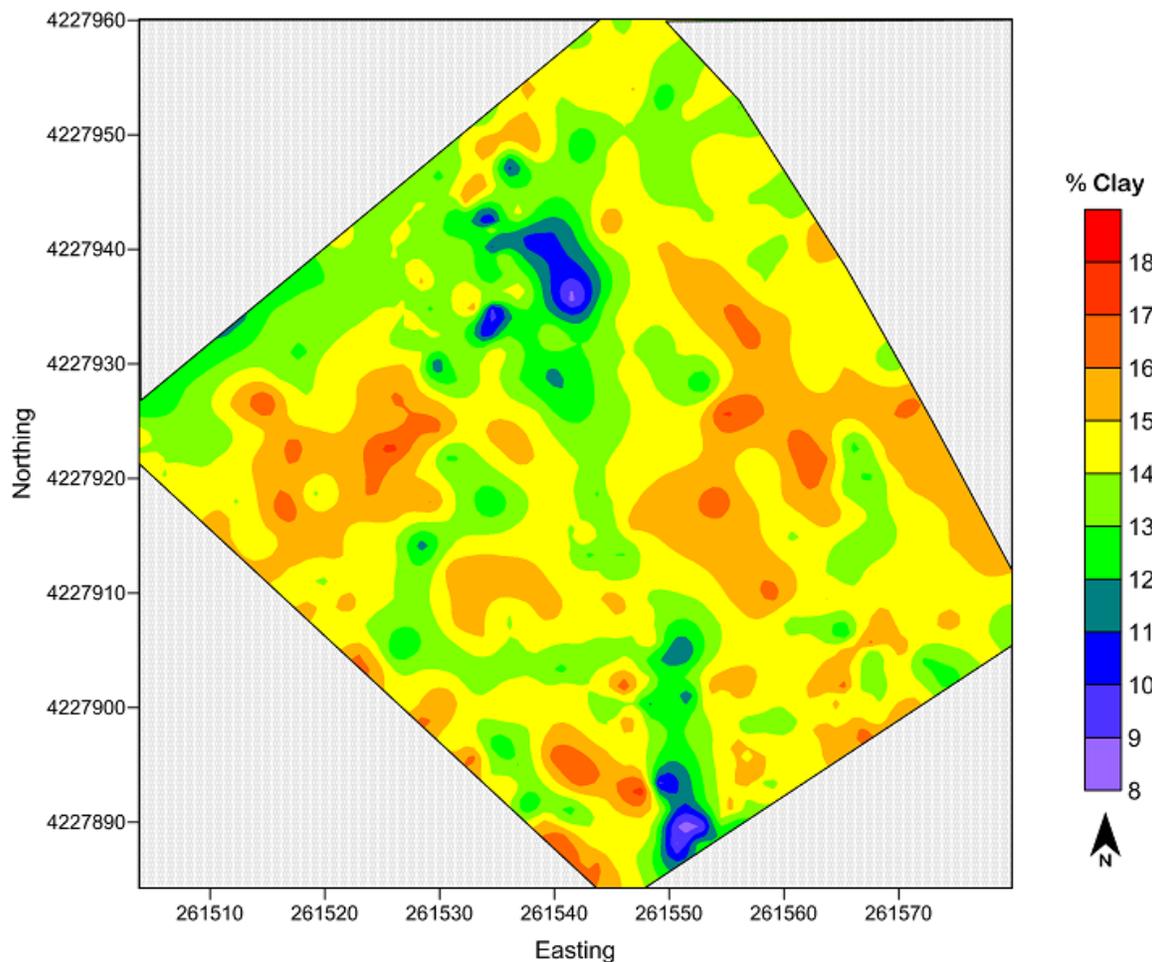


Figure 8. The ESAP predicted (R_2 of 0.6065) clay contents for the 0 to 100 cm depth interval at Sparta Site 3 is shown in this plot.

The spatial distribution of average clay content within the upper 100 cm of the soil materials across Sparta Site 3 is shown in Figure 8.

The results of this study have been provided without ample occasion to digest all the information or to understand the results and ramifications of this study. I welcome any discussions or observations that you can make concerning the processes that have been used. Results are highly site-specific; may be temporal dependent (soil moisture); and will be contingent on the inherent variability of other soil physiochemical properties. Different soil physiochemical properties interact and will affect EC_a measurements. Not all soil properties will significantly affect EC_a , for those that do, however, the magnitude of their impact on EC_a will depend on variations in other soil properties.

Best wishes,

Jim Doolittle