GEOSPATIAL MAPPING OF VINEYARD SOILS VIA ELECTROMAGNETIC INDUCTION

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Introduction:

Due to the unique morphology of the grapevine root, deep soils are of notable significance for successful viticulture. Additionally, the high disease susceptibility of *Vitis vinifera* calls for well-drained soils for high quality winegrape production. Due to the effects of soil nutrients upon vine vigor and berry maturation, a well-balanced fertility program is essential.

Initiation of vineyard development requires intensive soil mapping in order to detect the presence or absence of restrictive horizons (notably fragipan, duripan, argillic horizon, cementation), permeability, redoximorphic features, depth to bedrock or paralithic bedrock, "perched" horizon interface, penetration resistance, effective rooting depth, vertical tillage depth, and other pedotransfer functions such as texture, structure, and rock content by depth, which can be used to calculate available water capacity.

By marrying technologies such as GIS and pedology, greater reproducible accuracy can be attained in less time. The ability to create a computer-generated geospatial subsurface map would be extremely conducive for the exploration and computation of pedology analysis for vineyard development. This would provide the viticulturist a method to mollify disparity within each vineyard block. Greater uniformity is desirable in viticulture because winemaking often depends largely upon the weather and the limiting factor during harvest is time. Therefore the nature of winemaking calls for a wine to be made in bulk, and too much variability in quality would result in lesser quality wine. Hence, vineyard blocks are usually harvested in total.

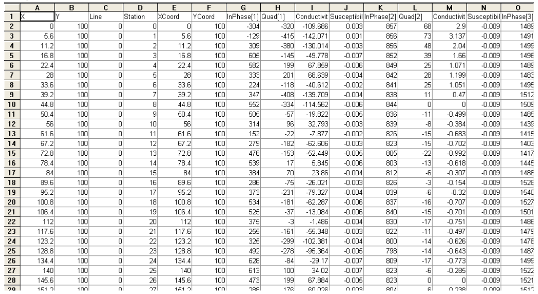
Electromagnetic induction (EMI) transmits a primary magnetic field at preselected frequencies to induce an electric current into a given pedon, polypedon, or solum. Depending upon the mineralogy of the soil solid, as well as the ionic strength of the soil solution and a host of other factors (such as water, clay, and nutrient content) – all of which effect soil electrical conductivity (EC) – a secondary magnetic field is created. The values generated by the particular pedon are quantifiable by EC units (dS/m), and can be heuristically stored in a compatible field computer. A geospatial map of the field site can be generated with compatible software, by correlating disparities in the soil's apparent electrical conductivity (EC_a), within a test area (Doolittle et al., 1995). Soil salinity is not a major contributor to EC_a readings in a udic regime (Anderson-Cook et al., 2002).

Theory:

Geospatial mapping via EMI can save time and money for soil mapping. EC is affected by soil depth, clay mineralogy, soil water, salinity, rock content (Sudduth et al., 2001). Doolittle et al. (1994), used electromagnetic induction to map clay pan soils.

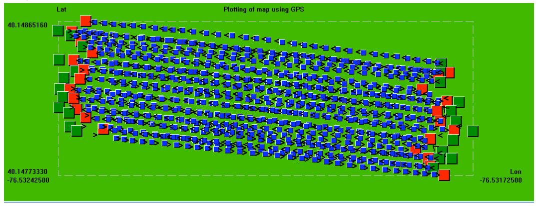
Analysis of a geospatial map of EC_a, can serve as a reconnaissance tool in order to economically position soil profiles. By correlating the overt trends of the field's EC_a values with the results of pedology analysis, a model of variance can be inferred in a time-efficient and cost-effective manner. Areas of interest can be further analyzed with pedology, EMI, and ground penetrating radar (GPR).

Fig. 3a



	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
1	X	Y	Line	Station	XCoord	YCoord	InPhase[1]	Quad[1]	Conductivit	Susceptibil	InPhase[2]	Quad[2]	Conductivit	Susceptibil	InPhase[3]
2	0	100	0	0	0	100	-304	-320	-109.686	0.003	857	68	2.9	-0.009	1489
3	5.6	100	0	1	5.6	100	-129	-415	-142.071	0.001	856	73	3.137	-0.009	1491
4	11.2	100	0	2	11.2	100	309	-380	-130.014	-0.003	856	48	2.04	-0.009	1499
5	16.8	100	0	3	16.8	100	605	-145	-49.778	-0.007	852	39	1.66	-0.009	1496
6	22.4	100	0	4	22.4	100	582	199	67.859	-0.006	849	25	1.071	-0.009	1489
7	28	100	0	5	28	100	333	201	68.639	-0.004	842	28	1.199	-0.009	1483
8	33.6	100	0	6	33.6	100	224	-118	-40.612	-0.002	841	25	1.051	-0.009	1495
9	39.2	100	0	7	39.2	100	347	-408	-139.709	-0.004	838	11	0.47	-0.009	1512
10	44.8	100	0	8	44.8	100	552	-334	-114.562	-0.006	844	0	0	-0.009	1509
11	50.4	100	0	9	50.4	100	505	-57	-19.822	-0.005	836	-11	-0.499	-0.009	1485
12	56	100	0	10	56	100	314	96	32.793	-0.003	839	-8	-0.384	-0.009	1439
13	61.6	100	0	11	61.6	100	152	-22	-7.877	-0.002	826	-15	-0.683	-0.009	1415
14	67.2	100	0	12	67.2	100	279	-182	-62.606	-0.003	823	-15	-0.702	-0.009	1403
15	72.8	100	0	13	72.8	100	476	-153	-52.449	-0.005	805	-22	-0.992	-0.009	1417
16	78.4	100	0	14	78.4	100	539	17	5.845	-0.006	803	-13	-0.618	-0.009	1445
17	84	100	0	15	84	100	384	70	23.86	-0.004	812	-6	-0.307	-0.009	1488
18	89.6	100	0	16	89.6	100	286	-75	-26.021	-0.003	826	-3	-0.154	-0.009	1528
19	95.2	100	0	17	95.2	100	373	-231	-79.327	-0.004	839	-6	-0.32	-0.009	1540
20	100.8	100	0	18	100.8	100	534	-181	-62.287	-0.006	837	-16	-0.707	-0.009	1527
21	106.4	100	0	19	106.4	100	525	-37	-13.084	-0.006	840	-15	-0.701	-0.009	1501
22	112	100	0	20	112	100	375	-3	-1.486	-0.004	830	-17	-0.751	-0.009	1486
23	117.6	100	0	21	117.6	100	255	-161	-55.348	-0.003	822	-11	-0.497	-0.009	1479
24	123.2	100	0	22	123.2	100	325	-299	-102.381	-0.004	800	-14	-0.626	-0.009	1478
25	128.8	100	0	23	128.8	100	492	-278	-95.364	-0.005	798	-14	-0.643	-0.009	1487
26	134.4	100	0	24	134.4	100	628	-84	-29.17	-0.007	809	-17	-0.773	-0.009	1499
27	140	100	0	25	140	100	613	100	34.02	-0.007	823	-6	-0.285	-0.009	1522
28	145.6	100	0	26	145.6	100	473	199	67.884	-0.005	823	0	0	-0.009	1521

Fig. 3b



Materials and Methods:

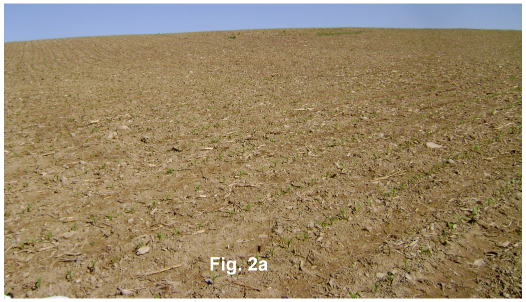
Reconnaissance studies were conducted with an EM-400 Profiler (GSSI, New Hampshire) in concert with a Trimble field computer (figure 4b), by walking a grid with the device held at a constant pre-ordained height from the soil surface (figure 4a). Field site OSV was 2 hectares (5 acres). Grid rows were staked every 3.04 meters (10 ft), oriented on the Y-axis, and extended 152 meters (500 ft). GPS can also be tracked, and synchronized with EC_a (See figure 3b).

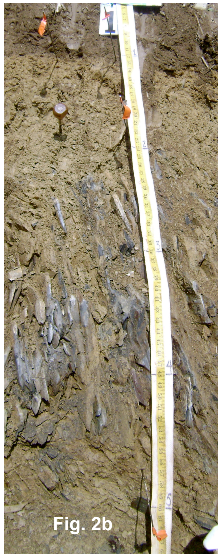
After completing data acquisition, the data is transferred from the field computer to a laptop computer and manipulated with MagMapper software to create a dat.file (figures 3a, 3b), which is exported as a grd.file into Surfer 8.0 software to create the map at upper right (figures 1a, 1b).

A northwest-to-southeast transect was established to represent disparity in EC_a. Soil profiles were dug in pedons, according to associative EC_a values. Pedology analysis was conducted in the field following the conventions of the Soil Survey Staff (1993).

Soil water greatly influences soil EC, therefore volumetric water content is recorded (OSV VWC= 18%) at every site before mapping EC_a, via time-domain reflectometry (TDR). The infiltrating saturation front initiates deprotonation thereby increasing the ionic strength of the soil solution. The penetrating front is supersaturated. Consistence was the goal for defining suitable conditions. Due to high frequency of rain in 2009, all mapping was performed at field capacity.

Particle size distribution and inductively coupled plasma emission spectrometry (ICP) were conducted by Logan Labs LLC, Lakeview, OH.





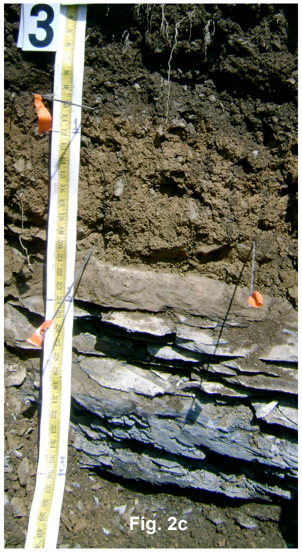


Fig. 1a, 1000 Hz

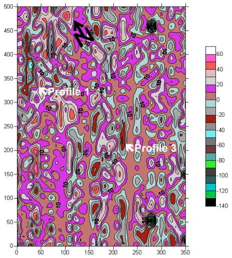
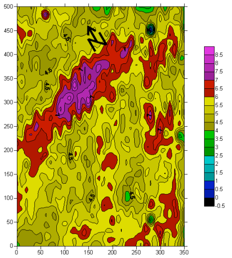


Fig. 1b, 15,000 Hz



Field site characteristics and pedology:

The solum of the proposed vineyard resides within the Great Valley Section of the Ridge & Valley Physiographic Province. The soils represent the summit, shoulder, and backslope of the hill, at an elevation of 700 ft. MSL, at 40º North latitude, on a southern aspect at 154º with a 4.1º slope. Surface morphometry (see figure 2a) ranges from convex-linear, to convex-convex at Profiles # 1 & 2, linear-convex at Profiles 3 & 4, linear-linear at the northeastern corner, and a slight depression at the southeastern corner (see figure 5).

The deep, friable, very well-drained, slightly acid, moderately permeable soils which reside on the shoulder and convex backslope of the hill varied drastically from the soils of Profile 3, which were very shallow with bedrock at 21 inches. The question to raise is the location of soils similar to Profile 3. The geospatial mapping can provide clues to locate these outliers.

The agricultural history of the soils is conventional tillage, with an Ap horizon to 10 inches. Currently, corn (*Zea maiz*) is being farmed, with weed patches of common burdock (*Arctium minus*), leafy spurge (*Euphorbia esula*), and Canadian thistle (*Cirsium arvense*).

Surface soils were dark brown (7.5YR 3/4) to brown (10YR 4/3), granular crumb to weak coarse subangular blocky, very friable with 15% channery/ 5% gravelly silt loams, underlain by strong brown (7.5YR 5/8) to yellowish brown (10YR 5/6), strong medium subangular blocky, friable, very sticky, very plastic, 20% channery/ 10% stony silty clay loams.

Subsoils were reddish yellow (5YR 6/6) to pale brown (10YR 6/3), massive, firm to hard, 85% channery silty clay loams to a depth of 57 inches or more. Skeletal grains - stable and not readily transported - represent the colloid.

Many fine rooting and high vesicular, tubular porosity in surface soils atop common fine rooting in the upper B horizons underlain by few and fine rooting to none below 27 inches. The slopes ranging from 4.1º - 8.4º exhibit a medium- to very high-hazard of surface runoff. Generally an accumulation of clay existed in the Bt horizon. Profile 3 however lacked substantial clay accumulation.

Results and Discussion:

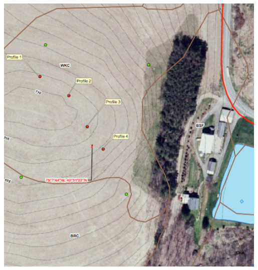
Higher frequency energy waves penetrate a shallower depth than lower frequencies. Therefore the values recorded at 15,000 Hz refer to surface soils; whereas values recorded at 1000 Hz refer to subsurface horizons (see figure 1a, 1b). Electromagnetic induction scans were measured in vertical dipole position, which penetrates at a greater depth than horizontal dipole mode.

The noticeable trend at 15,000 Hz could indicate a clay lens, deeper topsoil, or possibly a fertilizer plume; but this anomaly was not the focus of the field study. Instead, greater attention was paid to subsurface values recorded at 1000 Hz, in order to associate pedology of a given pedon to areas on the field which shared the same EC_a values.

In this case the pedology of interest resided at the outlier pedon of profile #3. This pedon possessed a shallow bedrock, a feature which could adversely affect vine growth uniformity within the block. Although we can do very little to mollify shallow soils such as these, we can apply viticultural techniques to moderate the ill effects. These techniques include - but are not limited to - altered vine spacing and usage of alternative rootstocks. Therefore the locations of such aberrations is of utmost importance.

The pedon of profile #3 represented an EC_a reading of -25 dS/m. Further pedology analysis can be directed at all areas on the map which exhibit the same EC_a values. EC_a values were inversely proportional with rock content, and positively correlated with clay content.

Fig. 5



Acknowledgements:

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