IRRIGATING THE SOIL TO MAXIMIZE THE CROP – AN APPROACH FOR WINTER WHEAT TO EFFICIENT AND ENVIRONMENTALLY SUSTAINABLE IRRIGATION WATER MANAGEMENT IN KENTUCKY

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PURPOSE

To develop a strategy for deriving a map of functional soil water characteristics based on easily obtainable land surface observations.

OBJECTIVES

- to derive a field-scale characterization of soil hydraulic properties for better irrigation management,
- to implement this information and sporadic soil and crop measurements into a computer model for describing the annual water status in different zones across the field while taking into account crop growth, and
- to evaluate different sources of land surface remotely sensed information as a basis for upscaling detailed information and knowledge to improve irrigation management at a regional scale.

REPORT ON ACCOMPLISHMENTS DURING YEAR 1

Summary of Results obtained in Year 1:

- First results on soil textural analysis reveal that our choice of sampling soil and plant properties at a 164-ft-grid has been successful. Properties measured show distinct variability, and based on their variability structure, their spatial distribution can be mapped, and they can be related with each other.
- Using VERIS EC-measurements, the precision of the soil texture map can substantially be improved.
- This basic soil survey is essential for the interpretations of results in years 2 and 3 of the project.
- Soil water potential measurements in different layers reflect the water availability for the crop under current conditions. For drier periods, we will explore their capability to indicate site-specific irrigation demand.

The experiments in this project are conducted at Hillview Farms in Princeton, KY with the farmer Trevor Gilkey. Investigations are conducted in the Hargis Field, which is classified as different types of silt loam soils. In both seasons, 2014 and 2015, corn has been and is grown in this field. In fall 2015, wheat will be grown in this field, followed by double-crop soybeans. The field is under pivot irrigation which covers an area of approximately 80 acres.

A graduate student, Javier Reyes with a M.S. degree from the University of Valdivia, Chile, joined the Integrated Plant & Soil Sciences graduate program in August 2014 to work on his PhD degree.

During year 1, a sampling grid of 96 points was laid out in the field in a 164 by 164 ft grid (50 by 50 m). The 96 sampling points are displayed as red bullets in Figure 1. The sampling locations are arranged in an 8 by 12 point rectangle. This rectangle covers an area of approximately 59 acres.

At each of the 96 sampling points, soil samples were taken for soil textural analysis for five depths increments, each 8” thick down to a depth of 40 inches. At every other location, water marks were installed at three depths (8, 16 and 24”) together with soil thermometers to measure the soil water potential which reflects the plant availability of soil water and can be converted into irrigation demand of the crop. The 48 locations with water marks at three depths are marked in Figure 1 with an **X** on top of the red bullet. The water mark sensors deliver an electrical resistance value as output. Together with the soil temperature at the depth of measurement, this resistance needs to be converted into a SWP value. In order to simplify the reading, two handheld computers were built by our technician Jason Walton. We are currently looking for funding sources to obtain wireless and remote access to the SWP measurements.

At the same 96 locations at which soil texture samples were collected, leaf area index measurements were taken in spring of 2015 using a Licor Canopy Eye LAI 2000. Before corn planting, electrical conductivity (EC) was measured using a VERIS 3150 disc scanner in parallel paths along and between the lines of soil textural sampling points. Between two rows of soil sampling points, 2 paths were measured with the VERIS, i.e., at a separation distance of 54 feet. This resolution yielded a total of approximately 8,000 EC measurement points. These points are displayed as blue dots in Figure 1.

RESULTS

Two of the five layers of soil textural samples have been analyzed so far, and the third layer is close to completion. In Table 1, the average values of particle size composition are displayed for the upper two soil layers that were investigated together with their basic statistics. Moreover, basic statistics for EC at two depths and for soil water potential measurements at three depths are provided as well.

In this study, not only the sand, silt and clay fractions of textural composition were quantified but sand and silt fractions were also further discriminated into their coarse, medium and fine fractional contents. We decided to further specify the textural composition, as we hope to obtain more specific information about the many different silt loam soil types that this field was classified for. Moreover, several soil indicator variables closely related to crop yield variability are based on mixtures of clay and fine silt content. Several pedotransfer function approaches for the indirect derivation of soil hydraulic properties are also based on fine resolution of the soil textural composition. As displayed in Figure 2 for the average particle size compositions of the upper two layers, the textural distribution function can be derived with high precision compared to a three-class discrimination only.

FIGURE 1. THE HARGIS FIELD AT HILLVIEW FARMS, PRINCETON, KY WITH SAMPLING LOCATIONS FOR VARIOUS MEASUREMENTS (SOIL TEXTURE, SOIL WATER POTENTIAL, LAI, EC) BEING INDICATED.

TABLE 1. AVERAGE VALUES AND BASIC STATISTICS FOR SOIL TEXTURE, ELECTRICAL CONDUCTIVITY (EC) AND SOIL WATER POTENTIAL (SWP) AT DIFFERENT DEPTHS.

Variable	Mean	Standard deviation	CV (%)
Sand 0-8” (%)	2.3	2.0	85.5
Silt 0-8” (%)	77.1	9.8	12.7
Clay 0-8 cm (%)	19.8	4.6	23.1
Sand 8-16” (%)	3.0	2.4	81.4
Silt 8-16” (%)	70.8	9.7	13.7
Clay 8-16” (%)	25.5	5.7	22.2
EC shallow layer (S m^{-1})	4.6	1.3	27.5
EC deep layer (S m^{-1})	14.8	3.9	26.3
SWP 8” (kPa)	30.1	3.8	12.6
SWP 16” (kPa)	28.8	3.0	10.4
SWP 24” (kPa)	27.6	2.8	10.1

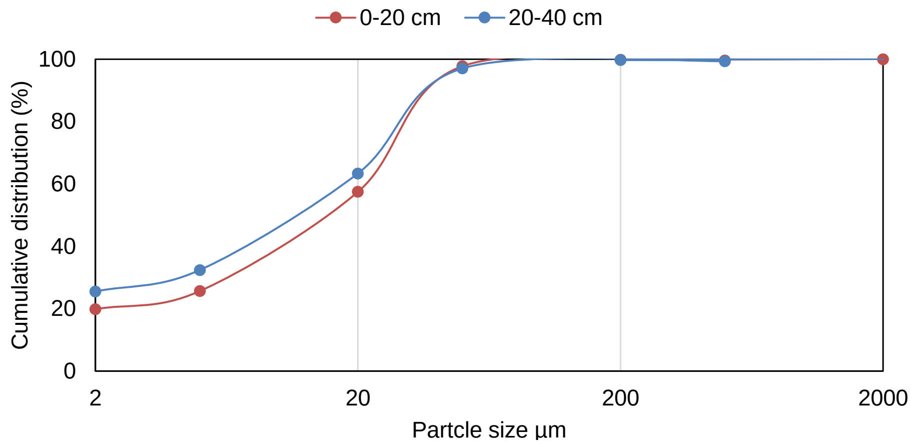


FIGURE 2. CUMULATIVE PARTICLE SIZE DISTRIBUTION FOR THE 0-8" (0-20 CM) AND 8-16" (20-40 CM) DEPTHS.

In the following, our first attempts of a spatial representation of distribution maps of the field observations are discussed.

In Figure 3, two maps of soil clay content for the upper soil depth (0-8") are displayed. The clay map for the upper layer is based on the measured clay content values, only. The procedure to interpolate such a map is called kriging. Kriging is based on a certain behavior of spatial variability, i.e., that measurements are taken close enough in order to differ less over short distances than they do over distances farther apart. This behavior is also called structured variability, and is a prerequisite to draw a map.

However, it is of great advantage if a second variable can be measured that is spatially related to clay content, especially in cases when this variable can be measured much easier and faster than clay content itself. It is known from the literature, that EC can be such a surrogate variable for clay content. Both variables are strongly correlated, because the electrical conductivity of a soil depends to a great extent on clay content. In addition, EC depends on still other variables, however, it can be used to estimate soil clay content for locations where clay content was not measured.

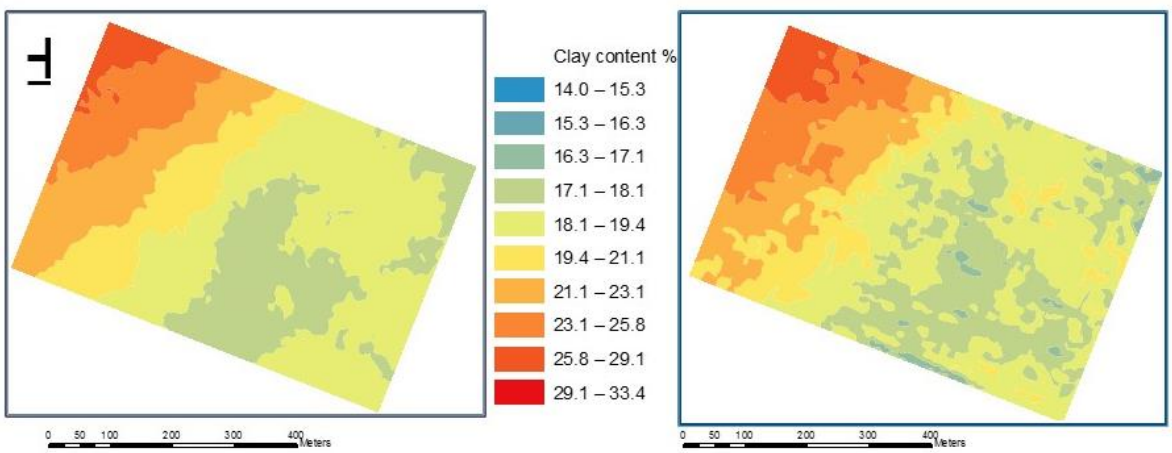
In this case, the spatial correlation between clay content and EC was calculated for those locations for which we had obtained measurements of both variables. Their spatial correlation was computed, and in a procedure called co-kriging, clay content distribution could even be calculated and mapped for those locations where no clay content measurement existed in the close vicinity of up to 80 feet.

The comparison between both clay maps shows, that the contours of the map including the EC information (lower part of Figure 3) shows much finer patterns and a more heterogeneous distribution than the map entirely based on clay content only (Figure 3, upper part). A result that is not visualized here reflects the fact that the map based on both, clay content and EC information reveals a higher precision than the one based only on clay content. These are only the first attempts in comparing different information sources and the ways in which they affect the appearance and the quality of a map.

In Figure 4, the spatial distribution of soil water potential (SWP) is displayed for the three different depths of measurements for a day in May. The SWP measurements at all three depths reflect soil water conditions close to or above field capacity. These relatively wet conditions are most probably the reason why the clay content map does not exhibit a close relationship with SWP. It is known from the literature, that SWP tends to be the closer correlated to clay content the drier the soil is.

SUMMARY

In the first year of the project, we obtained a basic survey of the field site. Our sampling scheme for soil texture at a 164 by 164 ft. grid revealed spatial structure of observations. Hence, maps for soil textural composition can be drawn and soil texture can be related to other measurements. The first sets of SWP measurements have been taken, and we will continue to monitor SWP until harvest. SWP measurements taken under drier conditions than in the season of 2015 are expected to show different water demands across the field.



Kriging estimation

Cokriging estimation (electrical conductivity as secondary variable)

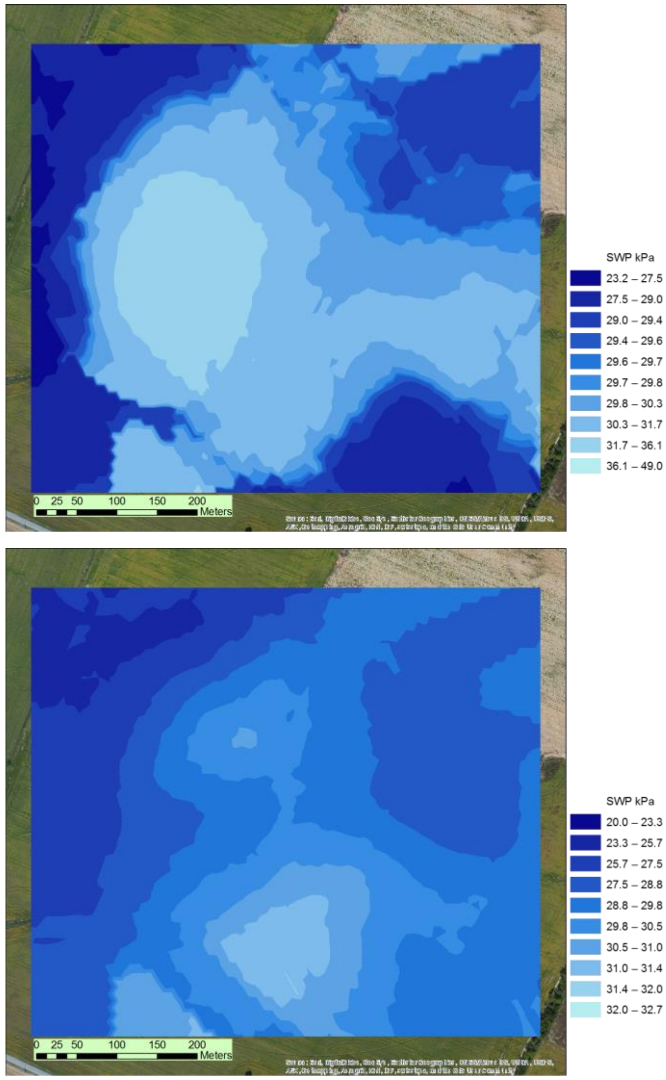


FIGURE 3. CLAY CONTENT MAPS FOR THE 0-8" (0-20 CM) SOIL DEPTH. THE MAP IN THE UPPER PART WAS GENERATED BASED ON MEASURED CLAY CONTENT ONLY (KRIGING), WHEREAS THE MAP IN THE LOWER PART WAS IN ADDITION TO CLAY CONTENT SUPPORTED BY THE HIGH-RESOLUTION EC DATA (CO-KRIGING).

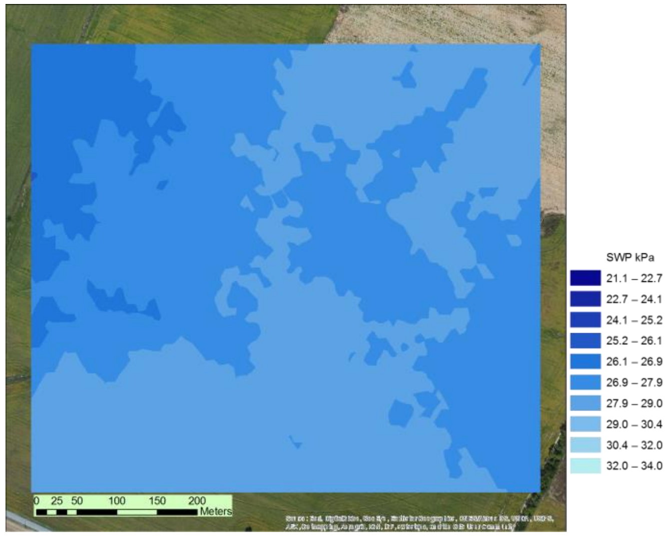


FIGURE 4. SOIL WATER POTENTIAL (SWP) MAPS AT THREE DEPTHS (UPPER PART: 8", MIDDLE PART: 16", BOTTOM PART: 24" DEPTH), MEASURED ON A DAY IN MAY 2015.

From September 22-25, 2015, we took soil samples from four different depths (0-6", 6-12", 12-24", and 24-36") and from three augers for each of the 96 points depicted in Figure 1. These samples are currently analyzed for soil water content and mineral nitrogen content. On Nov. 05-7, 2015, the soil water status sensors will be re-installed in the experimental field that is now planted with winter wheat. Sensors will be installed at three depths at the 48 locations

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