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ROOT ZONE AVAILABLE WATER CAPACITY

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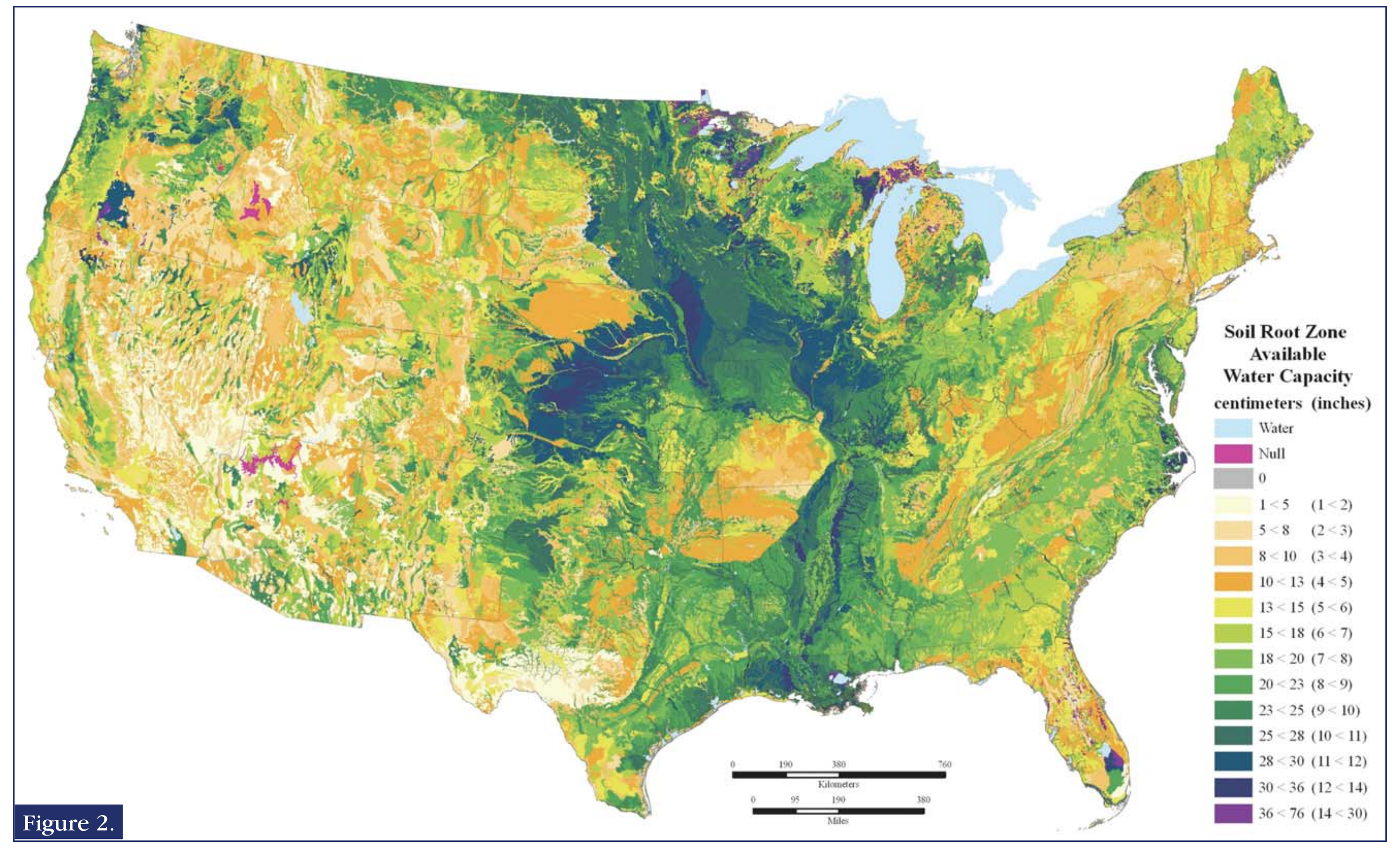

Figure 2.

Kansas

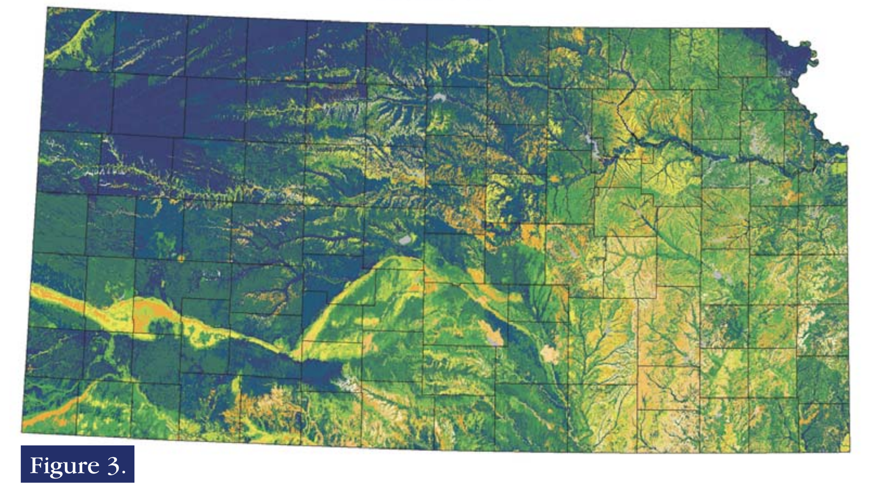

Figure 3.

Illinois

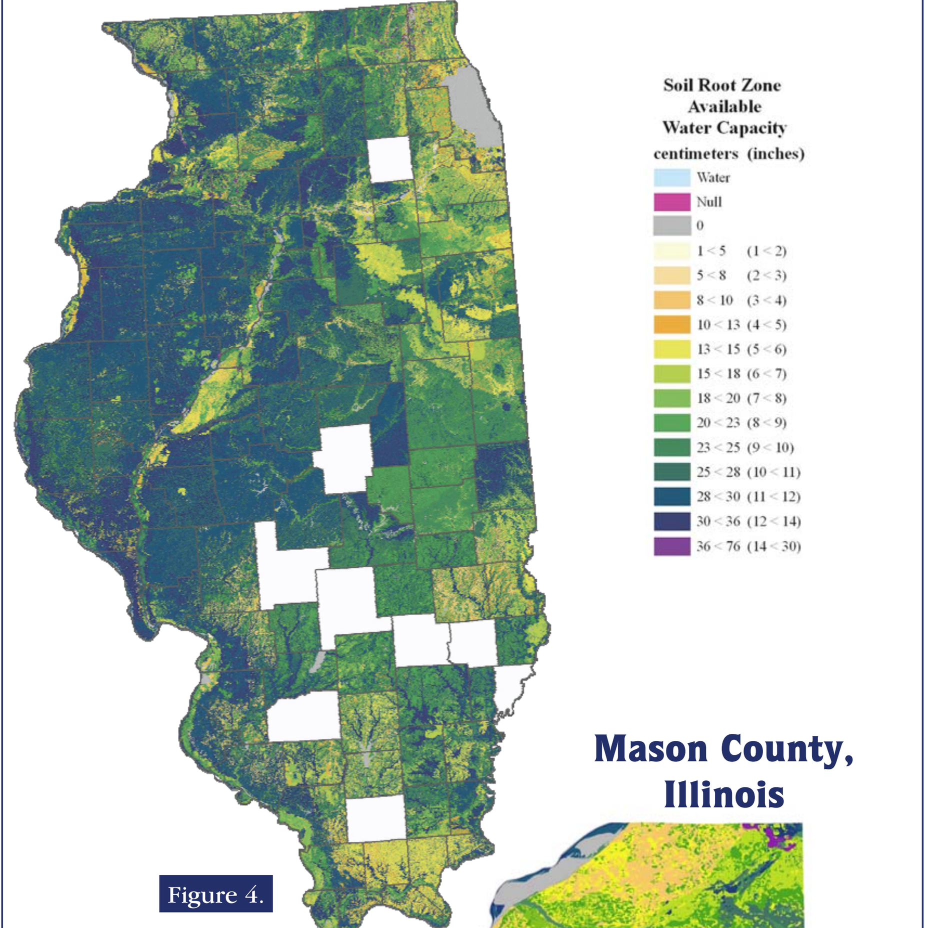

Figure 4.

Sherman County, Kansas

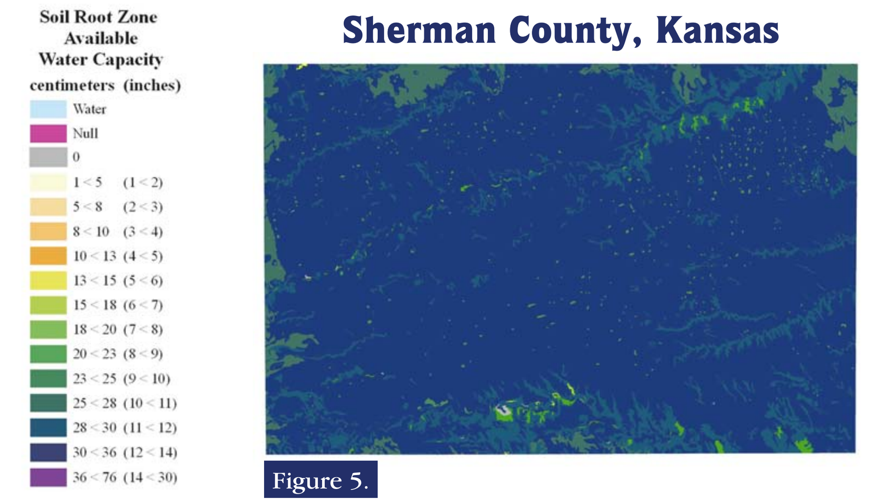

Figure 5.

Mason County, Illinois

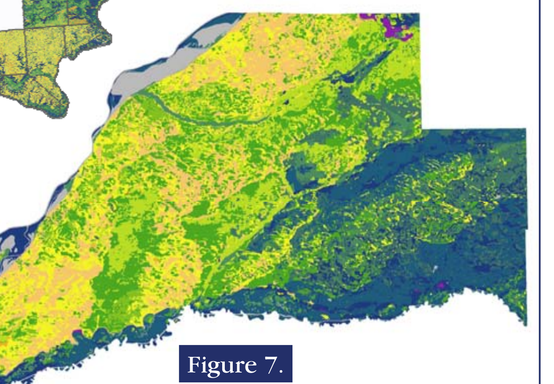

Figure 7.

Doniphan County, Kansas

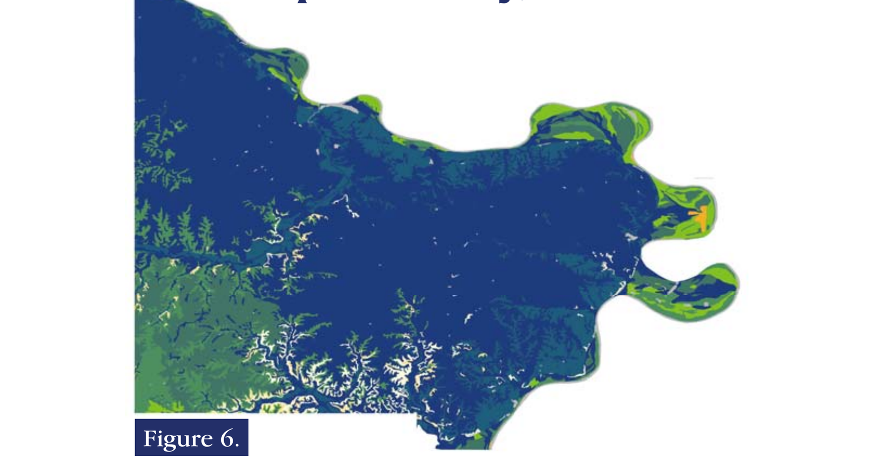

Figure 6.

General Soil Map – Mason County, Illinois

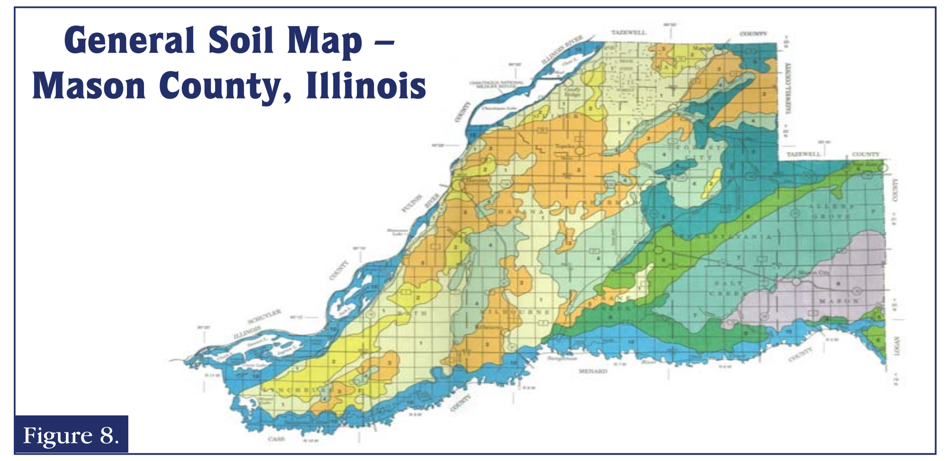

Figure 8.

INTRODUCTION

Root zone available water capacity (RZAWC) is one of the most important soil qualities impacting plant production. RZAWC is derived from the water retention difference (WRD), which is a laboratory measure of the volume of water that is held by a soil horizon between field capacity (1/3 bar) and 15 bars, inclusive of rock fragments. The available water capacity (AWC) is the volume of water held by a soil layer that should be available to plants if the soil, inclusive of rock fragments, were at field capacity (Soil Survey Staff, 1993). Reductions in AWC are made for incomplete root ramification associated with certain soil chemical and physical properties such as high bulk densities, high electrical conductivities, or high extractable aluminum. At some point, these soil properties restrict root growth and therefore limit the soil depth available for rooting. Other more visible soil features such as fragipans, salts, bedrock, or duripans require reduction in the water difference for root zone available water capacity (RZAWC) for incomplete root ramification that are associated with these soil limiting layers. The amount of RZAWC is calculated to the expected maximum depth of root penetration, commonly either 1 or 1.5 m, or to a physical or chemical root restricting layer, whichever is shallower. The reduction in RZAWC usually results in a soil being less productive.

Charles E. Kellogg (1959), nearly 50 years ago, put in plain words that soil performance data seem to be a different subject than soil correlation. Soil performance data are so important to the purpose of soil survey that little is said about it in relation to soil correlation.

> *"The general term "soil" is a collective term for all soils, comparable to the word "vegetation" for all plants. A soil is one individual three-dimensional body on the surface of the earth that we distinguish from the unlike adjacent bodies. A kind of soil is a collection of all the soils, wherever they are located, that are alike according to the definitions we write.*
>
> *Our objectives are both scientific and highly practical. Through the process of classification and the research it stimulates, we expand our basic understanding of soils. We want a system of classification that allows us to predict how soils will respond to management. For each kind of soil, we want to predict the adapted plants and their yields; the stability of the soil itself; how … practical objectives.*
>
> *Such practical predictions depend on the soil and our techniques. One cannot say that the production from a field results from either the soil or the management. The harvest results from an intricate set of interactions between a whole group of soil characteristics and a combination of management practices. The management practices that people use vary enormously from place to place, and from year to year, depending upon the current state of the arts; economic conditions; and the skills, resources, and desires of land occupiers.*
>
> *Thus it becomes important that we distinguish clearly between soil characteristics, which can be seen and measured in the field or measured in the laboratory, and soil qualities, which result from interactions between these characteristics and practices. The first are relatively permanent, whereas the second are subject to frequent change."*

For the last 110 years, researchers have written and documented that root-zone available water capacity (RZAWC) and climate usually determine the crop grown and its yield. Olson and Lang (2002) state that soil productivity is strongly influenced by the capacity of a soil to supply the nutrient and soil-stored water for growing a crop in a given climate. Brown and Carlson (1990) state that under dryland farming, water is the most limiting factor for crop production in Montana and the Northern Great Plains. They developed equations to relate grain yields related to stored soil water and growing season rainfall for winter and spring wheat, barley, oats, and safflower. Gross and Rust (1972) determined that relating soil moisture to temperature, precipitation, and water holding capacity provides a more realistic available moisture value for commodity crops. They documented that one of the variables most highly correlated with yield was soil moisture during the growing season. Schroeder (1992) stated that small grain yields on downslope positions of the landscape produce 30 to 80 percent higher yields than upslope positions when averaged over years. This indicated that landscape position played an important role in yields of small grains. Soil and climate properties have different interactions for plant growth. Some elements have a greater impact on plant growth than others. Typically, selected soil properties, e.g., proportion of sand, silt, and clay, pH, bulk density, salinity, sodicity, root limiting (earthy and non-earthy) layers, landscape position, amount of precipitation, organic matter, and rock fragments, etc. will determine the root zone available water capacity (RZAWC) of a soil (Dale, 1968). In years of normal precipitation, the RZAWC of prime farmland soils to a large extent determines the vegetative growth and crop yield (Shaw and Felch, 1972 and Voss et al., 1970). RZAWC is a surrogate for many other soil properties and features. Knowing the RZAWC relationship allows soil scientists to make relatively accurate vegetative growth predictions (Whitney et al., 1897). The current information substantiates the earlier information on RZAWC and climate.

METHODS

Soil scientists used guidelines established by the National Cooperative Soil Survey (NCSS, 2005) to complete the Soil Surveys of Mason County, Illinois (Calsyn, 1995) and Doniphan (Sallee, 1980) and Sherman (Angell et al., 1973) Counties, Kansas. The NCSS is a nationwide partnership of federal, regional, state, and local agencies and institutions. This partnership works closely with universities to cooperatively investigate, inventory, document, classify, and interpret soils and to disseminate, publish, and promote the use of information about the soils of the United States and its trust territories. The activities of the NCSS are carried out on national, regional, and state levels. Populating soil property data, climatic factors, and landscape features in the National Soils Information System (NASIS) followed the NCSS guidelines. The soil information in Tables 1 through 4 was extracted from the Soil Data Mart (Soil Survey Staff, 2007), calculated using data elements in the Soil Data Mart, or generated using interpretative models with data elements in NASIS. Hartung et al. (1991) state that soil-landscape relationship is the scientific basis that makes it possible to produce a soil mapping model. The soil scientist designs soil map units based on these models. Reliable soil maps can be made because the location of soils is predictable on the landscape.

Soil attribute data contained in the Digital General Soil Map of the United States (STATSGO2) and the Soil Survey Geographic (SSURGO) databases were used to develop thematic maps showing, at different scales and levels of resolution, the root zone available water capacity in units of inches and centimeters. The root zone calculation for both STATSGO2 and SSURGO were originally prepared in NASIS for correlated legends and then written to an MS Excel spreadsheet. The spreadsheets were converted to Dbase IV format and then joined to SSURGO and STATSGO2 feature classes for mapping using ArcGIS version 9.2. Root zone available water capacity small scale (1:3,500,000 and 1:500,000) map products for the nation and for individual states will be offered later this calendar year as part of the on-line Soil Survey Atlas (see http://www.ngdc.wvu.edu).

The Digital General Soil Map (STATSGO2) database was developed by the USDA-NRCS and published in 2007 (USDA-NRCS, 2007). These data were formerly known as a national collection of the State Soil Geographic database (STATSGO) and are now available for the conterminous United States, Alaska, Hawaii, and Puerto Rico. Because of the small compilation scale (1:250,000) of STATSGO2 maps, soil map units and polygons that appear on soil survey maps

METHODS, cont.

had to be combined and generalized. This procedure resulted in fewer soil map units and larger soil polygons. The STATSGO2 database contains 9,555 unique map units and 78,220 polygons. The minimum polygon size is about 6.25 square kilometers (1,544 acres). The composition of each map unit was coordinated so that the names and relative extent of each soil component would remain the same between survey areas and across political boundaries. In areas where detailed soil maps were not available, existing data were assembled, reviewed, and the most probable classification and extent of soils determined (USDA-NRCS, 1994). STATSGO2 data are available through the Soil Data Mart (http://soildatamart.nrcs.usda.gov/) by selecting "U.S. General Soil Map".

Larger scale, less generalized maps, which show in greater detail the spatial distribution of soil properties that influence the root zone available water capacity calculation, are prepared using the Soil Survey Geographic (SSURGO) database. The SSURGO database (USDA-NRCS, 2007) contains the most detailed level of soil geographic data developed by the USDA-NRCS. Soil maps in the SSURGO database generally duplicate the original soil survey maps, which were prepared using national standards and field methods at scales ranging from 1:12,000 to 1:63,360 (with minimum delineation size of about 1.5 to 40 acres, respectively) (Soil Survey Staff, 1993). Base maps are USGS 7.5-minute topographic quadrangles and 1:12,000 or 1:24,000 orthophotoquads.

Tabular and spatial SSURGO data are available through the Soil Data Mart. The USDA-NRCS is presently compiling and digitizing data from 2790 soil survey areas. Completion of the SSURGO data digitizing is scheduled for 2008. A status map showing the digitized soil survey areas can be accessed at http://www.ncgc.nrcs.usda.gov/products/datasets/ssurgo.

The Kuma, Marshall, and Tama soils formed in loess. The Onarga and Plainfield soils formed in wind- and water-deposited coarse-textured and moderately coarse-textured materials. The depth to a restrictive layer is more the 60 inches. There is no zone of water saturation within a depth of 72 inches. Their soil classification is given in Table 1.

DISCUSSION

Figure 1.

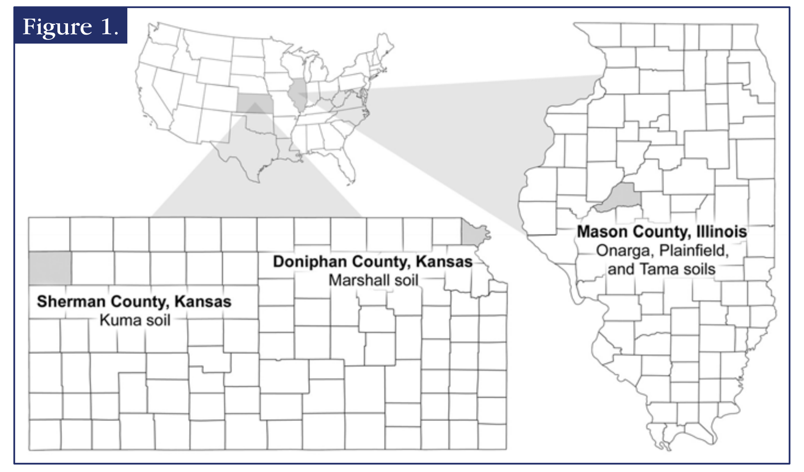

Figure 1 shows the location of the Kuma, Marshall, Onarga, Plainfield, and Tama soils. Figures 2, 3, 4, 5, 6, and 7 are RZAWC maps of the United States; Kansas; Illinois; Sherman and Doniphan Counties, Kansas; and Mason County, Illinois. Figure 8 is a general soil map of Mason County, Illinois (see Table 4 for details). Table 1 presents the soil legend and soil classification (Soil Survey Staff, 1999). Table 2 provides selected soil chemical and physical properties. Table 3 has RZAWC, mean annual precipitation, yields for corn and wheat, land capability subclass (Klingebiel and Montgomery, 1961 and Soil Survey Staff, 1958 and 1959), important farmland classification, National Commodity Crop Productivity Index, Thornthwaite PE Index (Daniels and Johnson, 2001), and latitude and longitude. The soils having the highest RZAWC with about the same mean annual precipitation have the highest yields. The Kuma soil compared to the other fine-silty soils has a lower yield. It has about one-half the mean annual precipitation as the other fine-silty soils which likely is not enough precipitation to have about 11 inches of RZAWC at the beginning of the growing season. Kuma soils have a lower PE index than the other soils. The Kuma's hazard/limitation according to the land capability subclass is climate. Kuma soil is prime farmland if it is irrigated. The RZAWC maps show a small amount of land capability class one land (requires more than 9 inches of RZAWC) exists. Especially if one remembers that the mean annual precipitation is insufficient at the start of the growing season for soil profiles to be at field capacity. Table 4 lists selected soil information for Figure 8. It specifies the soil in each soil association, corn and wheat yields, RZAWC, non-irrigated land capability subclasses, and the soil classification. There is a relationship between crop yields, RZAWC, and soil classification.

CONCLUDING REMARKS

The root-zone available water capacity (RZAWC), climate, and hydraulic conductivity (Ksat) usually determine the crop grown and its yield. Other soil chemical, physical, and biological properties and landscape features (including hydrology, slope, etc.) usually separate soils in a smaller geographical area. These two locations are separated at the second level of soil classification -- suborder. Soils in the Kansas location have a "dry udic" or typically an ustic soil moisture regime. Soils in the Illinois location have an udic soil moisture regime. The PE indices for Western Kansas is 32-43, Eastern Kansas is 46-80, and West Central Illinois is 80-120 (Daniels and Johnson, 2001).

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NRCS Natural Resources Conservation Service

Table 1. Soil map units and their classification.

State	County	Soil Symbol	Soil Map Name	Classification
Illinois	Mason	36B	Tama sil loam, 2 to 5 percent slopes	Fine-silty, mixed, mesic, Typic Argiudolls
Illinois	Mason	54B	Plainfield sand, 1 to 7 percent slopes	Mixed, mesic, Typic Udipsamments
Illinois	Mason	150B	Onarga sandy loam, 2 to 5 percent slopes	Coarse-loamy, mixed, mesic, Typic Argiudolls
Kansas	Doniphan	7290	Marshall silt loam, 2 to 5 percent slopes	Fine-silty, mixed, superactive mesic, Typic hapludolls
Kansas	Sherman	1652	Kuma silt loam, 0 to 1 percent slopes	Fine-silty, mixed, superactive mesic, Pachic Argiustolls

Table 2. Physical and chemical soil properties.

Soil Symbol	Depth (in)	Moist Bulk Density (g/cc)	Saturated Hydraulic Conductivity (micro m/sec)	Available Water Capacity (in/in)	Organic Matter (%)	Soil Reaction (pH)	Calcium Carbonate (%)	Salinity (mmhos/cm)
36B	0-16	1.25-1.30	4.23-12.11	0.22-0.24	3.0-4.0	5.1-7.3	0	0
	16-38	1.30-1.35	4.23-12.11	0.18-0.20	1.0-2.0	5.1-6.5	0	0
	38-60	1.35-1.40	4.23-12.11	0.18-0.20	0.0-0.5	5.6-7.3	0	0
54B	0-9	1.50-1.65	42.34-141.14	0.04-0.09	0.5-1.0	4.5-7.3	0	0
	Sep-31	1.50-1.65	42.34-141.14	0.04-0.08	0.0-0.5	4.5-7.3	0	0
	31-60	1.50-1.70	42.34-141.14	0.04-0.08	0.0-0.5	4.5-6.5	0	0
150B	0-18	1.15-1.45	4.23-42.34	0.13-0.22	2.0-4.0	5.6-7.8	0	0
	18-33	1.45-1.70	4.23-42.34	0.15-0.19	0.2-0.6	4.5-7.3	0	0
	33-60	1.65-1.9	42.34-141.14	0.05-0.13	0.0-0.2	5.1-7.3	0	0
7290	0-7	1.25-1.30	4.23-14.11	0.21-0.23	2.5-5.0	5.6-7.3	0	0
	18-Jul	1.25-1.30	4.23-14.11	0.21-0.23	1.5-3.5	5.6-7.3	0	0
	18-47	1.30-1.35	4.23-14.11	0.18-0.20	0.5-2.0	5.6-6.5	0	0
	47-58	1.30-1.40	4.23-14.11	0.20-0.22	0.3-0.8	6.1-7.3	0	0
	58-68	1.30-1.40	4.23-14.11	0.20-0.22	0.1-0.5	6.1-7.3	0	0
1652	0-5	1.20-1.30	4.23-14.11	0.18-0.21	2.0-4.0	6.1-8.4	0	0
	39231	1.25-1.35	4.23-14.11	0.18-0.21	0.6-3.0	6.6-8.4	0-5	0
	29-60	1.40-1.50	4.23-14.11	0.16-0.18	0.1-1.0	7.9-9.0	0-15	0.0-2.0

Table 3. Selected soil information.

Soil Symbol	Root-Zone Available Water Capacity (in)	Mean Annual Precipitation (in)	Wheat (bu/ac)	Corn (bu/ac)	Land Capability Subclass	Important Farmland	NCCPI	Thornthwaite PE Index	Latitude / Longitude
36B	12.2	32-41	65	167	2e	Prime Farmland	0.95	80-120	40.32 N. / 90.04 W.
54B	3.64	32-41	37	0	6s	Farmland of Statewide Importance	0.31	80-120	40.32 N. / 90.04 W.
150B	8.13	32-41	54	133	2e	Prime Farmland	0.62	80-120	40.32 N. / 90.04 W.
7290	12.2	31-40	51	156	2e	Prime Farmland	0.89	46-80	39.79 N. / 95.09 W.
1652	10.93	16-20	45	55	2c	Prime Farmland, if irrigated	0.63	32-43	39.33 N. / 101.69W

Table 4. Soil information for the General Soil Map of Mason County, Illinois (see Figure 8).

Soil Assoc.	Comp. Name	Corn non-irr (bu/ac)	Wheat non-irr (bu/ac)	RZAWC (cm)	RZAWC (in)	Soil Name	Non-irr Land Capability Subclass	Classification
2	Ade	121	51	12.7	5	Ade loamy fine sand, 1 to 7% slopes	3s	Mixed, mesic Psammentic Argiudolls
9	Alvin	135	53	22.3	8.8	Alvin fine sandy loam, 0 to 2% slopes	2s	Coarse-loamy, mixed, mesic Typic Hapludalfs
9	Alvin	134	52	22.3	8.8	Alvin fine sandy loam, 2 to 5% slopes	2e	Coarse-loamy, mixed, mesic Typic Hapludalfs
9	Alvin	126	49	22.1	8.7	Alvin fine sandy loam, 5 to 10% slopes, eroded	3e	Coarse-loamy, mixed, mesic Typic Hapludalfs
9	Alvin	118	46	22.1	8.7	Alvin fine sandy loam, 10 to 18% slopes, eroded	3e	Coarse-loamy, mixed, mesic Typic Hapludalfs
9	Alvin			22.3	8.8	Alvin fine sandy loam, 18 to 30% slopes	6e	Coarse-loamy, mixed, mesic Typic Hapludalfs
10	Beaucoup	159		28.7	11.3	Beaucoup silty clay loam, occasionally flooded	2w	Fine-silty, mixed, mesic Fluvaquentic Haplaquolls
10	Beaucoup			28.6	11.3	Beaucoup silty clay loam, wet	5w	Fine-silty, mixed, mesic Fluvaquentic Haplaquolls
1/9	Bloomfield	103	44	15	5.9	Bloomfield sand, 1 to 7% slopes	3s	Mixed, mesic Psammentic Hapludalfs
1/9	Bloomfield	98	41	15	5.9	Bloomfield sand, 7 to 15% slopes	4e	Mixed, mesic Psammentic Hapludalfs
7	Broadwell	169	66	26.8	10.5	Broadwell silt loam, 0 to 2% slopes	1---	Fine-silty, mixed, mesic Typic Argiudolls
7	Broadwell	167	65	26.8	10.5	Broadwell silt loam, 2 to 5% slopes	2e	Fine-silty, mixed, mesic Typic Argiudolls
7	Broadwell	157	61	27.2	10.7	Broadwell silt loam, 5 to 10% slopes, eroded	3e	Fine-silty, mixed, mesic Typic Argiudolls
3	Dakota	135	55	15.7	6.2	Dakota fine sandy loam, 0 to 2% slopes	2s	Fine-loamy over sandy or sandy-skeletal, mixed, mesic Typic Argiudolls
3	Dakota	134	54	17.2	6.8	Dakota fine sandy loam, 2 to 5% slopes	2e	Fine-loamy over sandy or sandy-skeletal, mixed, mesic Typic Argiudolls
10	Dockery	109		32.8	12.9	Dockery silty clay loam, frequently flooded	4w	Fine-silty, mixed, nonacid, mesic Aquic Udifluvents
7	Edgington	150	59	31	12.2	Edgington silt loam	2w	Fine-silty, mixed, mesic Argiaquic Argialbolls
6	Elburn	178	67	29.1	11.5	Elburn silt loam	1---	Fine-silty, mixed, mesic Aquic Argiudolls
9	Fayette	148	59	29	11.4	Fayette silt loam, 1 to 5% slopes	2e	Fine-silty, mixed, mesic Typic Hapludalfs
9	Fayette	140	56	28.5	11.2	Fayette silt loam, 5 to 10% slopes, eroded	3e	Fine-silty, mixed, mesic Typic Hapludalfs
9	Fayette	130	52	28.5	11.2	Fayette silt loam, 10 to 18% slopes, eroded	4e	Fine-silty, mixed, mesic Typic Hapludalfs
9	Fayette	119	47	28.5	11.2	Fayette silty clay loam, 7 to 15% slopes, sev. eroded	4e	Fine-silty, mixed, mesic Typic Hapludalfs
9	Fayette			29	11.4	Fayette silt loam, 18 to 30% slopes	6e	Fine-silty, mixed, mesic Typic Hapludalfs
5	Harpster	164	61	30.2	11.9	Harpster silty clay loam	2w	Fine-silty, mesic Typic Calciaquolls
8	Ipava	172	69	27.3	10.7	Ipava silt loam	1---	Fine, montmorillontic, mesic Aqic Argiudolls
4	Marshan	150	58	17.3	6.8	Marshan loam	2w	Fine-loamy over sandy or sandy-skeletal, mixed, mesic Typic Endoaquolls
3	Onarga	134	55	20.7	8.1	Onarga sandy loam, 0 to 2% slopes	2s	Coarse-loamy, mixed, mesic Typic Argiudolls
3	Onarga	133	54	20.7	8.1	Onarga sandy loam, 2 to 5% slopes	2e	Coarse-loamy, mixed, mesic Typic Argiudolls
3	Onarga	125	51	21.5	8.5	Onarga fine sandy loam, 5 to 10% slopes, eroded	3e	Coarse-loamy, mixed, mesic Typic Argiudolls
7	Pillot	146	58	23.2	9.1	Pillot silt loam, 0 to 2% slopes	2s	Fine-silty over sandy or sandy-skeletal, mixed, mesic Typic Argiudolls
7	Pillot	144	57	23.2	9.1	Pillot silt loam, 2 to 5% slopes	2e	Fine-silty over sandy or sandy-skeletal, mixed, mesic Typic Argiudolls
7	Pillot	136	64	22.8	9	Pillot silt loam, 5 to 10% slopes, eroded	3e	Fine-silty over sandy or sandy-skeletal, mixed, mesic Typic Argiudolls
1/2	Plainfield			9.2	3.6	Plainfield sand, 1 to 7% slopes	6s	Mixed, mesic Typic Udipsamments
1/2	Plainfield			9.2	3.6	Plainfield sand, 7 to 15% slopes	6s	Mixed, mesic Typic Udipsamments
1/2	Plainfield			9.2	3.6	Plainfield sand, 15 to 30% slopes	7s	Mixed, mesic Typic Udipsamments
6	Plano	175	67	28.4	11.2	Plano silt loam, 0 to 2% slopes	1---	Fine-silty, mixed, mesic Typic Argiudolls
6	Plano	173	66	28.4	11.2	Plano silt loam, 2 to 5% slopes	2e	Fine-silty, mixed, mesic Typic Argiudolls
5	Selma	157	62	25.9	10.2	Selma clay loam	2w	Fine-loamy, mixed, mesic Typic Haplaquolls
2/3	Sparta	106	45	12.7	5	Sparta loamy sand, 1 to 7% slopes	4s	Sandy, mixed, mesic Entic Hapludolls
2/3	Sparta			12.7	5	Sparta loamy sand, 7 to 15% slopes	6s	Sandy, mixed, mesic Entic Hapludolls
8	Tama	169	66	30.1	11.9	Tama silt loam, 0 to 2% slopes	1---	Fine-silty, mixed, mesic Typic Argiudolls
8	Tama	167	65	30.1	11.9	Tama silt loam, 2 to 5% slopes	2e	Fine-silty, mixed, mesic Typic Argiudolls
8	Tama	157	61	29.3	11.5	Tama silt loam, 5 to 10% slopes, eroded	3e	Fine-silty, mixed, superactive, mesic Typic Argiudolls
6	Thorp	153	60	27.3	10.7	Thorp silt loam	2w	Fine-silty, mixed, mesic Argiaquic Argialbolls
4	Udolpho	124	50	21.5	8.5	Udolpho fine sandy loam	2w	Fine-loamy over sandy or sandy-skeletal, mixed, mesic Mollic Endoaqualfs