United States
Department of
Agriculture

Natural
Resources
Conservation
Service

User Guide for the National Commodity Crop Productivity Index (NCCPI)

Version 2.0, 2012

Cover Photos

***Top.*—A no-till wheat field near Pendleton, Oregon. Photo by Sara Wilson, USDA, NRCS.**

***Middle.*—A cotton field in New Madrid County, Mississippi. Photo by Lynn Betts, USDA, NRCS.**

***Bottom.*—Contour stripcropping in York County, Pennsylvania. Photo by Ron Nichols, USDA, NRCS.**

Contents

Preface

Introduction

The National Commodity Crop Productivity Index (NCCPI) model is a national soil interpretation that is not intended to replace other crop production models developed by individual states. At present, NCCPI is generated in the National Soil Information System (NASIS) environment and is reported in the Soil Data Mart and on Web Soil Survey. It presently deals only with nonirrigated crops, but at a later date it will be expanded to include irrigated crops, rangeland, and forestland productivity.

The NCCPI, version 2.0, arrays soils according to their inherent capacity to produce dryland (nonirrigated) commodity crops. Most of the NCCPI criteria relate directly to the ability of soils, landscapes, and climates to foster crop productivity. A few criteria relate to factors that can limit use of the land (e.g., surface boulders). All criteria used in the index affect crop culture and production and are referred to as factors affecting inherent productivity. The rating indices are derived using the interpretations module of NASIS.

Inherent productivity is considered nearly invariant over time. Temporary fluctuations in productivity caused by good or bad management and year-to-year variations in weather are not addressed. More permanent changes in soil properties that cause significant changes in productivity can affect the NCCPI when current NASIS information is used. Extreme erosion, compaction, land leveling, and salinization are examples that could cause such changes.

Traditional steps in creating soil survey interpretations are:

1. Studying an array of soils having known, documented performance.
2. Constructing conceptual and mathematical relationships that predict soil performance.
3. Using the National Cooperative Soil Survey (NCSS) soil database (NASIS) to generate predictions on a wider array of soils.
4. Testing predictions against the soil survey knowledge base, that is, known local relationships that are accumulated from personal experience; field observations by soil scientists (soil surveyors) and NCSS cooperators and collaborators; and the scientific literature.

Why the NCCPI Was Developed

The Conservation Reserve Program (CRP) of USDA provided one stimulus for the development of the NCCPI. The inherent capacity of soil to produce commodity crops is one factor needed to adjust average rental payments. A soil model that is consistent across political boundaries and over time is required for many uses. Crop varieties, management scenarios, and yields vary from place to place and over time, reflecting choices made by farmers and ranchers. These factors partially mask inherent soil quality. Except for the extreme circumstances mentioned above, inherent soil quality or inherent soil productivity varies little over time or from place to place for a specific soil (map unit component) identified by the NCSS.

Staff of the National Soil Survey Center in Lincoln, Nebraska, developed the NCCPI to use soil survey information that is accessible in every county where commodity crops are grown. The system arrays soils according to their relative productivity for commodity crops and avoids the inequities that are possible when yield data alone are used to rate soils.

Although the immediate focus of the NCCPI is on commodity crops, productivity for certain other crops was considered in those areas where other crops dominate.

Why the NCCPI Uses the NASIS Database

The NCCPI uses soil data stored in NASIS. It rates all soils that are used for the production of commodity crops. The NCCPI model data parameters are items that are (1) uniformly available across the Nation, (2) calculated and/or produced by the same standards throughout the Nation, (3) accessible electronically throughout the Nation, (4) capable of producing results through a system that uses routinely maintained data and information, and (5) detailed enough to accurately represent a few acres in highly variable soils. The NASIS database meets these criteria. Some other attributes important to plant growth are not available in the NASIS database. These attributes include such information as day length and photosynthetically active radiation. The United States was therefore divided into areas that commonly produce specific commodity crops. These areas have climatic factors that remain fairly constant. In some cases criteria from *Soil Taxonomy* (Soil Survey Staff, 1999) are used as effective surrogates for specific climatic variables.

The NASIS database provides information and soil data for nearly all of the Nation's farmland. After soils and their properties in a specific field have been identified, recorded, stored in a database, and published, the database can be queried to obtain data about soil properties and accessory information about landscape features, soil climate, parent material, and taxonomic classes.

As NCCPI development continues and is expanded to include other land uses, the expert knowledge of soil scientists who collected the data and populated the database will be used to calibrate the NCCPI indices across the Nation. As known relative productivities and geographic relationships of soils and crop growth become more clearly understood, new information will be added and used to refine aspects of the model.

Each database entity used in the calculation of NCCPI ratings is called a map unit component. A map unit component is a phase or type of a soil series or higher taxonomic unit. Numerical values for each component stored in the database are typical values for each map unit component of the soil series or higher taxa within a soil survey area. Thus, the index for a soil series may differ from place to place because of the geographic variability of the soils in the series. Many map units consist of more than one component. Not every component name is included in map unit names, but components are identified by name in map unit descriptions and within the database.

Short-term soil variations caused by differences in land management are not yet in the database. Dynamic soil properties, the sampling protocol, and data storage are currently under discussion as parts of projected adjustments in standard NCSS protocols and in the structure of the NASIS database. Results from soil survey data are applicable to the current norms for each soil component of each map unit within the NCCPI.

Present Applicability

In version 2.0 of the NCCPI, the model arrays soils according to their productivity only for *nonirrigated* crops. The focus is on commodity crops in the United States, except for areas where commodity crops are not important. The best soils for the growth of commodity crops generally are the best soils for the growth of other crops.

The NCCPI model focuses on a relative productivity index or ranking over periods of years, not for a single year. Productivity during a single year may be dramatically affected by annual weather or changes in management practices.

This user guide is intended to provide a general overview of the NCCPI and is therefore not a rigorous scientific treatment of soil productivity. A future series of peer-reviewed publications will provide more detailed background information.

User Guide for the National Commodity Crop Productivity Index (NCCPI), Version 2.0

By R.R. Dobos, H.R. Sinclair, Jr., and M.P. Robotham,
United States Department of Agriculture, Natural Resources Conservation Service, National Soil Survey Center,
Lincoln, Nebraska

The National Commodity Crop Productivity Index is a national interpretation in NASIS. It is not intended to replace models developed by individual states. It is for nonirrigated commodity crops only. The interpretation uses natural relationships of soil, landscape, and climate factors to model the response of commodity crops. The NASIS interpretations generator uses a fuzzy systems approach to modeling. Each soil, climate, or landscape characteristic is given a rating (score) by comparing its value to an empirical optimum value (see Appendix 3). These scores are manipulated in various ways to produce the index. The model only uses data available in the NASIS data structure. The following discussion will identify attribute data used and illuminate relationships among the soil, landscape, and climatic properties and the productivity index for each commodity crop category.

The structure of the model consists of three main submodels (fig. 1), each of which represents the response of a suite of crops to soil, landscape, and climatic conditions. The “OR” operator indicates that the highest of the ratings calculated by three main submodels is reported as the NCCPI for the map unit component. This system has the flexibility to add more crop submodels if needed. The three current submodels (categories) are Corn and Soybeans, Small Grains, and Cotton. These categories represent three major divisions of commodity crops, in terms of climatic, landscape, and soil adaptation. Each of the three submodels will be examined in this publication. While the overall look of the three submodels is similar, the inner workings are somewhat different.

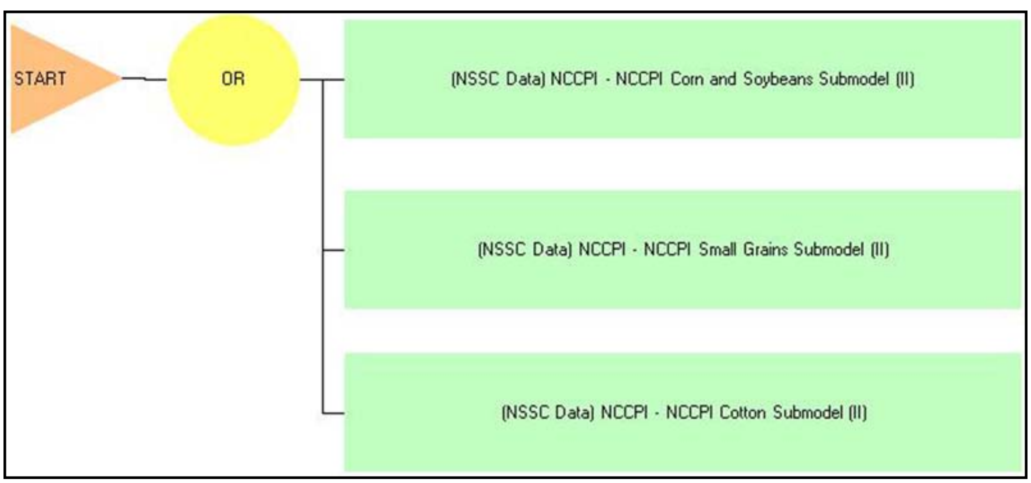


Figure 1.—The Main Model of NCCPI, version 2.0.

The Corn and Soybeans Submodel

Figure 2 illustrates the Corn and Soybeans Submodel. Five of the subrules in this submodel have reasonable fuzzy logic relationships, whereas two of the subrules use crisp relationships. Crisp relationships are used because the data available for specific parameters, such as those for erosion, are not of a continuous nature but rather are class data. This information is not of sufficient quality to develop a fuzzy relationship, since the quantitative impact of an erosion class on crop productivity is generally unknown.

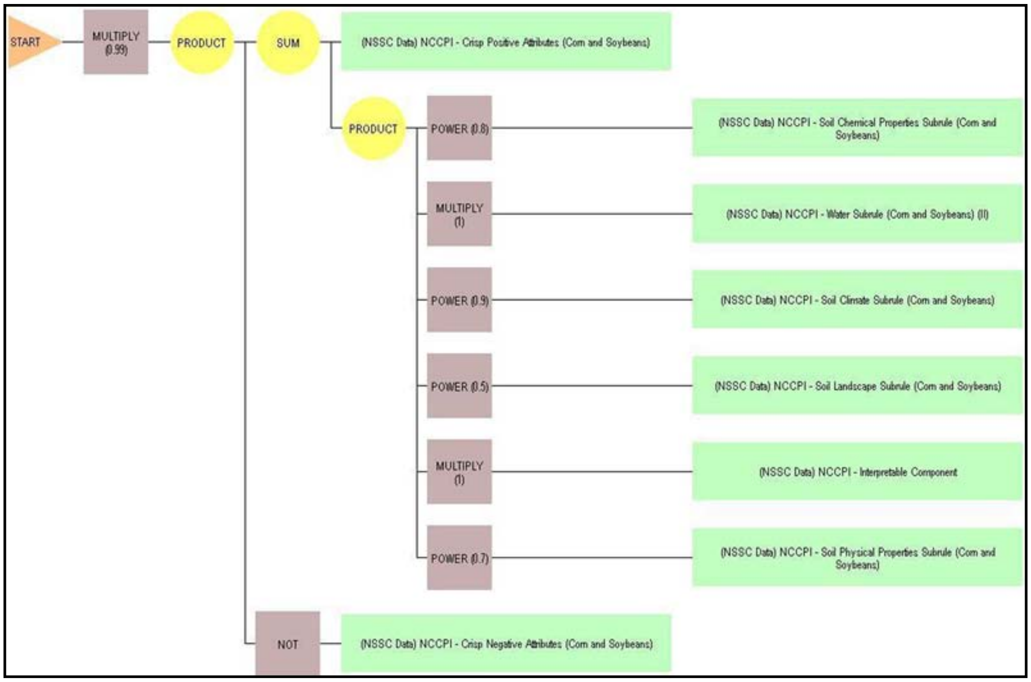


Figure 2.—The Corn and Soybeans Submodel.

In the calculation of the corn and soybeans index, ratings from the chemical, water, physical, climate, and landscape subrules are multiplied together in a manner similar to that of the Storie Index model used in California (Storie, 1937, 1978). The crisp factors are added to the score (positive attributes) or subtracted from 1.0 and multiplied by the score (negative attributes), depending upon whether they enhance or detract from soil productivity.

The Interpretable Component Subrule occurs in all three submodels. It is the method used to ensure that soil components that should not be rated are not rated. Without affecting the ratings of arable soils, it causes miscellaneous areas (nonsoil components) to be rated as zero.

The Soil Chemical Properties Subrule (Corn and Soybeans), shown in figure 3, quantifies the effects of pH, CEC, organic matter, and adverse chemical properties in the root zone, which is considered to be from the soil surface to a depth of 150 cm or to a root-limiting layer. The effects of pH are considered for depths of 0 to 20 cm and 20 to 150 cm. The most limiting of the two scores is used for the calculation. The CEC influence is based on the total exchange capacity found in a 1-cm-square area extending from the surface to a depth of 150 cm or to a root-restricting layer. Horizon CEC, rock fragment content, and bulk density are used in the calculation. A small input of CEC is allowed for soils having a water table. Organic matter also is considered for

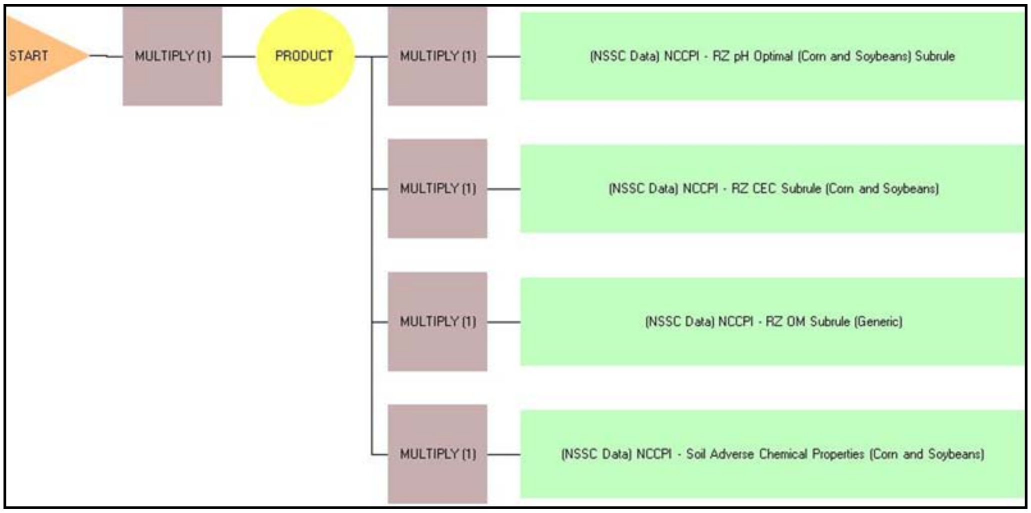


Figure 3.—The Soil Chemical Properties Subrule (Corn and Soybeans).

the depth ranges of 0 to 20 cm and 20 to 150 cm; the average condition is then used in the calculation. Adverse chemical properties, namely, SAR, EC, and gypsum content, are considered in a third-level subrule, and the most limiting of the three is used in the chemical properties calculation.

The Water Subrule (Corn and Soybeans), shown in figure 4, quantifies the capability of the soil, climate, and landscape to supply water for crop growth. Four sources of water are considered: available water-holding capacity in the root zone (RZ AWC), precipitation during the growing season (Precipitation Recharge), the effects of subirrigation (Water Table Recharge), and surface contributions (Water-Gathering Surface). RZ AWC is the amount of plant-available water a soil can store between the surface and a root-limiting layer or between the surface and a depth of 150 cm, whichever is less.

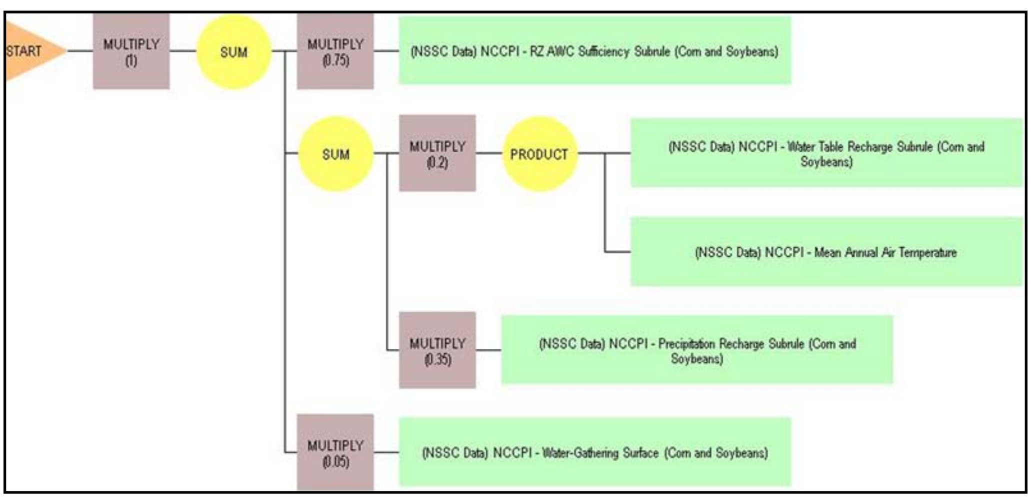


Figure 4.—The Water Subrule (Corn and Soybeans).

Precipitation Recharge is intended to represent the effect of rainfall during the growing season. The amount of rainfall indicated for a component in the database is decreased because of the effects of temperature, and a proportion is assigned for crop use. For example, consider two soils, both receiving 1,000 mm of rainfall per year. One soil is hot thermic, and the other is cool mesic. The rainfall on the cooler site is more readily available for crop growth, and so the cool mesic component receives a higher “precipitation recharge” score. This adjustment lessens the negative effect on crop yields that is observed in soils having low RZ AWC. For soils that receive timely rainfall, AWC is less important. Therefore, if the soil component occurs in an area of high rainfall, the “precipitation recharge” becomes important if the temperature is not too high. Conceptually, “precipitation recharge” is an oversimplified Thornthwaite-style calculation (Thornthwaite, 1948) using available NASIS data fields.

Water table recharge quantifies effects of a saturated zone deep within the root zone where roots can exploit water during summer or during other parts of the growing season. The Water-Gathering Surface Subrule accounts for additions of water (run on) resulting from the position of the soil on the landform. This calculation uses the sum of a proportion of each of the four factors.

Figure 5 shows the Soil Physical Properties Subrule (Corn and Soybeans), which quantifies the effects of saturated hydraulic conductivity (Ksat), linear extensibility percent (LEP), bulk density, content of rock fragments, and soil depth on soil productivity. The actual entity used in the Ksat calculation is the logarithm of saturated hydraulic conductivity multiplied by LEP, which is used to account for the effects of cracks on aeration and water movement in highly expansive soils. The effect of this product is estimated for soil depths of 0 to 50 cm, 50 to 100 cm, and 100 to 150 cm. The populated LEP value is used for the calculation of the LEP subrule. The effect of bulk density on soil productivity is estimated by comparing the deviation of the populated bulk density for the set of layers of a map unit component from depths of 0 to 150 cm to a calculated optimal density for that soil. The score for the content of rock fragments is based on the weighted average of the volumetric estimates for each soil horizon of the map unit component. The soil depth subrule examines the thickness of soil material over a root-limiting zone (see Appendix 6).

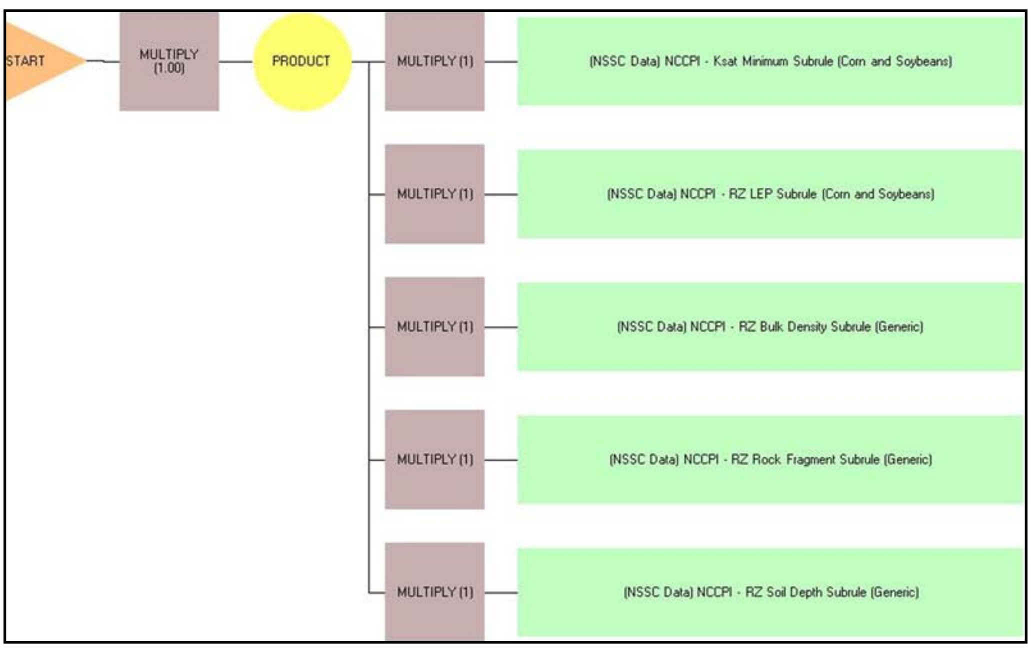


Figure 5.—The Soil Physical Properties Subrule (Corn and Soybeans).

In the Soil Climate Subrule (Corn and Soybeans), shown in figure 6, two major aspects of soil climate—frost-free days and precipitation—are considered. Data for both of these are extracted from the Component Table of NASIS. Multiplying the scores together determines the soil climate rating.

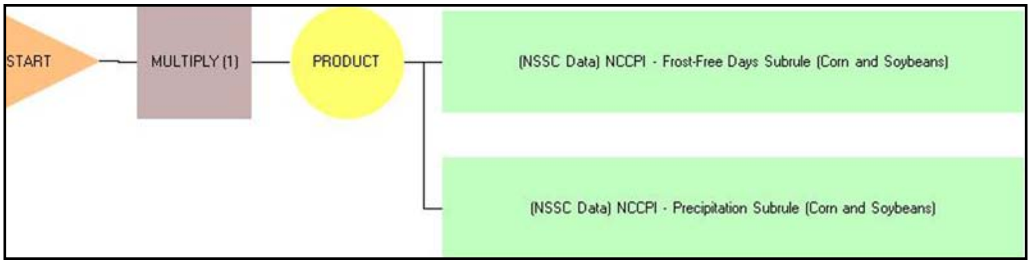


Figure 6.—The Soil Climate Subrule (Corn and Soybeans).

The Soil Landscape Subrule (Corn and Soybeans), shown in figure 7, uses slope gradient, depth to a water table during the growing season, and the occurrence of ponding and flooding during the growing season to calculate an index for the landscape or site component of corn and soybean productivity. Determining the actual depth to a water table is difficult when soils are drained. To adjust for artificial drainage, the Component Local Phase is queried for the word "drained." If a component is listed as drained, the water table is assumed to be at a depth of 160 cm. Also, Land Capability Class and Subclass are used as indicators of the presence or absence of artificial drainage. Another enigma is determining when the growing season actually occurs. This time period is based on the taxonomic temperature regime, populated in the Component Table, and is the same as the growing season used by the hydric soil calculation.

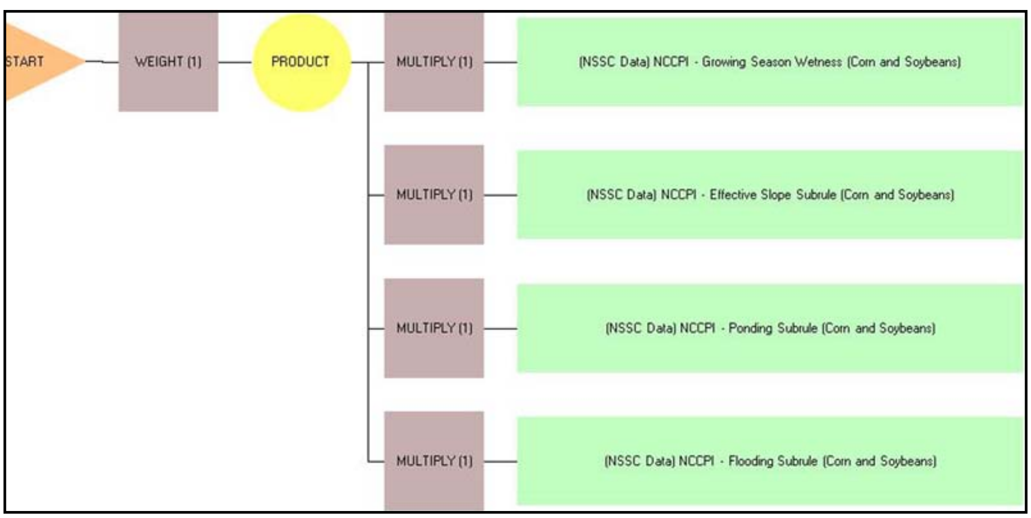


Figure 7.—The Soil Landscape Subrule (Corn and Soybeans).

The Crisp Positive Attributes Subrule (Corn and Soybeans), shown in figure 8, quantifies soil attributes that foster high productivity but cannot, at present, be reasonably represented by fuzzy set methods. Currently, the corn and soybeans model recognizes the benefits of loess as a parent material, which is observed for at least

Wisconsinan-aged loess material. This relationship may or may not hold true for older loess deposits. The result of the crisp positive attributes score is added to the fuzzy score.

Figure 8.—The Crisp Positive Attributes Subrule (Corn and Soybeans).

The Crisp Negative Attributes Subrule (Corn and Soybeans), shown in figure 9, quantifies the effect of detrimental soil conditions for which obtaining a fuzzy set is difficult. This difficulty may result from the lack of consistent NASIS data or from the need for more time to analyze existing data. Surface rock fragments, erosion, rock outcrop, surface degradation, and lack of a surface outlet are the current crisp attributes considered. Negative attributes are summed, and the summed total is subtracted from 1.0 (the “NOT” square at the bottom of figure 2). The difference is used to proportionately decrease the sum of the fuzzy and crisp positive features.

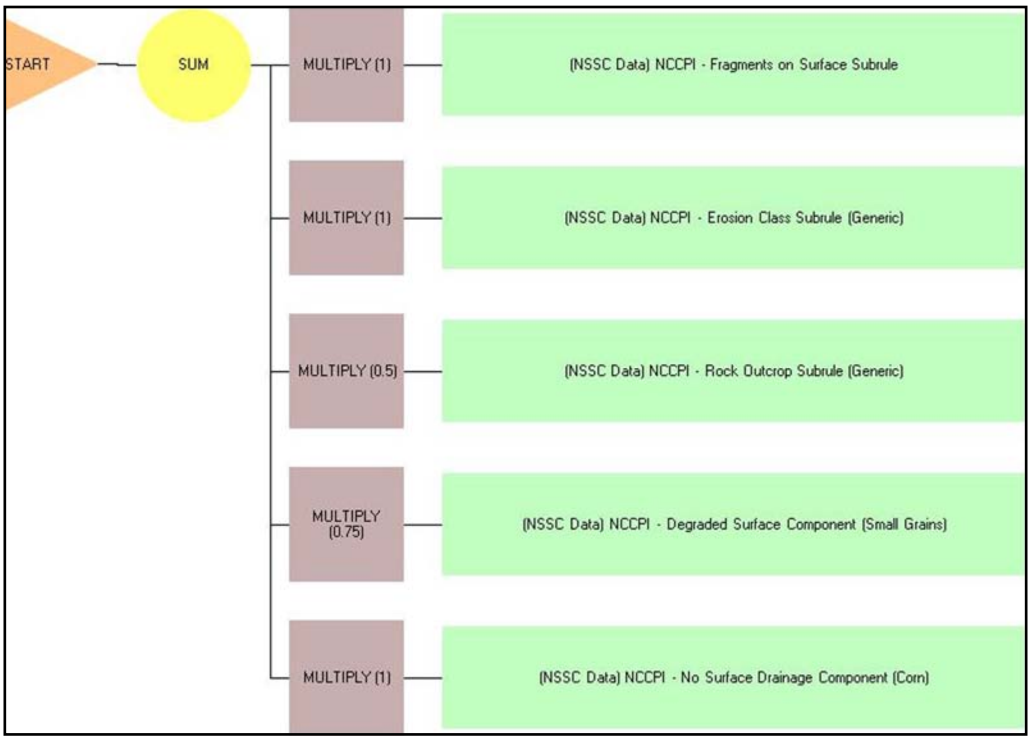


Figure 9.—The Crisp Negative Attributes Subrule (Corn and Soybeans).

The Small Grains Submodel

Figure 10 illustrates the Small Grains Submodel. Five of the subrules in this submodel have reasonable fuzzy relationships. Several crisp negative relationships are aggregated in the Crisp Negative Attributes Subrule. Crisp relationships are used because the data available for specific parameters, such as those for erosion, are not

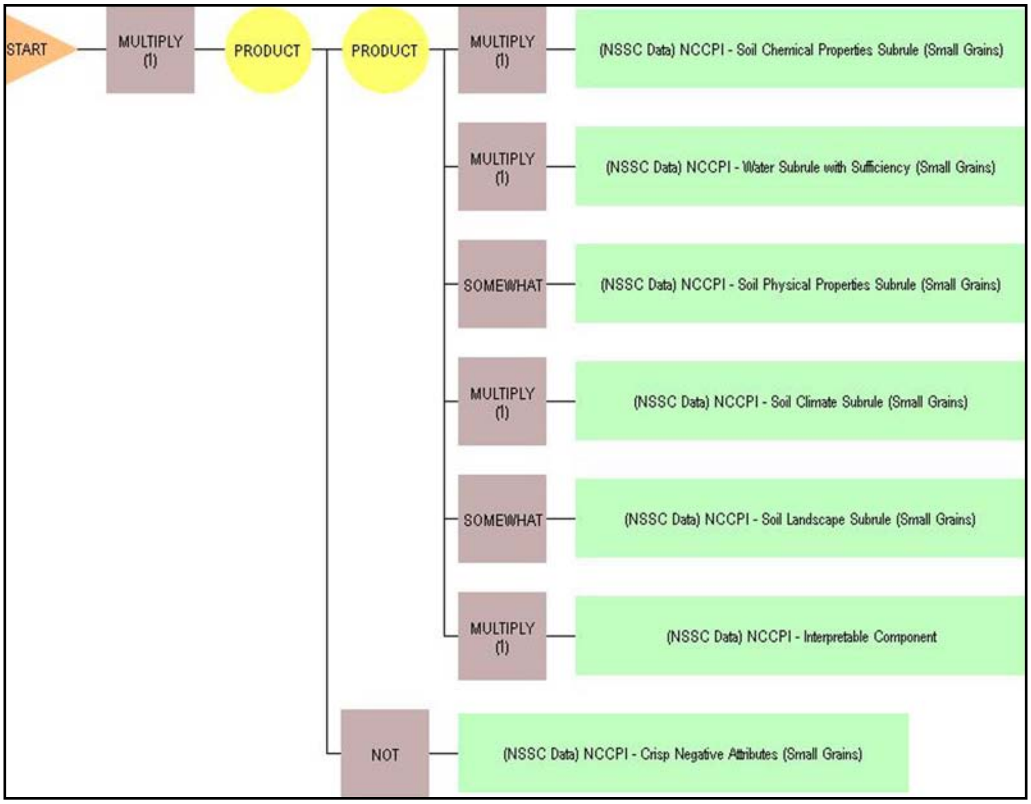


Figure 10.—The Small Grains Submodel.

of a continuous nature but rather are class data. This information is not of sufficient quality to develop a fuzzy relationship, since the quantitative impact of an erosion class on crop productivity is generally unknown. The results of soil chemical properties, water, soil physical properties, climate, and soil landscape subrules are multiplied together in a manner similar to that of the Storie Index model (Storie, 1937, 1978). The quantity of the negative effects of the crisp negative attributes is subtracted from 1.0, and the difference is used to adjust the product of the fuzzy attributes.

The Interpretable Component Subrule occurs in all three submodels. It is the mechanism used to ensure that soil components that should not be rated are not rated. Without affecting the ratings of arable soils, it causes miscellaneous areas (nonsoil components) to be rated as zero.

The Soil Chemical Properties Subrule (Small Grains), shown in figure 11, quantifies the effects of pH, CEC, organic matter, and adverse chemical properties in the root zone, which is considered to be from the soil surface to a depth of 150 cm or to a root-limiting layer. The effects of pH are considered for depths of 0 to 20 cm and 20 to 150 cm. The most limiting score is used in the calculation. The CEC influence is based on the calculated total exchange capacity of a 1-cm-square area extending from the surface to a depth of 150 cm or to a root-limiting layer. Horizon CEC, content of rock fragments, and bulk density are used in this calculation. A small input of CEC is allowed for soils having a water table. Organic matter also is considered for the depth ranges 0 to 20 cm and 20 to 150 cm. The average condition is then used in the calculation. Adverse chemical properties, namely, SAR, EC, and gypsum content, are considered in a third-level subrule, and the most limiting of the three properties is used in the chemical properties calculation.

The Water Subrule (Small Grains), shown in figure 12, quantifies the effect of the water-supplying capability of the soil, landscape, and climate on crop growth. Four

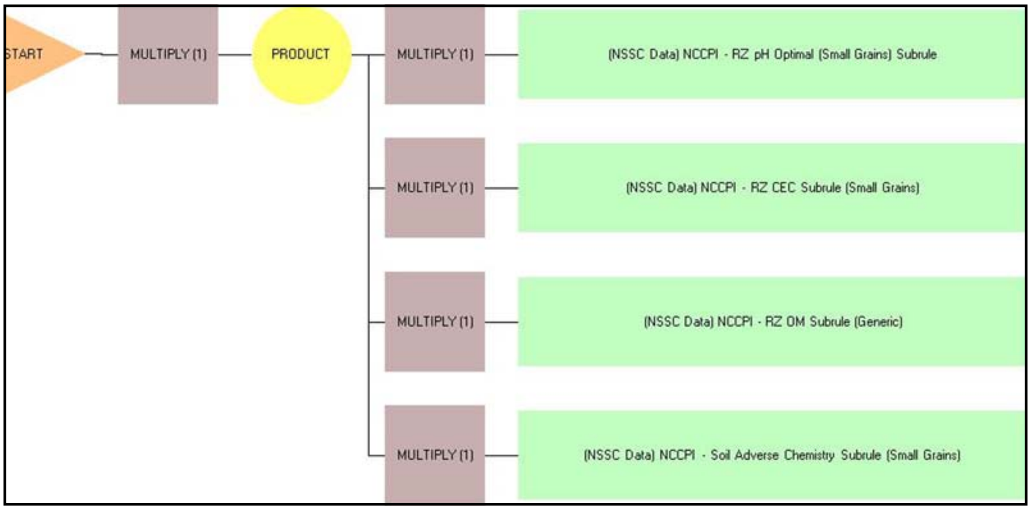


Figure 11.—The Soil Chemical Properties Subrule (Small Grains).

sources of water are currently considered: available water-holding capacity in the root zone (RZ AWC), precipitation during the growing season (Precipitation Recharge), the effects of subirrigation (Water Table Recharge), and surface contributions (Water-Gathering Surface). RZ AWC is the amount of plant-available water a soil can store between the surface and a root-limiting layer or between the surface and a depth of 150 cm, whichever is less.

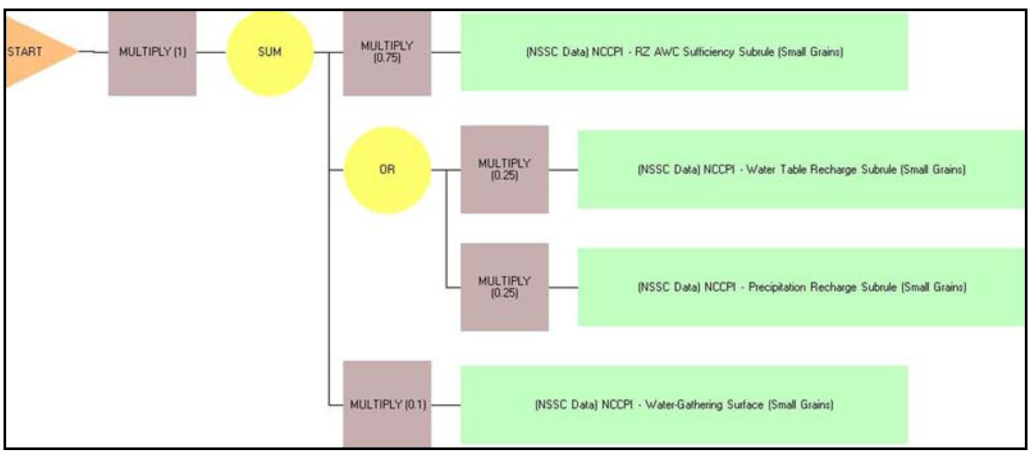


Figure 12.—The Water Subrule (Small Grains).

Precipitation Recharge is intended to capture the effect of rainfall during the growing season. The amount of rainfall considered is decreased because of the effects of temperature and some proportion of crop use. For example, consider two soils, both receiving 1,000 mm of rainfall per year. One soil is hot thermic, and the other is cool mesic. The rainfall on the cooler site is more readily available for crop growth, and so the cool mesic component receives a higher “precipitation recharge” score. This adjustment lessens the negative effect on crop yield that is observed in soils having a low RZ AWC. If the soil receives timely rainfall, AWC is less important. If a soil is in an area of higher rainfall, the “precipitation recharge” becomes important if the temperature is not too high. Conceptually, “precipitation recharge” is an oversimplified

Thornthwaite-style calculation (Thornthwaite, 1948) using the data fields available in NASIS. The various subrule components are tailored to the response of small grains to water.

Water Table Recharge quantifies the effects of a saturated zone deep within the root zone where roots can exploit the water during summer or during other parts of the growing season. The Water-Gathering Surface Subrule accounts for water additions (run on) resulting from the position of the soil on the landform.

This calculation uses the highest score of either the water table or precipitation recharge. This score is added to the RZ AWC and Water-Gathering Surface scores. About 25 percent of the water available for crop growth is attributed to water table or precipitation recharge, and 75 percent is attributed to RZ AWC.

Figure 13 shows the Soil Physical Properties Subrule (Small Grains), which quantifies the effects of saturated hydraulic conductivity (Ksat), linear extensibility percent (LEP), bulk density, content of rock fragments, and soil depth on small grain production. The actual entity used in the Ksat calculation is the logarithm of saturated hydraulic conductivity multiplied by LEP, which is used to account for the effects of cracks on aeration and water movement in highly expansive soils. The effect of this product is estimated for soil depths of 0 to 50 cm, 50 to 100 cm, and 100 to 150 cm. The populated LEP value is used in the calculation of the LEP subrule. The effect of bulk density on soil productivity is estimated by comparing the deviation of the populated bulk density for the set of layers of a component from depths of 0 to 150 cm to a calculated optimal density for that soil. The score for the content of rock fragments is based on the weighted average of the volumetric estimates for each soil horizon of a map unit component. The soil depth subrule examines depth of soil material over a root-limiting zone (see Appendix 5).

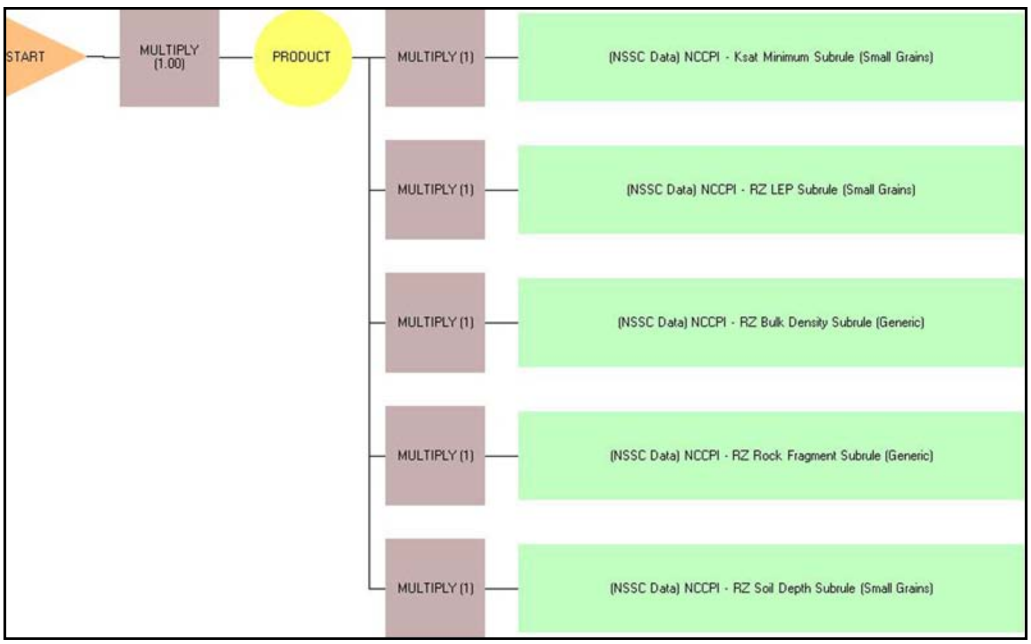


Figure 13.—The Soil Physical Properties Subrule (Small Grains).

In the Soil Climate Subrule (Small Grains), shown in figure 14, two major aspects of soil climate—frost-free days and precipitation—are considered. Data for both aspects are drawn from the Component Table of NASIS. Multiplying the scores together determines the soil climate rating.

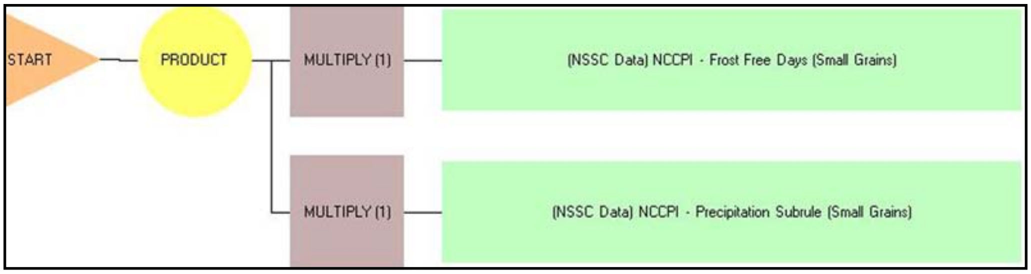


Figure 14.—The Soil Climate Subrule (Small Grains).

The Soil Landscape Subrule (Small Grains) is shown in figure 15. The Effective Slope Subrule quantifies the effect of slope gradient. The Excess Water Subrule calculates the combined effects of a water table, ponding, and flooding in the context of a crop that is often seeded in the fall and begins to grow very early in the growing season. Determining the actual depth to a water table is difficult when soils are drained. To adjust for drainage, the Component Local Phase and the Component SIR Phase are queried for the word "drained." If a component is listed as drained, the water table is assumed to be at a depth of 160 cm. Another enigma is determining when the growing season actually occurs. This time period is based on the taxonomic temperature regime, populated in the Component Table, and is the same as the growing season used by the hydric soil calculation. This result is multiplied by the results of the Fragments on Surface and Effective Slope Subrules to obtain the score for landscape factors.

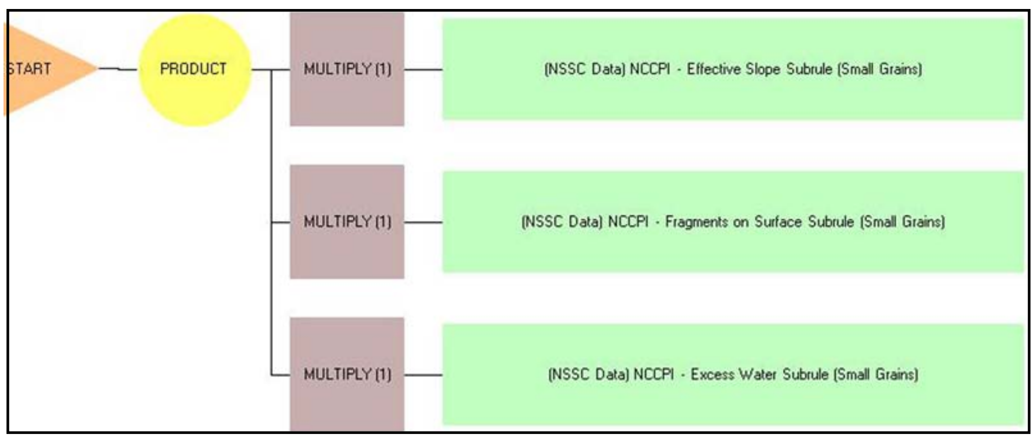


Figure 15.—The Soil Landscape Subrule (Small Grains).

The Crisp Negative Attributes Subrule (Small Grains) is shown in figure 16. The most intriguing feature of this subrule is the Not Xeric Climate Subrule. A Mediterranean climate (wet winters and dry summers) has been shown to be highly conducive to winter and spring wheat growth. When a soil component does not have a xeric soil moisture regime, its score is lowered by a given amount. The Degraded Surface Component Subrule provides a stored rating for such characteristics as "channeling," "gullies," "impacted," or "undrained," as indicated in the map unit name. Erosion and rock outcrop are known to negatively impact crop yields, but the relationships are not well quantified. The rating for each of these factors is summed to obtain the crisp negative attributes score. The crisp negative attributes score is subtracted from 1.0, and this difference is multiplied by the fuzzy soil properties score.

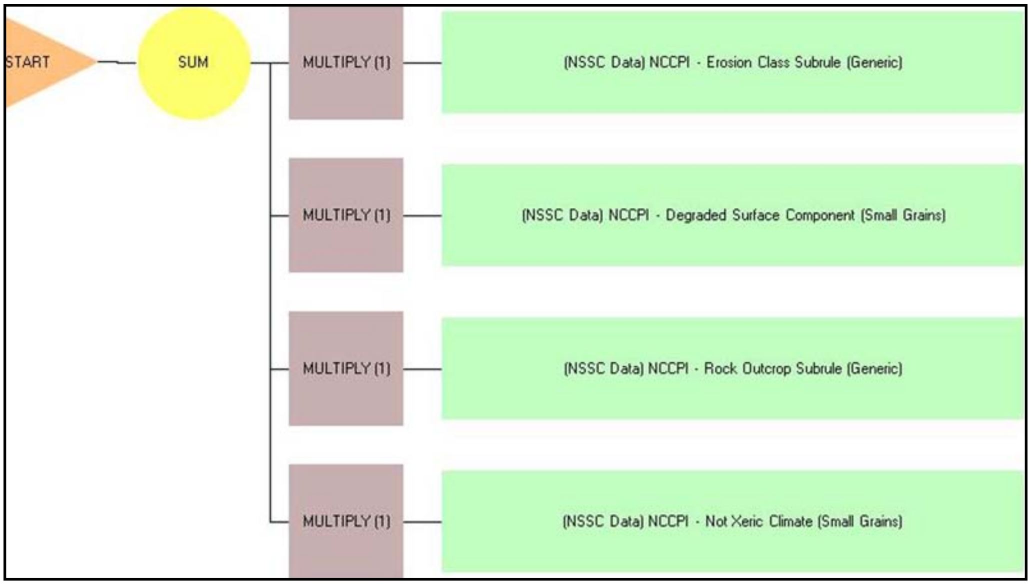


Figure 16.—The Crisp Negative Attributes Subrule (Small Grains).

The Cotton Submodel

Cotton is a unique crop requiring a very warm climate (by U.S. standards), a climate significantly warmer than that required for the production of corn and soybeans and much warmer than that required for the production of small grains. The Cotton Submodel is shown in figure 17. Five of the subrules in this submodel have realistic fuzzy logic relationships, whereas two of the subrules use crisp relationships. The crisp relationships are used because the data available for some parameters, such as those for erosion, are not of a continuous nature but rather are class data. This information is not of sufficient quality to develop a fuzzy relationship.

In the calculation of the cotton index, the results of soil chemical properties, water, soil physical properties, climate, and soil landscape subrules are multiplied together, as in the Storie Index model (Storie, 1937, 1978). The crisp positive factors are added to the score, since they enhance soil productivity. The score for the crisp negative factors is subtracted from 1.0, and the difference is multiplied by the sum of the crisp positive and fuzzy attribute scores.

The Interpretable Component Subrule occurs in all three submodels. It is the method used to ensure that soil components that should not be rated are not rated. Without affecting the ratings of arable soils, it causes miscellaneous areas (nonsoil components) to be rated as zero.

The Soil Chemical Properties Subrule (Cotton), shown in figure 18, quantifies the effects of pH, CEC, and adverse chemical properties within the root zone, which is considered to be from the surface to a depth of 150 cm or to a root-limiting layer. The effects of pH are considered for depths of 0 to 20 cm and 20 to 150 cm. The most limiting of the two scores is used in the calculation. The pH adaptation for cotton is broader than that for the submodel for corn and soybeans or for small grains. The CEC influence is based on the calculated total exchange capacity of a 1-cm-square area extending from the surface to a depth of 150 cm or a root-limiting zone. Horizon CEC, content of rock fragments, and bulk density are used in the calculation. A small input of CEC is allowed for soils having a water table. Since cotton is quite often grown in low CEC soils, management techniques largely mask responses related to clay activity. Adverse chemical properties, namely, SAR, EC, and gypsum content, are considered

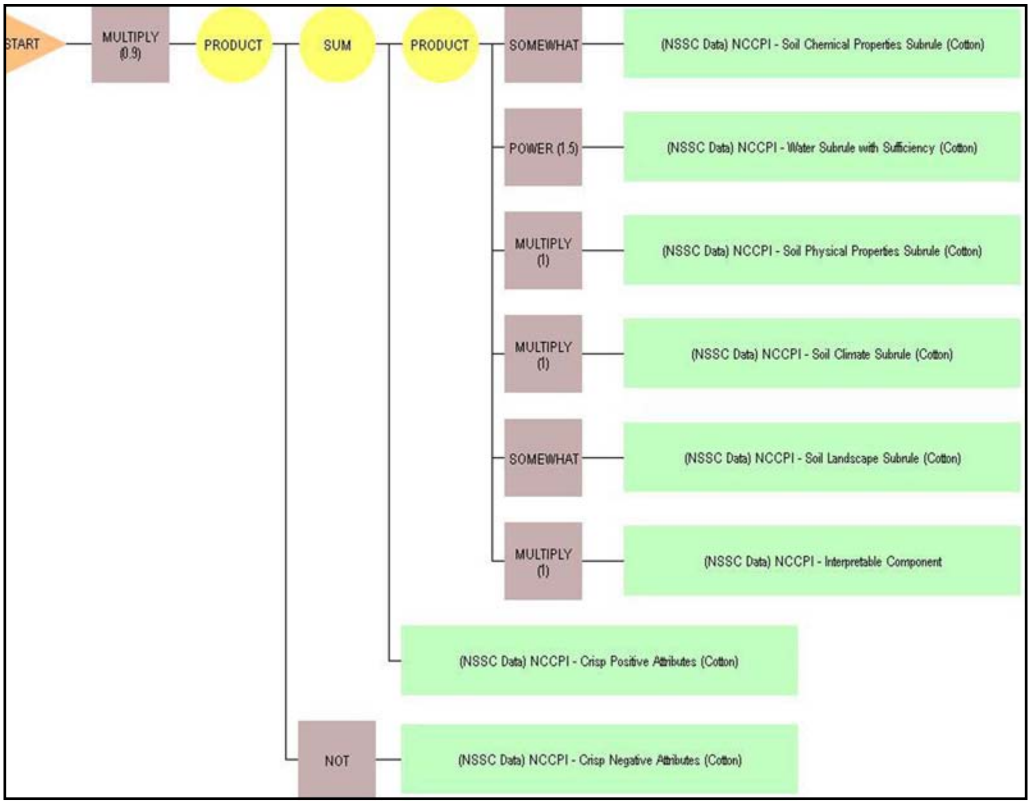


Figure 17.—The Cotton Submodel.

in a third-level subrule, and the most limiting of the three is used in the chemical properties calculation. The salinity tolerance of cotton is broader than that of corn and soybeans. Multiplying the scores of the three subrules together determines the chemical properties score for the cotton submodel.

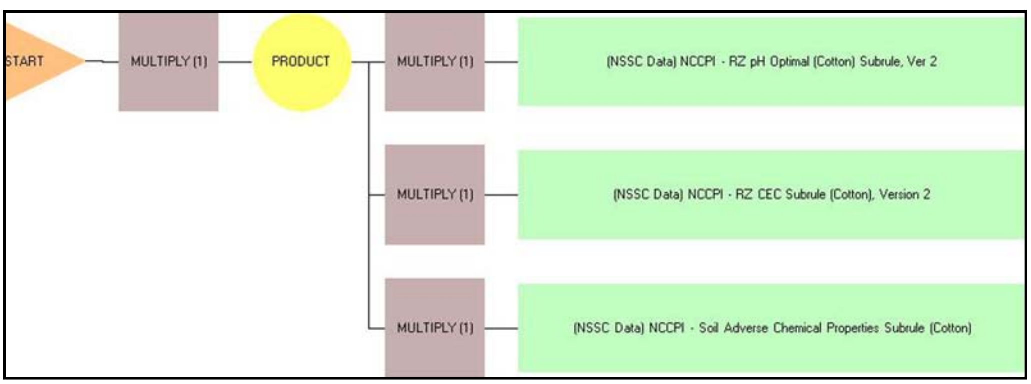


Figure 18.—The Soil Chemical Properties Subrule (Cotton).

The Water Subrule (Cotton), shown in figure 19, quantifies the capability of the soil and climate to supply water for crop growth. Three sources of water are currently considered: the available water-holding capacity in the root zone (RZ AWC), precipitation during the growing season (Precipitation Recharge), and the effects of subirrigation (Water Table Recharge). RZ AWC is the amount of water the soil can

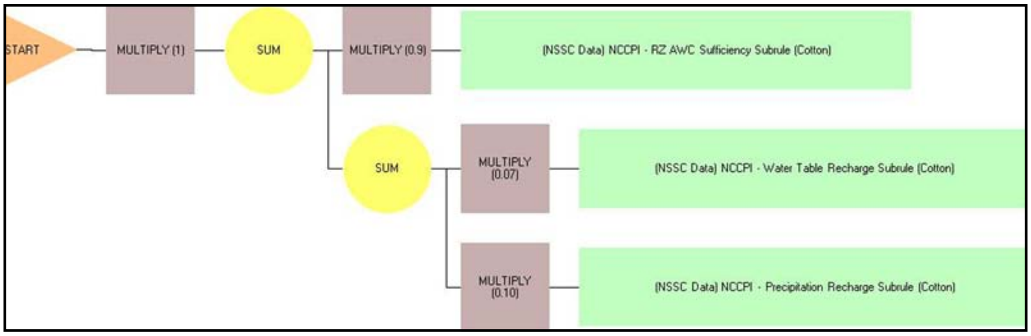


Figure 19.—The Water Subrule (Cotton).

store between the surface and a root-limiting layer or between the surface and a depth of 150 cm, whichever is less.

Precipitation Recharge is intended to represent the effect of rainfall during the growing season. The amount of rain that falls on a component is reduced because of the effects of temperature and crop use. For example, consider two soils, both receiving 1,000 mm of rainfall per year. One soil is hot thermic, and the other is cool mesic. The rainfall on the cooler site is more readily available for crop growth, and so the cool mesic component receives a higher “precipitation recharge” score. This calculation lessens the negative effect on soil productivity that may be predicted but not observed for soils having a low RZ AWC. If the soil receives timely rainfall during the growing season, the AWC is less important. Therefore, if the soil is in an area of higher rainfall, the “precipitation recharge” contributes a significant amount of water to crop growth if the temperature is not too high. Conceptually, “precipitation recharge” is an oversimplified Thornthwaite-style calculation (Thornthwaite, 1948) using the data fields available in NASIS.

Water Table Recharge quantifies the effects of a saturated zone deep within the root zone where roots can exploit the water during summer or during other parts of the growing season. In the calculation, a proportion of the water table, precipitation recharge, and RZ AWC scores is added to obtain the final score for the Water Subrule.

The Soil Physical Properties Subrule (Cotton), shown in figure 20, is used to index the effects of saturated hydraulic conductivity (Ksat), linear extensibility percent (LEP), bulk density, content of rock fragments, and soil depth on cotton production. The actual entity used in the Ksat calculation is the logarithm of saturated hydraulic conductivity multiplied by LEP, which is used to account for the effects of cracks on aeration and water movement in highly expansive soils. The effect of this product is estimated for soil depths of 0 to 50 cm, 50 to 100 cm, and 100 to 150 cm or to a root-limiting layer. The most limiting result is used in the calculation. A weighted average of linear extensibility from the surface to a depth of 150 cm or a root-limiting layer is used to obtain the score for the LEP Subrule.

The effect of bulk density on soil productivity is estimated by comparing the deviation of the populated bulk density for the set of layers of a map unit component from the surface to a depth of 150 cm or a root-limiting layer to a calculated optimal density for that soil. The score for the content of rock fragments is based on the weighted average of the volumetric estimates for the component. The soil depth subrule examines the depth of soil material over a root-limiting zone (see Appendix 5).

The Soil Climate Subrule (Cotton), shown in figure 21, calculates the effect of precipitation, frost-free days, and mean annual air temperature on cotton yields. The

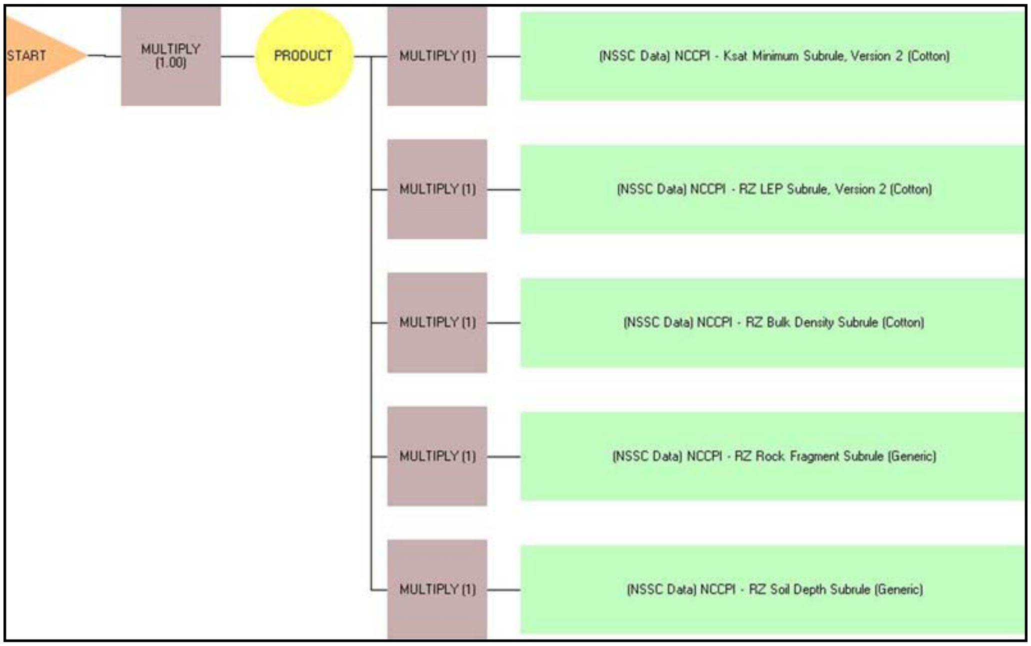


Figure 20.—The Soil Physical Properties Subrule (Cotton).

index is calculated by multiplying the precipitation score by the score for the mean annual air temperature or for frost-free days, whichever is lower.

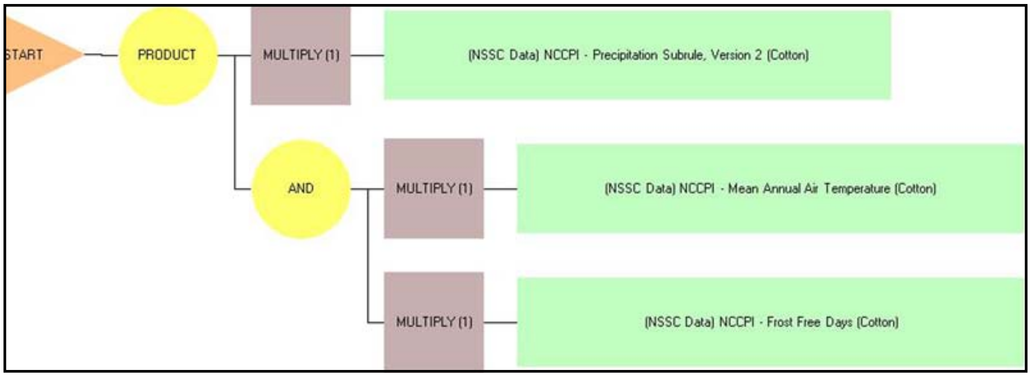


Figure 21.—The Soil Climate Subrule (Cotton).

The Soil Landscape Subrule (Cotton), shown in figure 22, uses the slope gradient, depth to a water table during the growing season, ponding during the growing season, and flooding during the growing season to calculate an index for the landscape component of cotton productivity. Determining the actual depth to a water table is difficult when soils are drained. To adjust for drainage, the Component Local Phase and the Component SIR Phase are queried for the word “drained.” For components listed as drained, the water table is assumed to be at a depth of 160 cm. Another problem is addressing when the growing season actually occurs. This time period is based on the taxonomic temperature regime, populated in the Component Table, and is the same as the growing season used by the hydric soil calculation.

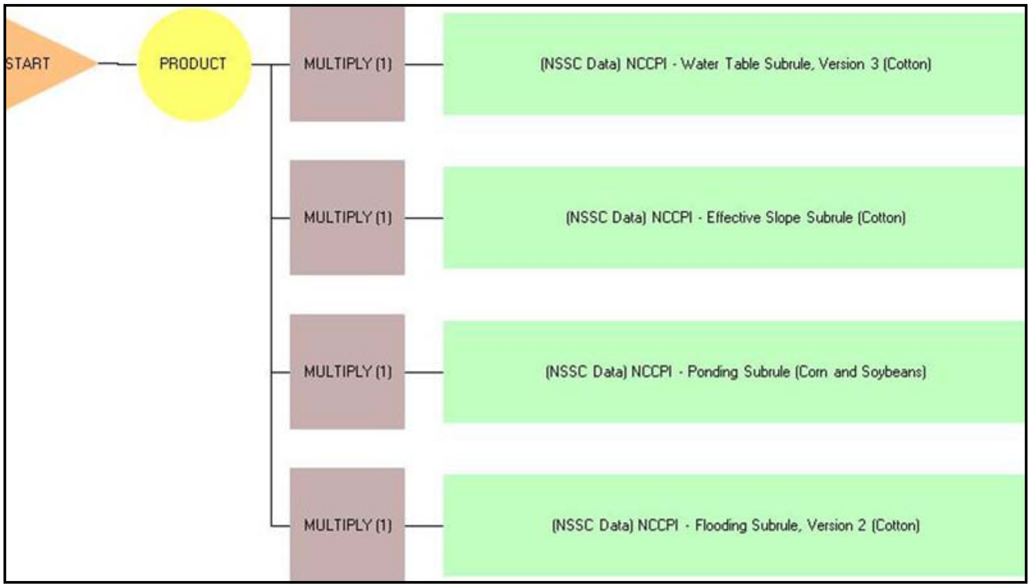


Figure 22.—The Soil Landscape Subrule (Cotton).

The Crisp Negative Attributes Subrule (Cotton), shown in figure 23, quantifies the effect of detrimental soil conditions for which obtaining a fuzzy set is difficult. The difficulty can result from the lack of consistent data within NASIS or from the need for more time to analyze the existing data. Surface fragments, erosion, rock outcrop, surface degradation, and lack of a surface outlet are the current attributes considered

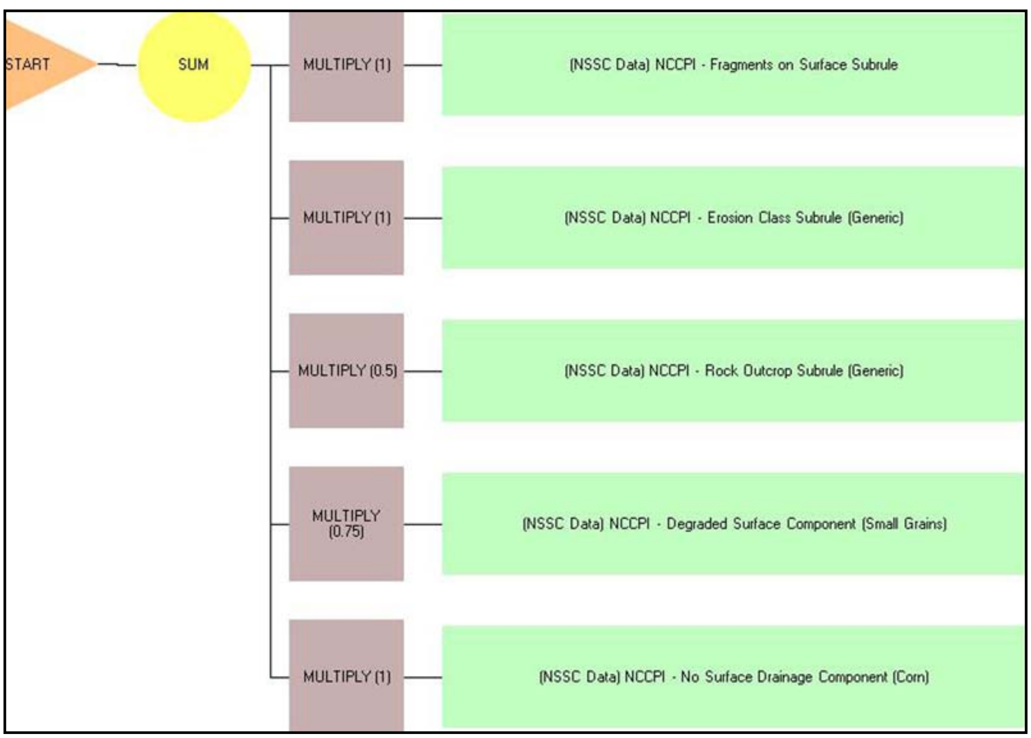


Figure 23.—The Crisp Negative Attributes Subrule (Cotton).

to be crisp. The negative attributes are summed, the total is subtracted from 1.0, and the difference is multiplied by the product of the fuzzy and crisp positive features. The Cotton Submodel uses the same negative attributes as the Corn and Soybeans Submodel.

The Crisp Positive Attributes Subrule (Cotton), shown in figure 24, quantifies the beneficial effect of the landscape position where rare flooding is expected.

Figure 24.—The Crisp Positive Attributes Subrule (Cotton).

Discussion

While the submodels for the types of crops are generally similar, differences in the physiology of the crops and the geography of the soils in which the crops are grown cause some variations in the details of the submodels. For example, it was initially thought that only the climatic parameters of the model would be substantially different among the three submodels. The climatic adaptation of the small grains is quite broad in comparison with that of cotton and that of corn and soybeans. The diverse levels of salt tolerance, pH, and other properties became evident upon further study.

Version 2.0 of the NCCPI further explores the interaction of soil properties and climate and their effects on crop physiology and productivity. An examination of cotton production, for example, shows that the effect of linear extensibility percentage (LEP), or shrinking and swelling, is dependent upon the climate. In areas of low rainfall (less than 700 mm), the optimal LEP is about 5 percent; in areas where rainfall is over 1000 mm, the optimal LEP is about 2.5 percent. A distinct maximum pH of 7.5 is typical in areas where rainfall is less than 700 mm, but pH seems to have little effect on cotton production in areas where rainfall exceeds 1000 mm; in these areas pH ranges from 4.5 to 8.0. Cation-exchange capacity also shows a geographic tendency in its impact on cotton production.

The impact of loess as a parent material is an interplay of geography and crop physiology. In areas where small grains are dominant, even though many of the soils formed in loess, the growing season is too short for crop roots to fully exploit the favorable characteristics of the material. Where corn is grown, the benefits of loess can be exploited by crop roots since the growing season is longer. Where cotton is grown, the soils generally did not form in loess, so no side-by-side comparison was possible. Also, more strongly weathered (pre-Wisconsinan) loess has developed characteristics that are less favorable for plant growth.

The curves shown in Appendix 3 are the result of several lines of thought. Many of them are renderings of spline curves fit through scatterplots of the various soil, landscape, and climate factors against the populated yields for each crop in the NASIS database. When available, these curves are influenced by data from the soil productivity literature. Since performance data for some soil properties data are not available in a geographic quantity that fits the scope of this model, the "boundary line model" is used as yet a third interpretation applied to the bivariate plots in some cases. This method seemed particularly applicable since the crux of the model is biological rather than statistical (Milne et al., 2006).

Appendices

Appendix 1.—What Is Different?

Version 2.0 of the NCCPI differs from version 1.0 in several respects. In version 1.0, the “Crisp Negative Attributes” were subtracted from the fuzzy score for a component. As a result, the rating for many soils was deemed to be too low. In version 2.0, the score for the negative attributes is subtracted from 1.0, and the difference is multiplied by the fuzzy score. Thus, the fuzzy score for a soil having few negative attributes may be multiplied by 0.95, whereas the fuzzy score for a soil with more severe negative attributes may be multiplied by 0.80. The rating for erosion takes soil depth into account by returning a less suitable rating based on the depth to any root-restricting layer. Thus, a moderately eroded deep loess soil is not penalized as heavily as a moderately eroded soil that is only moderately deep.

The manner in which available water-holding capacity in the root zone (RZ AWC) is rated has been improved in version 2.0. In the previous version, available water held at a depth of 150 cm was given the same weight as available water at a depth of 10 cm. In version 2.0, water at a depth of 10 cm is considered to be more valuable to the plant and thus is rated higher than water at a depth of 150 cm. This “sufficiency” calculation was developed by the soil survey staff in Missouri.

The determination of the impact of a seasonal high water table during the growing season has been revised. Formerly, an index of soil wetness was calculated by subtracting the depth to water from 200 and summing by growing season months. This method, however, would return the same results for 1 month of saturation at the surface as it would for a series of months that were not as wet. The new method rates depth to saturation in such a manner that wetness between the surface and a depth of 15 cm, for example, is scored as 1888, and saturation between depths of 100 and 200 cm scores as 1. These scores are summed over the growing season, and the logarithm of the total is reported as the water table score. Thus, a soil having 1 month of saturation at the surface returns a score of 3.27, whereas a soil that is saturated at a depth of 120 cm during a 5-month growing season returns a score of 0.7. Formerly, the first soil would have scored 200 and the second soil 400. The shaping of the evaluation improves the modeling of the impact of multiple months of varying depths of saturation. The manner in which artificial soil drainage is inferred has been revised so that it uses more of the clues implied in the database. For example, a Component Local Phase designated as “drained” was used in the past. Presently, various combinations of soil drainage class and land capability class and subclass are used in some geographic regions as an indicator of the presence of artificial soil drainage.

Cotton is a unique crop in many respects, and this fact is reflected in version 2.0. The influences of AWC, CEC, Ksat, LEP, and pH on cotton yields are now stratified by mean annual precipitation. This process is an accommodation of the various varieties and types of plants that are grouped as “cotton” in the model.

Appendix 2.—Reports and Data

The NSSC Pangaea reports called “AGR - Nat. Com. Crop Prod. Ind. Corn and Soybeans Export,” “AGR - Nat. Com. Crop Prod. Ind. Small Grains Export,” and “AGR - Nat. Com. Crop Prod. Ind. Cotton Export” will produce exports of the results of the subrules described in the body of this guide. If any indeterminate nulls occur, the score for that subrule will be “not rated.” The missing parameter will be mentioned. This appendix lists all of the data fields currently used in NCCPI. It is assumed that horizon depths are correctly populated, horizon names are appropriate, other validations have been performed, and any corrections have been made.

Measured data in NASIS are populated with high, low, and representative values. NCCPI uses the representative value (rv). Character data typically are populated as one value only, or a representative value is indicated if more than one character value describes an attribute.

The data elements currently used in NCCPI are listed below.

Soil Chemical Properties Subrules

pH
Component Horizon, pH H2O_rv
Component Horizon, pH CaCl2_rv

CEC
Component Horizon, CEC-7_rv
Component Horizon, ECEC_rv
Component Horizon, Db 0.33 Bar H2O_rv
Horizon Fragments, Vol %_rv

OM
Component Horizon, OM_rv

SAR
Component Horizon, SAR_rv

EC
Component Horizon, EC_rv

Gypsum
Component Horizon, Gypsum_rv

Water Subrules

RZ AWC
Component Horizon, AWC_rv
Component Restriction, Top Depth_rv
Component Restriction, Kind

Water Table Recharge
Component Soil Moisture, Top Depth_rv
Component Soil Moisture, Moisture Status
Component Month, Month
Component, Temp Regime

Precipitation Recharge
Component, MAAT_rv
Component, MAP_rv
Component, Suborder
Component, Subgroup

Water-Gathering Surface
Component Slope Shape Surface Morphometry Table, Slope Shape Across
Component Slope Shape Surface Morphometry Table, Slope Shape Up/Down
Component, Taxonomic Moisture Class

Physical Properties Subrules

Ksat
Component Horizon, Ksat_rv
Component Horizon, LEP_rv

LEP
Component Horizon, LEP_rv

Bulk Density
Component Horizon, Db 0.33 Bar H2O_rv
Component Horizon, Total Sand_rv
Component Horizon, Total Silt_rv
Component Horizon, Total Clay_rv
Component, Order

Rock Fragments
Horizon Fragments, Vol %_rv

Soil Depth
Component Restriction, Kind
Component Restriction, Top Depth_rv
Component Horizon, pH H2O_rv

Soil Climate Subrules

Frost-Free Days
Component, Frost Free Days_rv

Precipitation
Component, MAP_rv

Mean Annual Air Temperature
Component, Mean Annual Air Temperature_rv

Soil Landscape Subrules

Water Table
Component Soil Moisture, Top Depth_rv
Component Soil Moisture, Moisture Status
Component Month, Month
Component, Temp Regime
Legend Area Overlap, Area Type (MLRA)

Effective Slope
Component, Slope Gradient_rv

Flooding
Component Month, Month
Component Month, Flooding Frequency
Component Month, Flooding Duration
Component, Temp Regime

Ponding Component Month, Month
Component Month, Ponding Frequency
Component Month, Ponding Duration
Component, Temp Regime

Crisp Positive Attributes Subrules

Soil Fabric Component Parent Material, Kind

Water From Rare Flood
Component Month, Flooding Frequency

Crisp Negative Attributes Subrules

Fragments on Surface
Component Surface Fragments, Cover %_rv

Erosion Class
Component, Local Phase
Component, SIR Phase
Mapunit, Mapunit Name

Not Xeric Map Unit Area Overlap Table, MLRA Area Type
Component, Taxonomic Class

Rock Outcrop Component, Local Phase
Component, SIR Phase
Mapunit, Mapunit Name

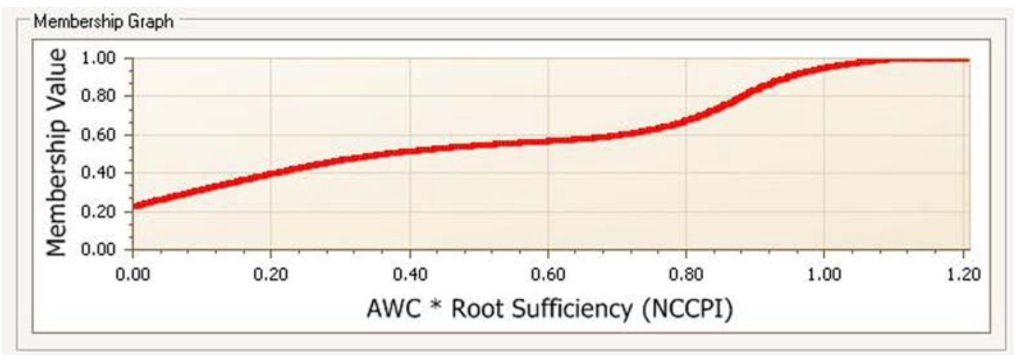
Degraded Surface
Component, Local Phase
Component, SIR Phase
Mapunit, Mapunit Name

No Surface Outlet
Component, Local Phase
Component, SIR Phase
Mapunit, Mapunit Name

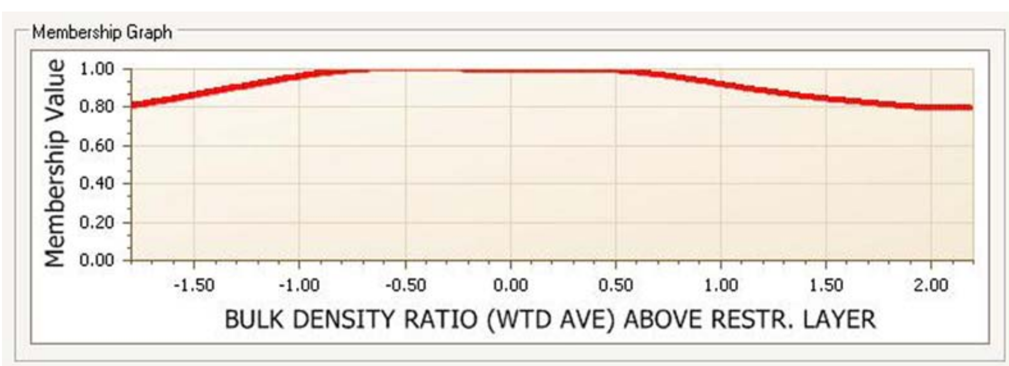
Appendix 3.—Evaluations

This appendix shows the evaluations used in the calculation of NCCPI. The evaluations indicate the range of property data used to produce the fuzzy numbers. The functions rarely go to zero. The lowest value of a variable was found to be a convenient way to weight the variables. Properties that are more closely correlated with yields are given more impact than factors that are not so closely correlated. The appendix does not show an exhaustive list, but it does display the evaluations for properties where a reasonable fuzzy relationship has been established. The graphs represent the best fit curves and are based on the observed data. Relating the response of yields to one independent variable is nearly impossible because of covariance and interaction. The fuzzy relationships occasionally exhibit a function that is being influenced by variables other than what is being modeled. The resulting curves may look unexpected, but they fit well in the empirical model.

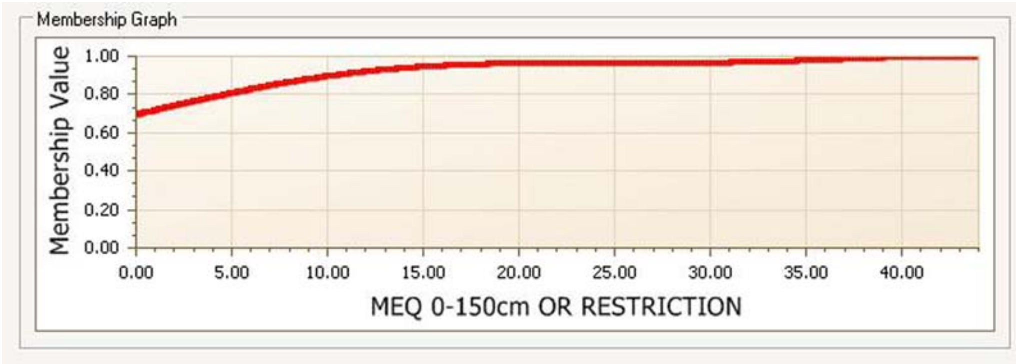
3a.—Corn and Soybeans Submodel Evaluations for Soil Properties



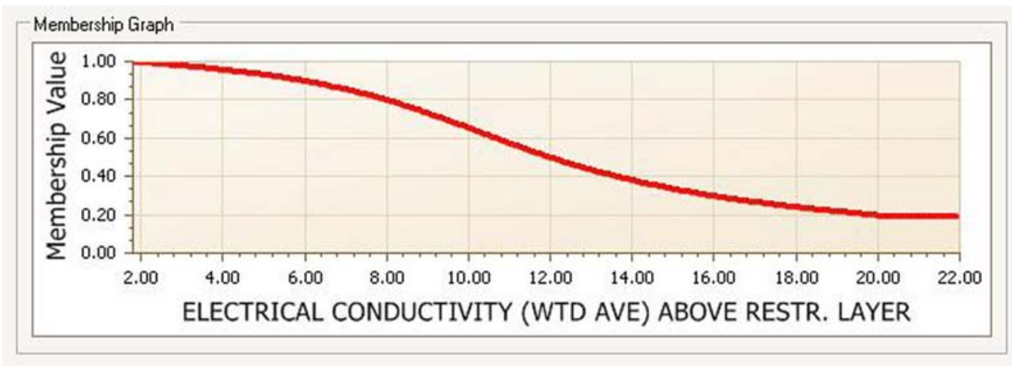
3a1.—AWC evaluation. AWC is in cm.



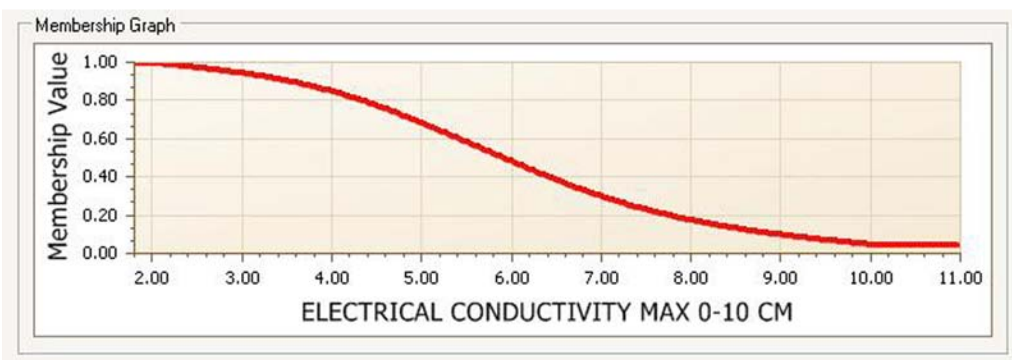
3a2.—Bulk Density ratio evaluation. The units of the ratio are $g/cm^3/g/cm^3$.



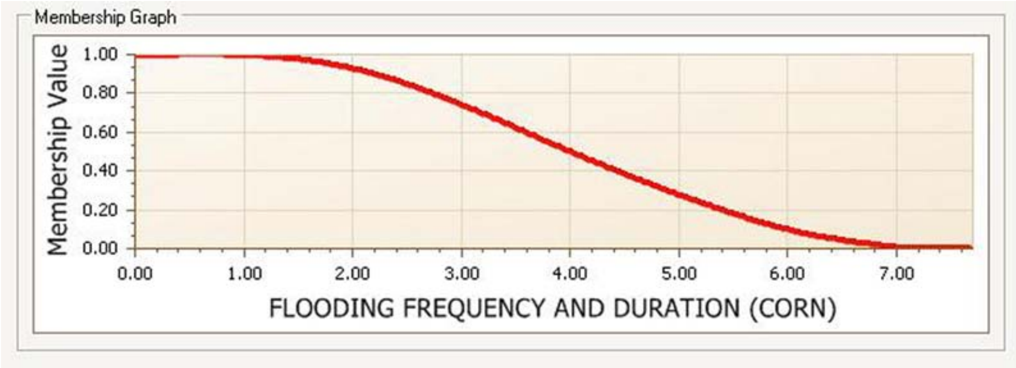
3a3.—CEC evaluation. Units are meq/cm².



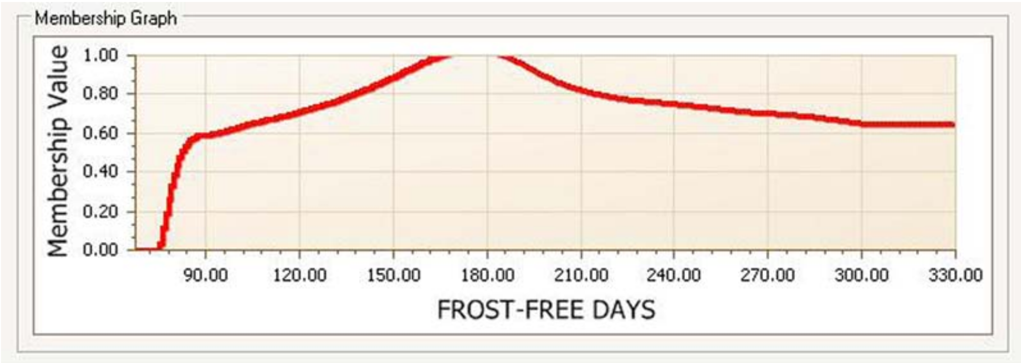
3a4.—Electrical Conductivity Growth evaluation. Units are mmhos/cm.



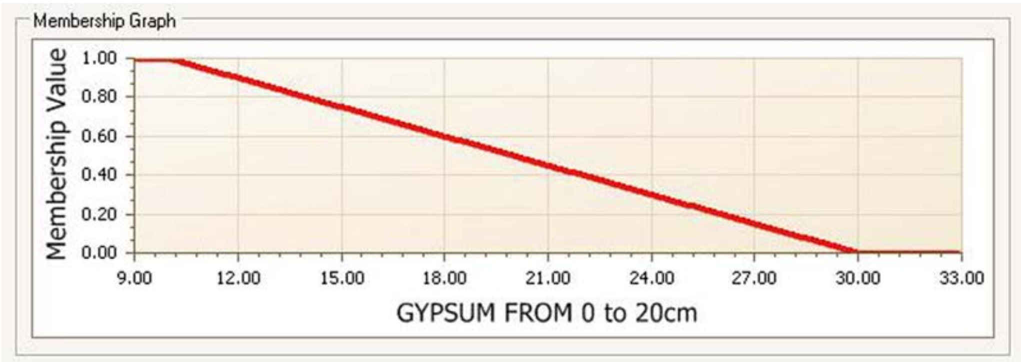
3a5.—Electrical Conductivity Germination evaluation. Units are mmhos/cm.



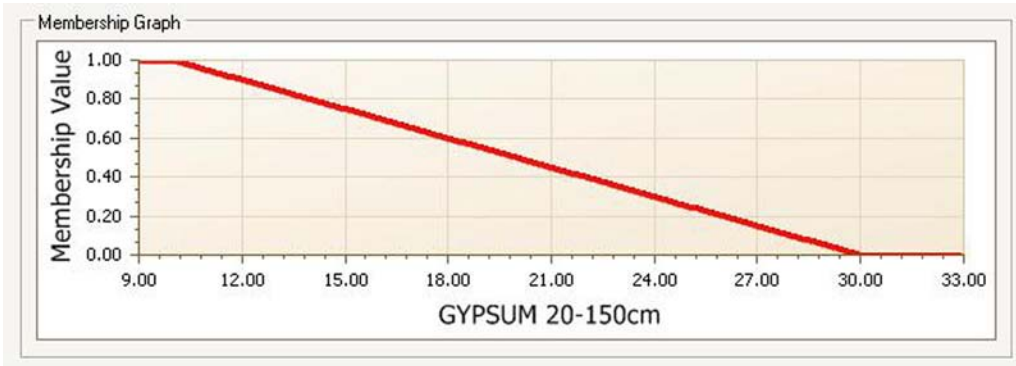
3a6.—Flooding During the Growing Season evaluation. Units are (days)*(inundations/month)*(months).



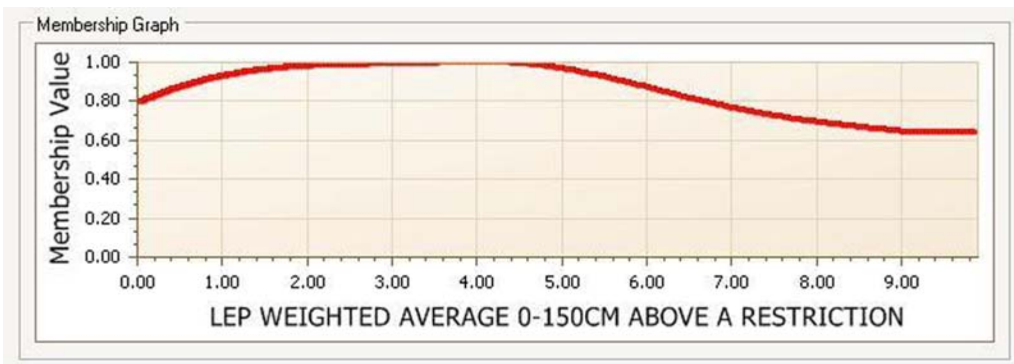
3a7.—Frost-Free Days evaluation. Units are frost-free days/year.



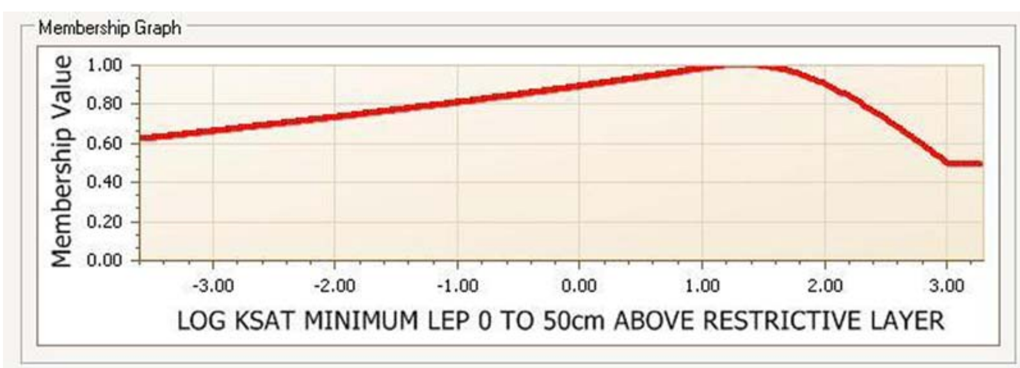
3a8.—Gypsum from 0-20 cm evaluation. Units are percent by weight of less than 20 mm material.



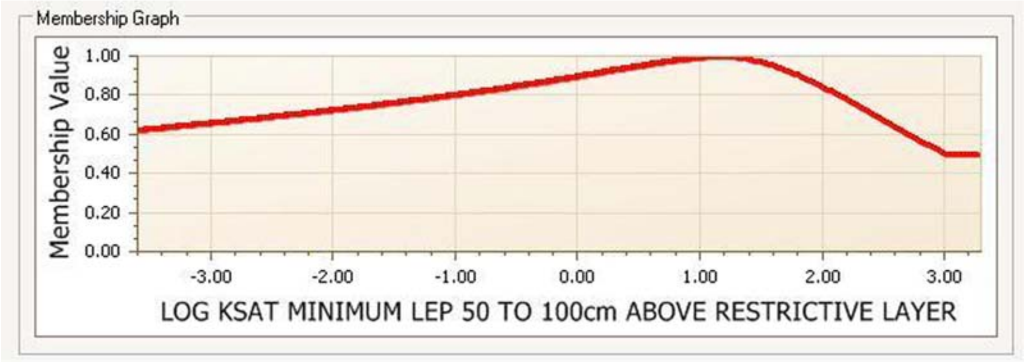
3a9.—Gypsum from 20 to 150 cm evaluation. Units are percent by weight of less than 20 mm material.



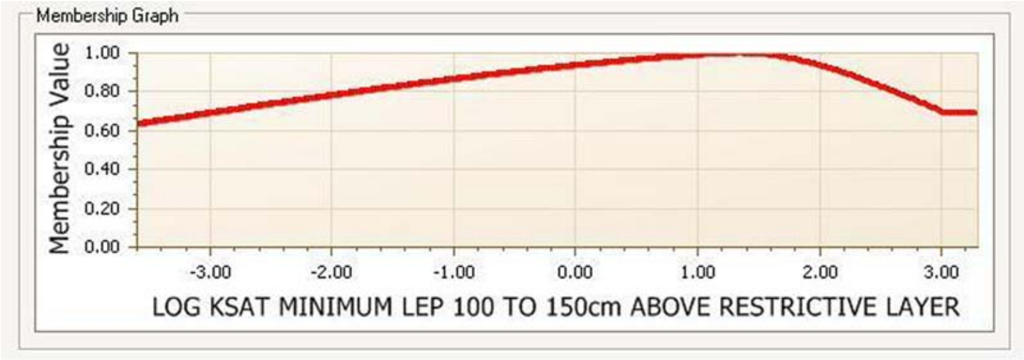
3a10.—LEP from 0 to 150 cm evaluation. Units are cm^3/cm^3.



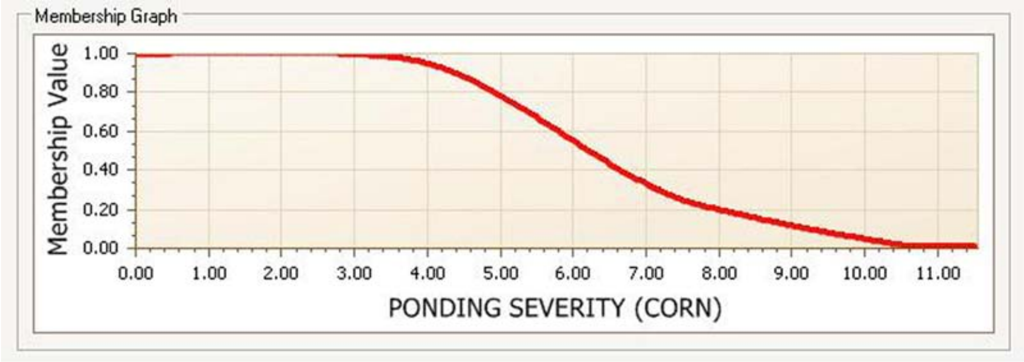
3a11.—Log (Ksat times LEP) from 0-50 cm evaluation. Units are log(μ/sec).



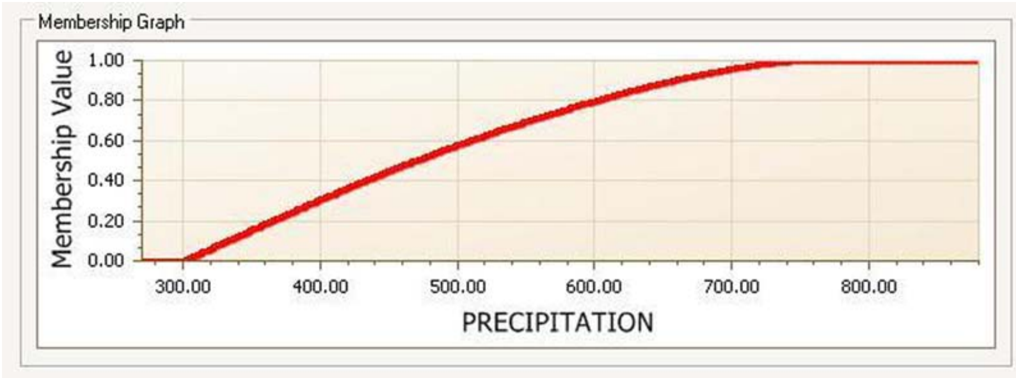
3a12.—Log (Ksat times LEP) from 50-100 cm evaluation. Units are log(μ/sec).



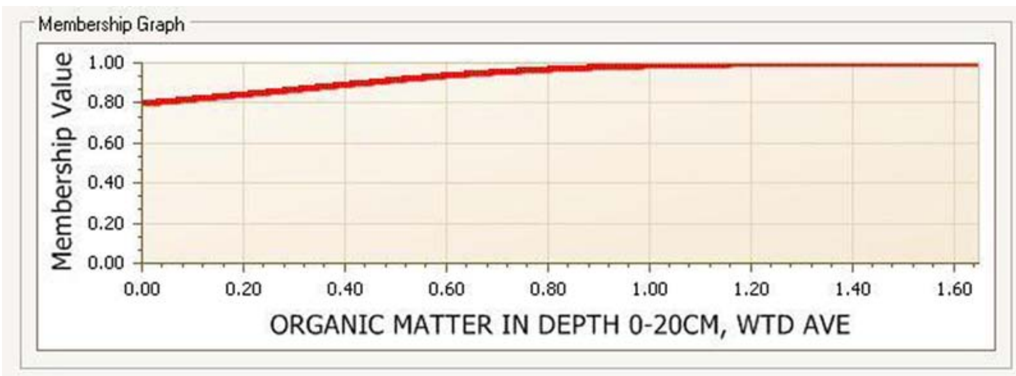
3a13.—Log (Ksat times LEP) from 100-150 cm evaluation. Units are log(μ/sec).



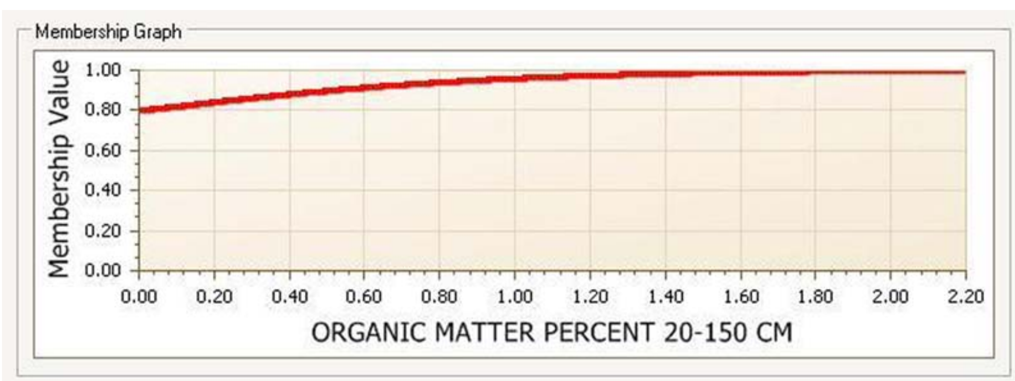
3a14.—Ponding During the Growing Season evaluation. Units are (days)*(inundations)*(months).



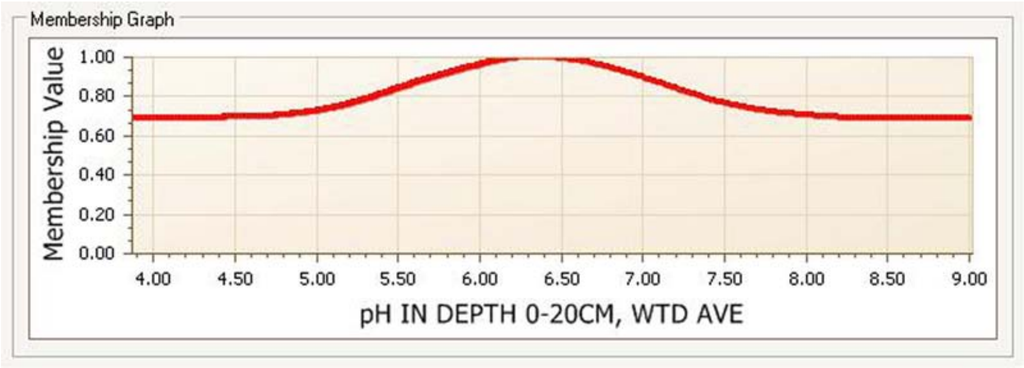
3a15.—Precipitation evaluation. Units are mm/year.



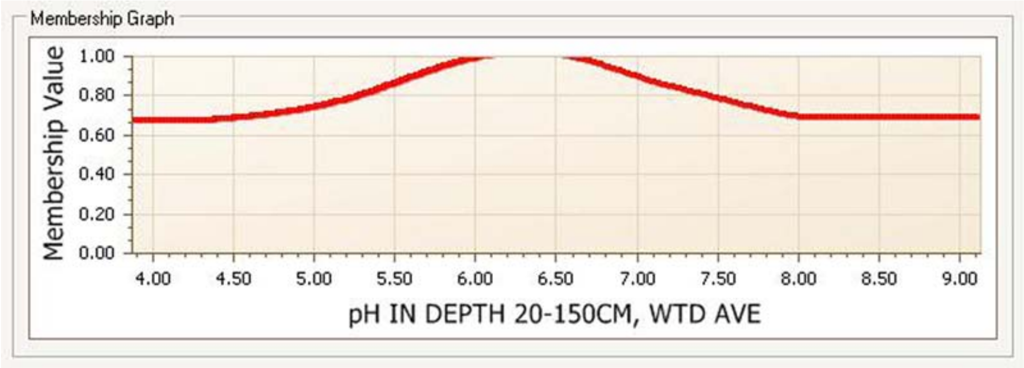
3a16.—Organic Matter 0-20 cm evaluation. Units are percent by weight.



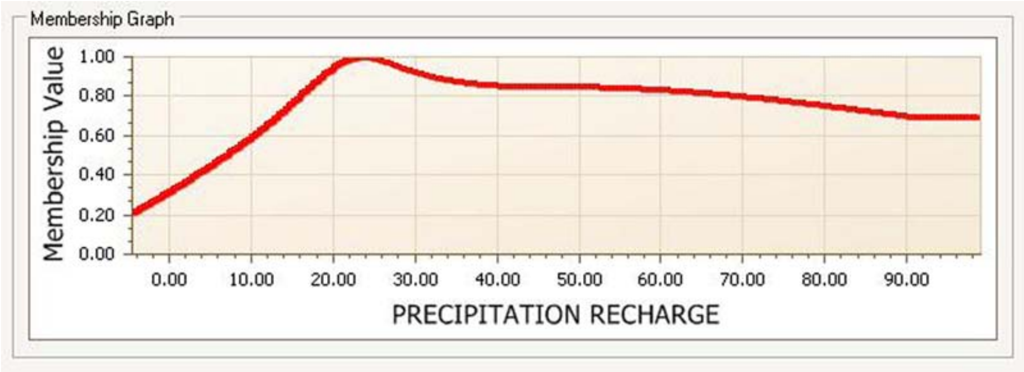
3a17.—Organic Matter 20-150 cm evaluation. Units are percent by weight.



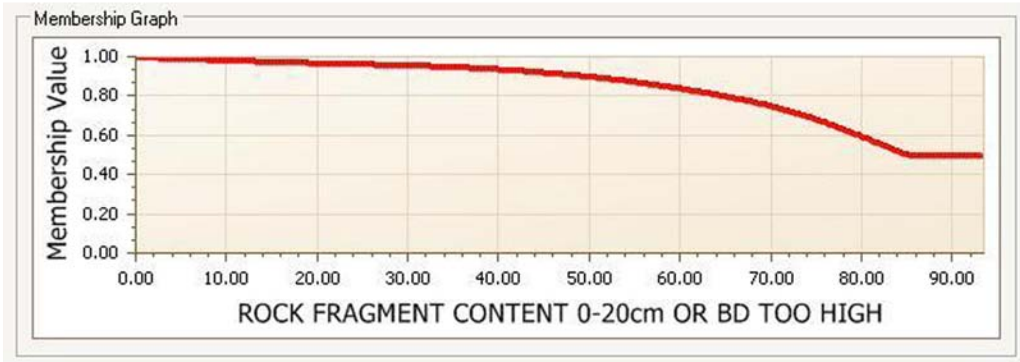
3a18.—pH 0-20 cm evaluation (pH units).



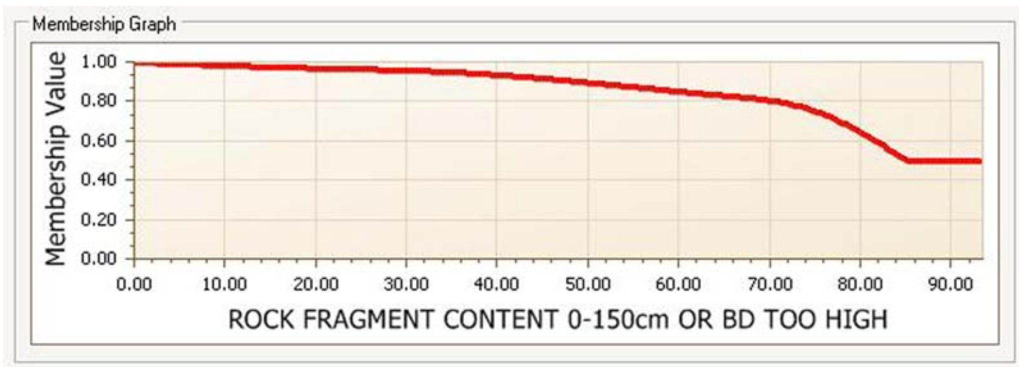
3a19.—pH 20-150 cm evaluation (pH units).



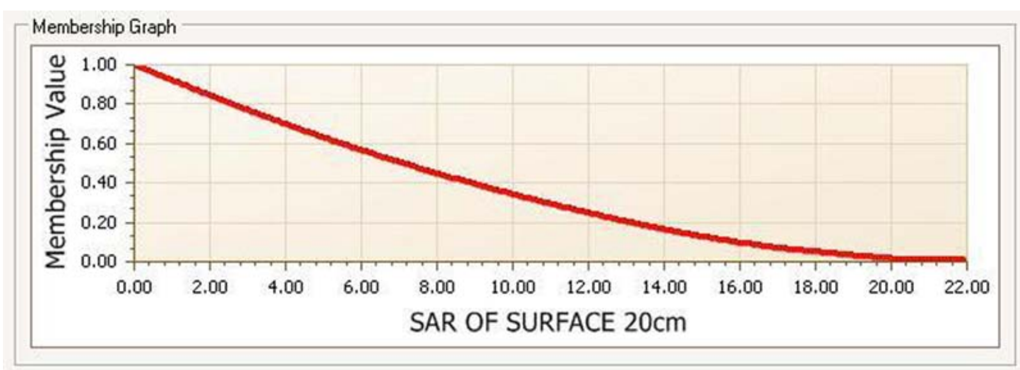
3a20.—Precipitation Recharge evaluation. Units are mm/year.



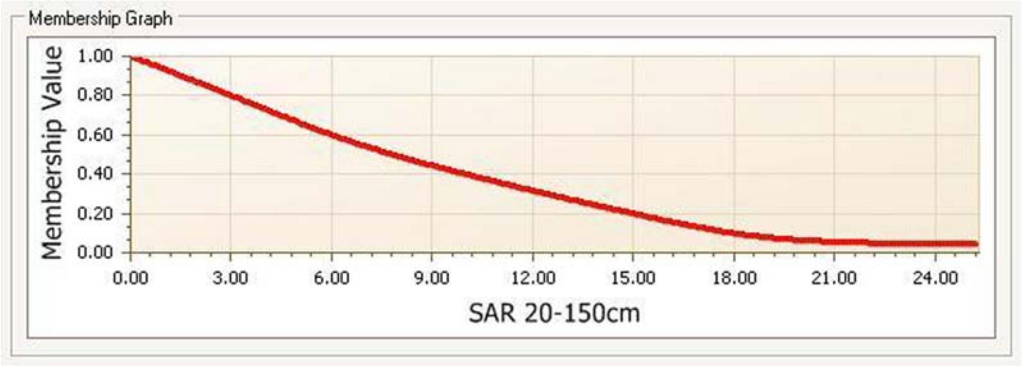
3a21.—Rock fragment volume 0-20 cm evaluation. Units are percent by volume.



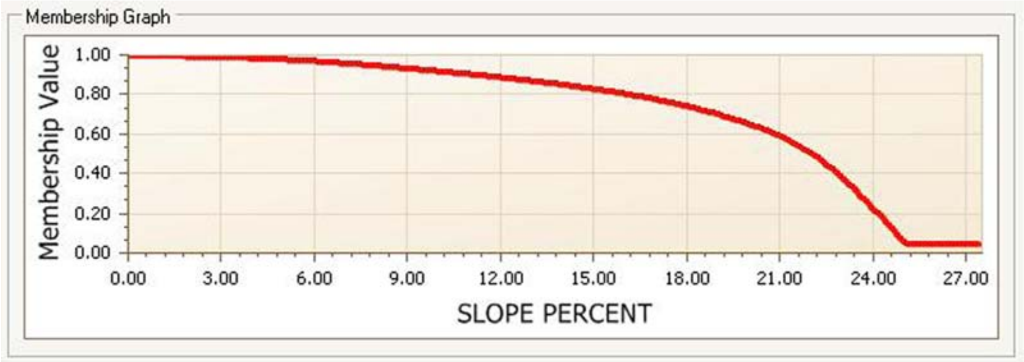
3a22.—Rock fragment volume 20-150 cm evaluation. Units are percent by volume.



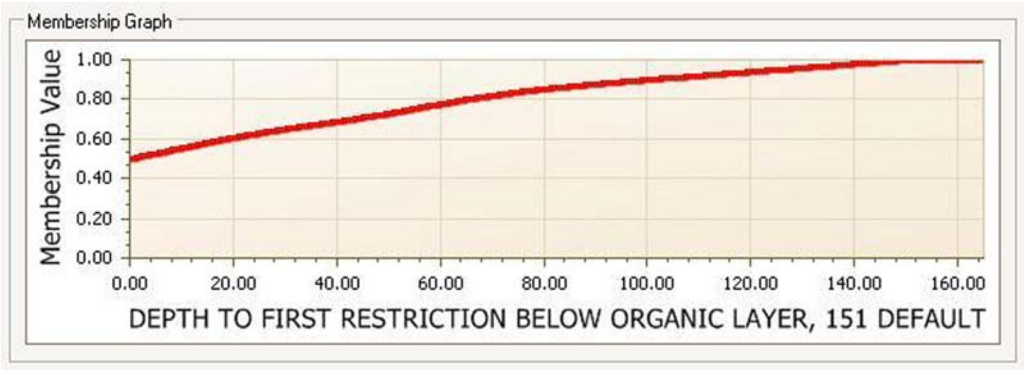
3a23.—SAR 0-20 cm evaluation. SAR is a unitless ratio.



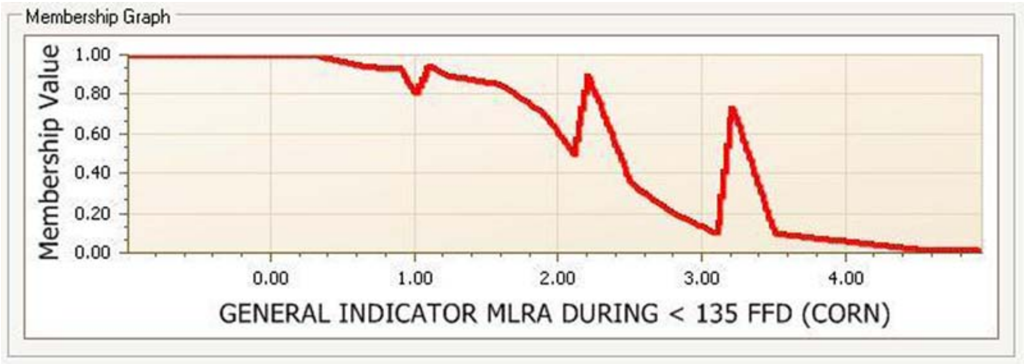
3a24.—SAR 20-150 cm evaluation. SAR is a unitless ratio.



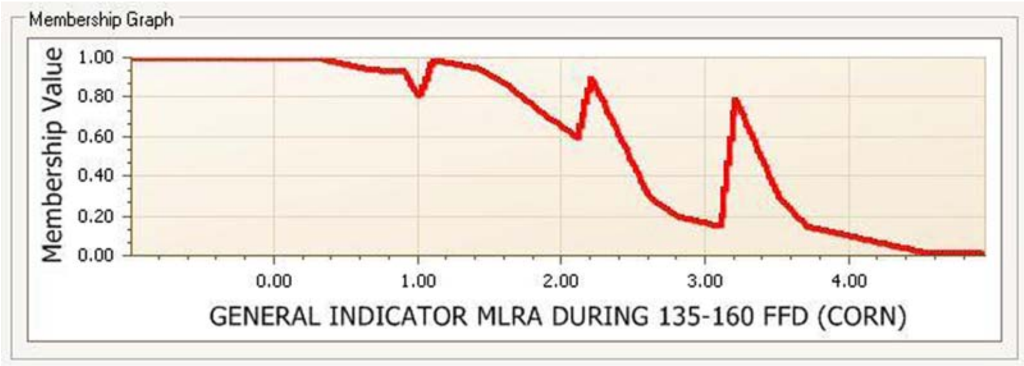
3a25.—Slope evaluation. Units are percent slope.



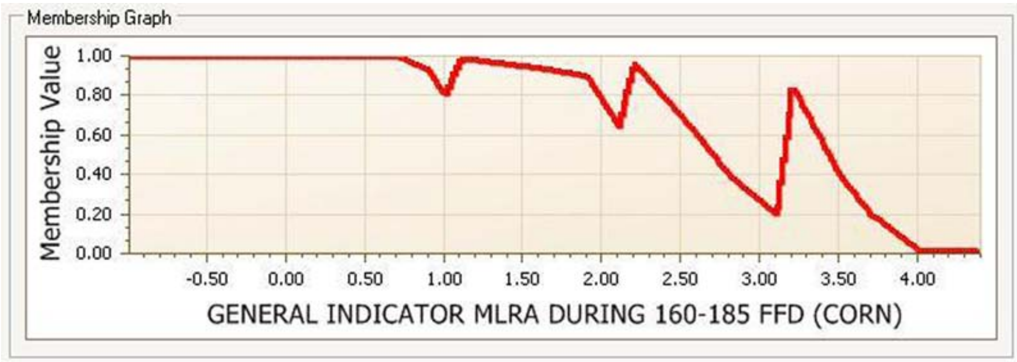
3a26.—Soil Depth evaluation. Units are cm.



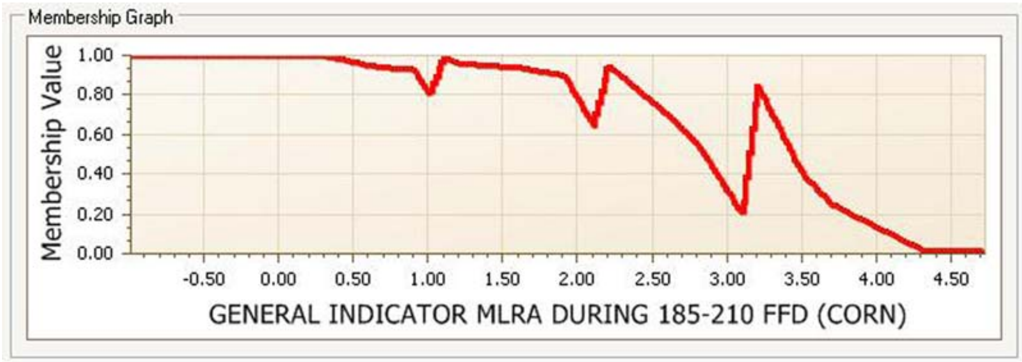
3a27.—Water Table Index <135 Frost-Free Days (unitless).



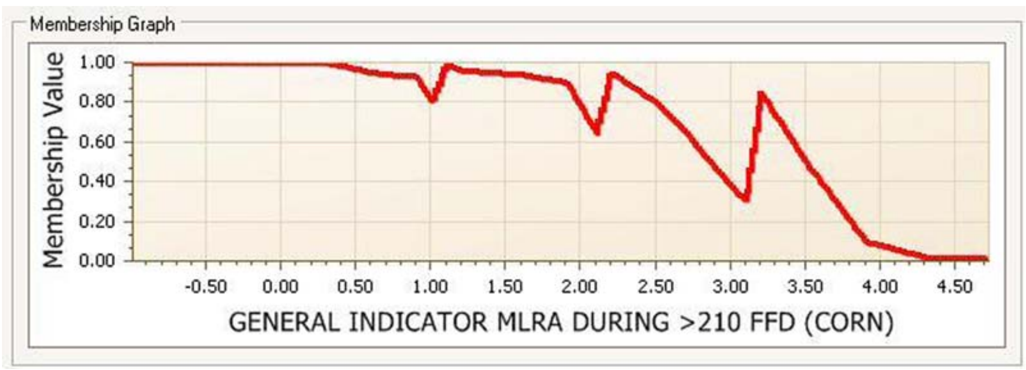
3a28.—Water Table Index >135 to <=160 Frost-Free Days (unitless).



3a29.—Water Table Index >160 to <=185 Frost-Free Days (unitless).

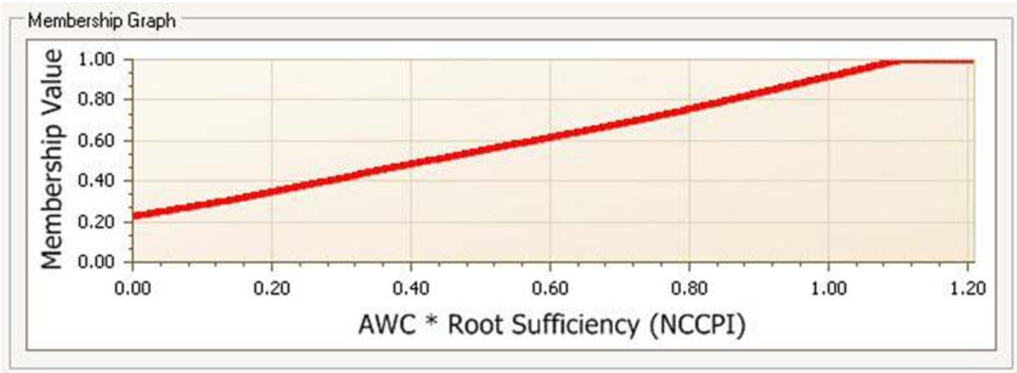


3a30.—Water Table Index >185 to <=210 Frost-Free Days (unitless).

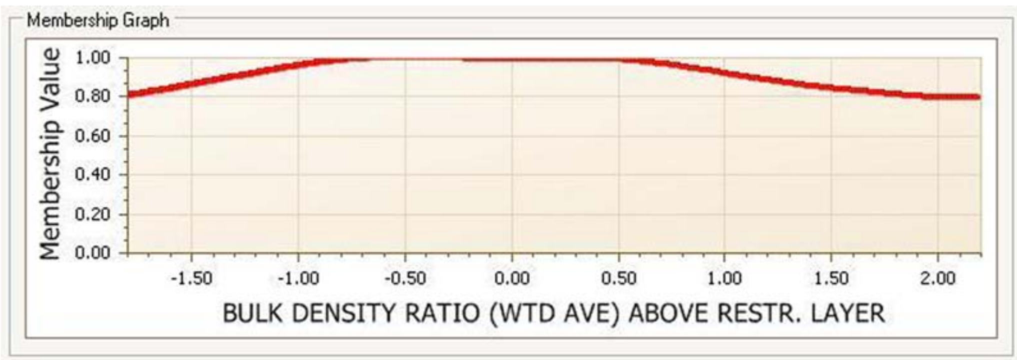


3a31.—Water Table Index >210 Frost-Free Days (unitless).

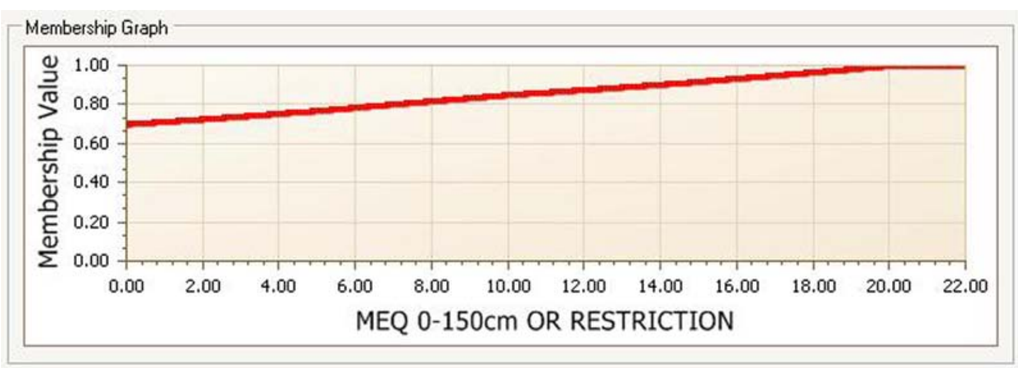
3b.—Small Grains Submodel Evaluations for Soil Properties



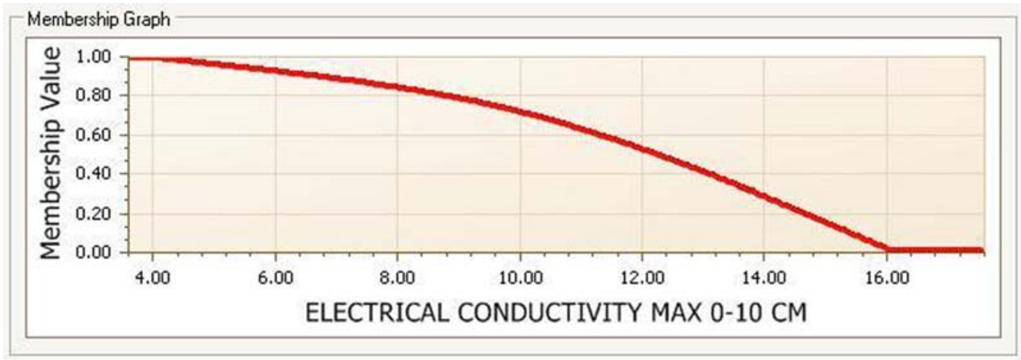
3b1.—AWC evaluation. AWC is in cm.



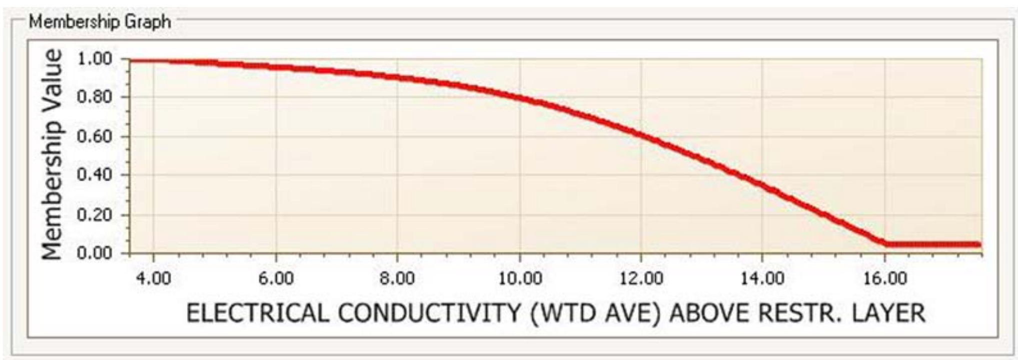
3b2.—Bulk Density Ratio evaluation. The units of the ratio are $g/cm^3/g/cm^3$.



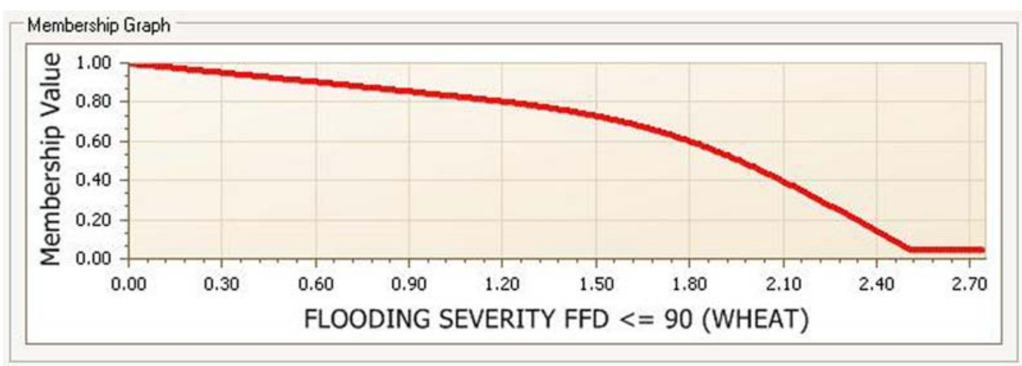
3b3.—CEC evaluation. Units are meq/cm^2.



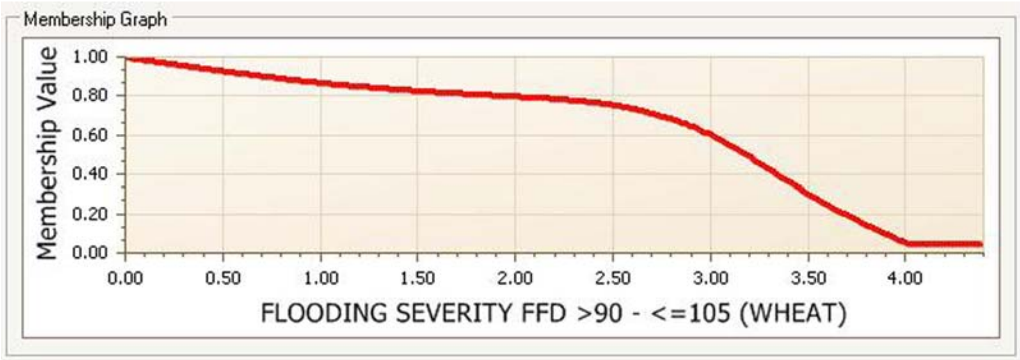
3b4.—Electrical Conductivity Germination evaluation. Units are mmhos/cm.



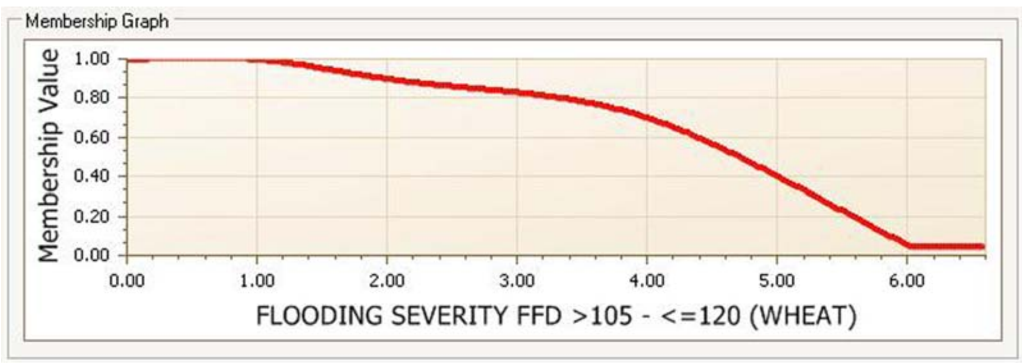
3b5.—Electrical Conductivity Growth evaluation. Units are mmhos/cm.



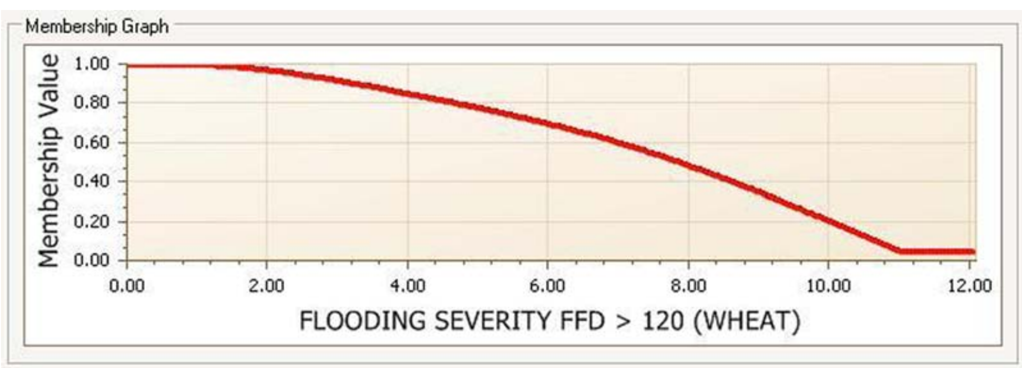
3b6.—Flooding During Growing Season <90 FFD (Wheat). Units are (days)*(inundations/month)*(months).



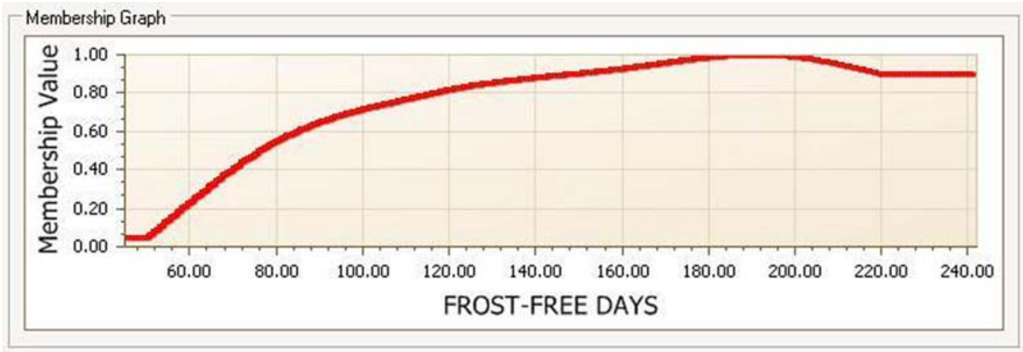
3b7.—Flooding During Growing Season 90-105 FFD (Wheat). Units are (days)*(inundations/month)*(months).



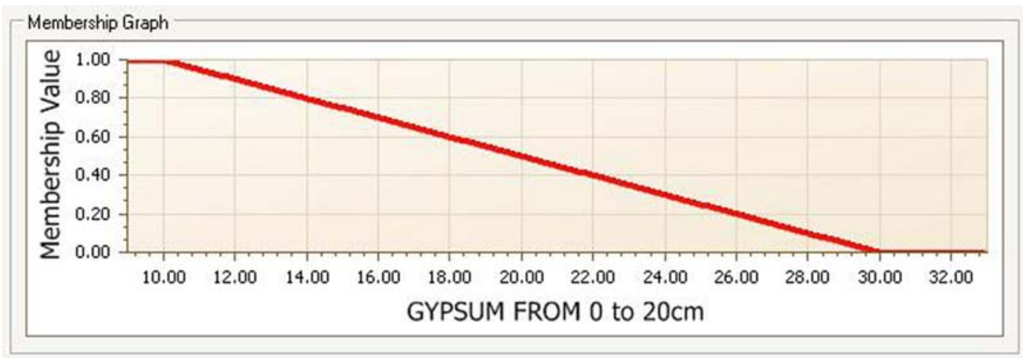
3b8.—Flooding During Growing Season 105-120 FFD (Wheat). Units are (days)*(inundations/month)*(months).



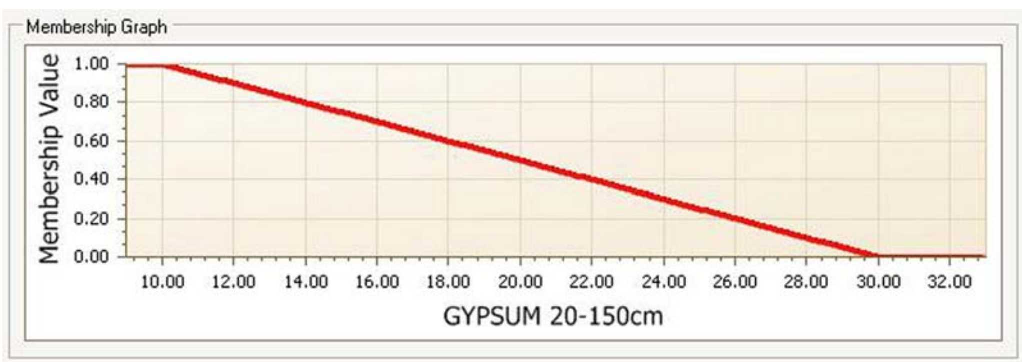
3b9.—Flooding During Growing Season >120 FFD (Wheat). Units are (days)*(inundations/month)*(months).



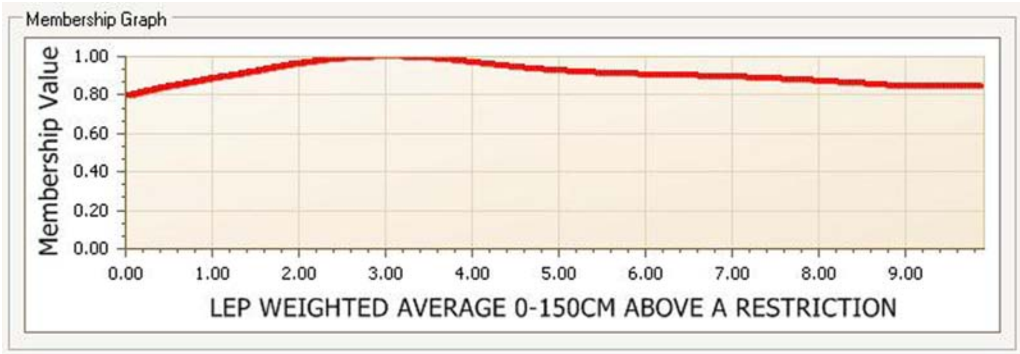
3b10.—Frost-Free Days (Wheat) evaluation. Units are frost-free days/year.



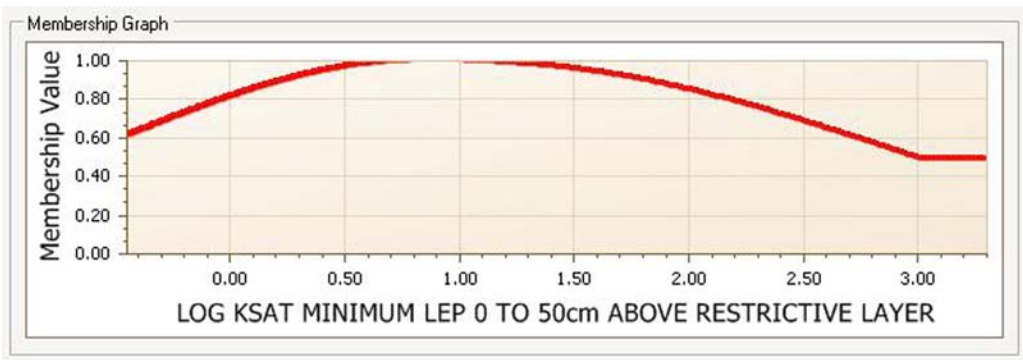
3b11.—Gypsum from 0-20 cm evaluation. Units are percent by weight of less than 20 mm material.



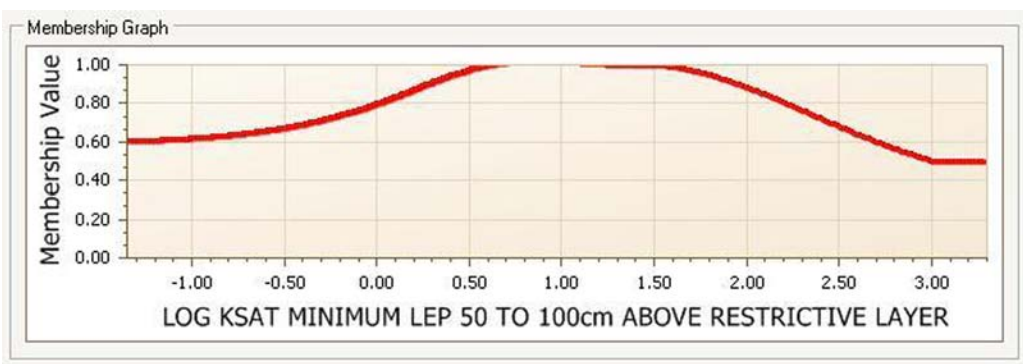
3b12.—Gypsum from 20 to 150 cm (Wheat) evaluation. Units are percent by weight of less than 20 mm material.



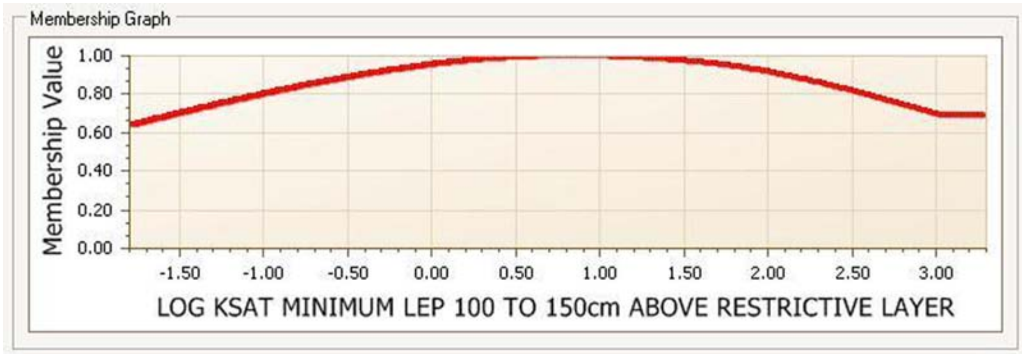
3b13.—LEP from 0 to 150 (Wheat) evaluation. Units are cm³/cm³.



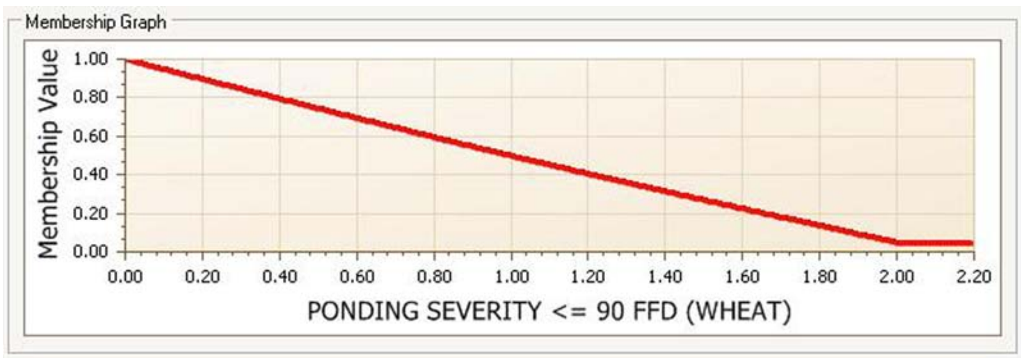
3b14.—Log (Ksat Min X LEP) 0 to 50 cm (Wheat) evaluation. Units are log(μ/sec).



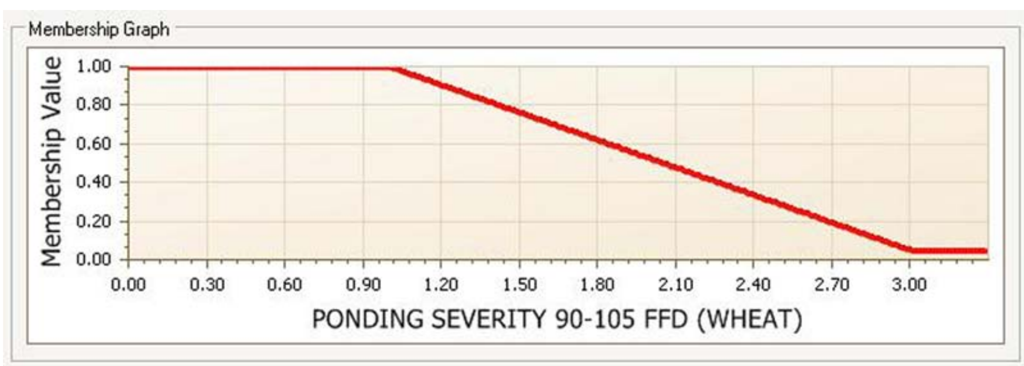
3b15.—Log (Ksat Min X LEP) 50 to 100 cm (Wheat) evaluation. Units are log(μ/sec).



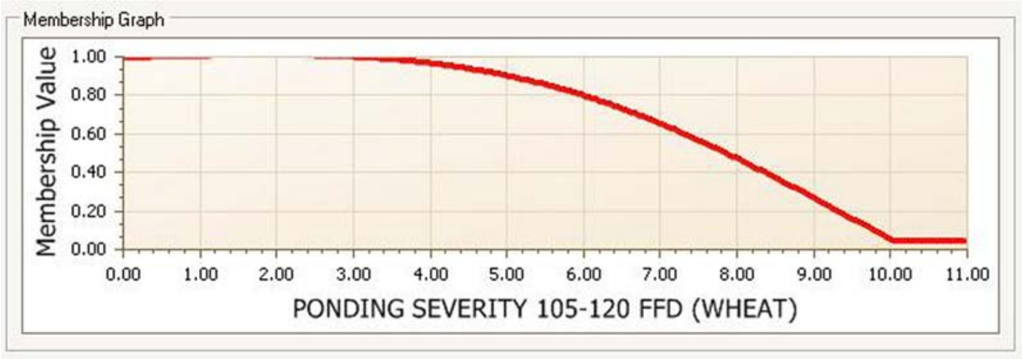
3b16.—Log (Ksat Min X LEP) 100 to 150 cm (Wheat) evaluation. Units are log(μ/sec).



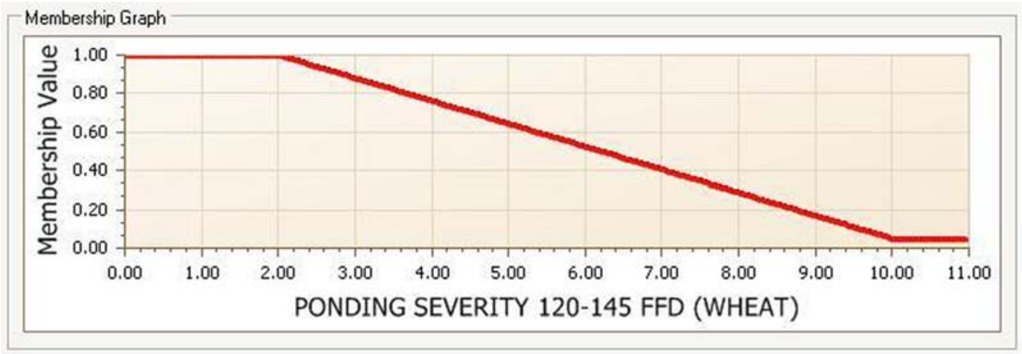
3b17.—Ponding During Growing Season <90 FFD (Wheat). Units are (days)*(inundations)*(months).



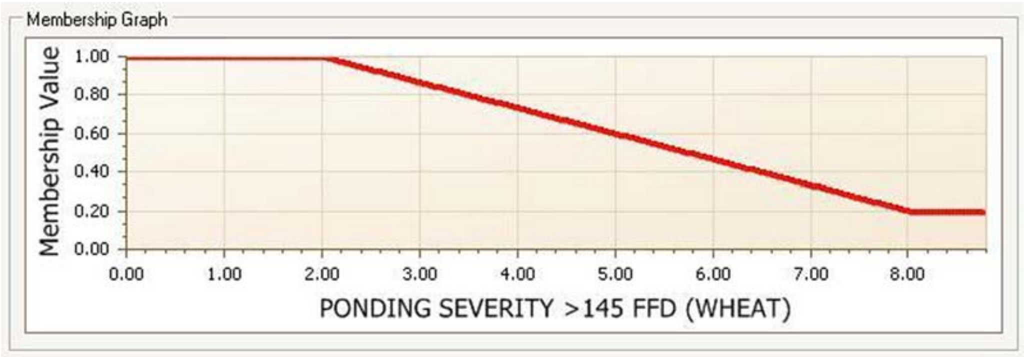
3b18.—Ponding During Growing Season 90-105 FFD (Wheat). Units are (days)*(inundations)*(months).



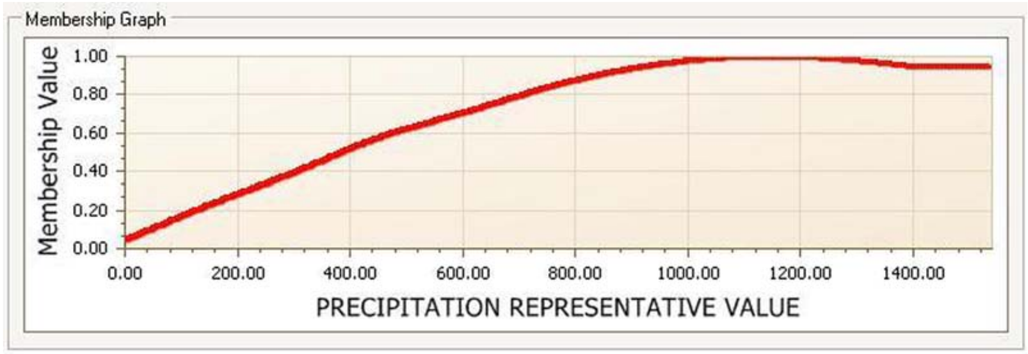
3b19.—Ponding During Growing Season 105-120 FFD (Wheat). Units are (days)*(inundations)*(months).



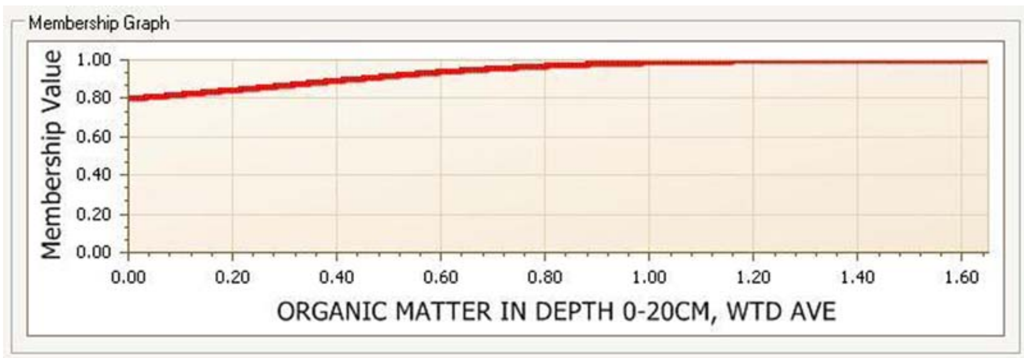
3b20.—Ponding During Growing Season 120-145 FFD (Wheat). Units are (days)*(inundations)*(months).



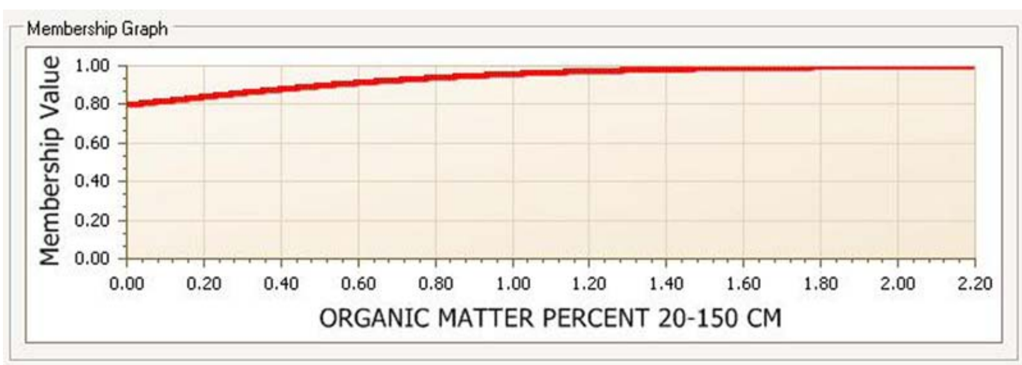
3b21.—Ponding During Growing Season >145 FFD (Wheat). Units are (days)*(inundations)*(months).



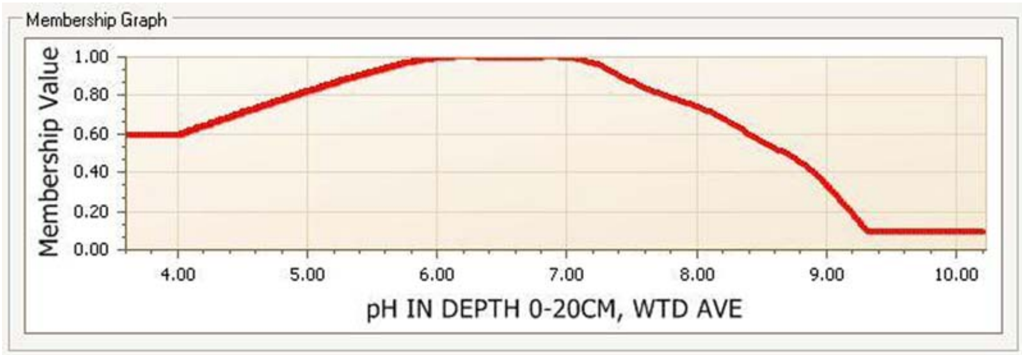
3b22.—Mean Annual Precipitation (Wheat) evaluation. Units are mm/year.



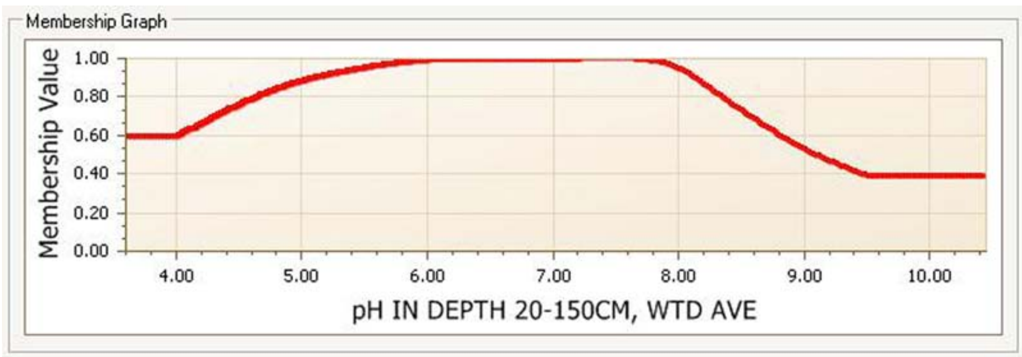
3b23.—Organic Matter 0-20 cm evaluation. Units are percent by weight.



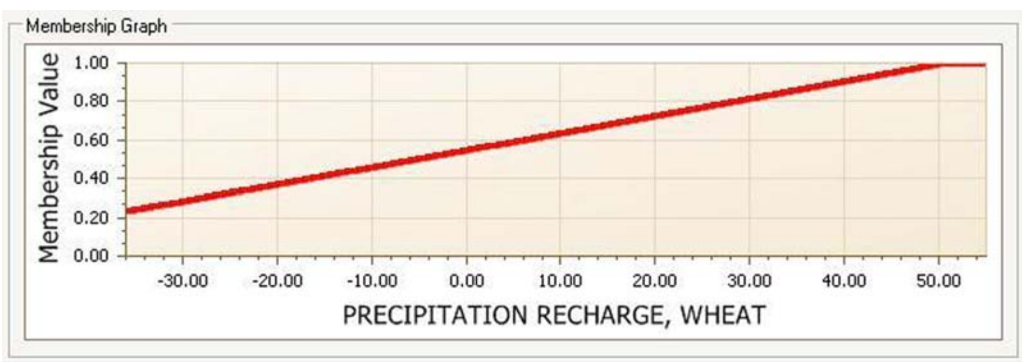
3b24.—Organic Matter 20-150 cm evaluation. Units are percent by weight.



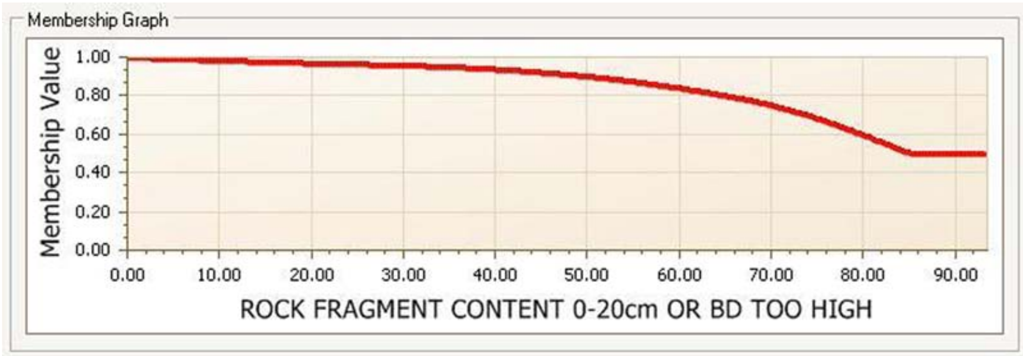
3b25.—pH 0-20 cm (Wheat) evaluation (pH units).



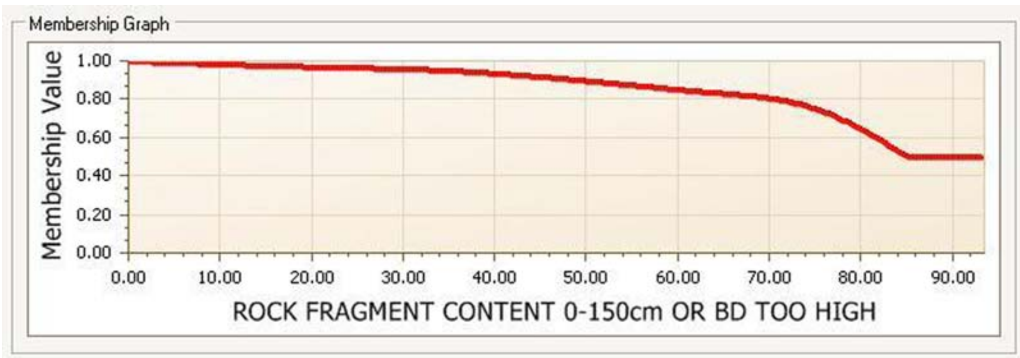
3b26.—pH 20-150 cm (Wheat) evaluation (pH units).



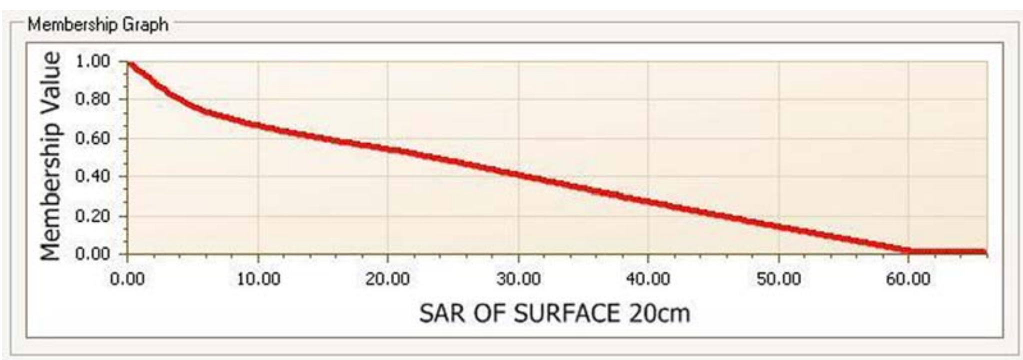
3b27.—Precipitation Recharge (Wheat) evaluation. Units are mm/year.



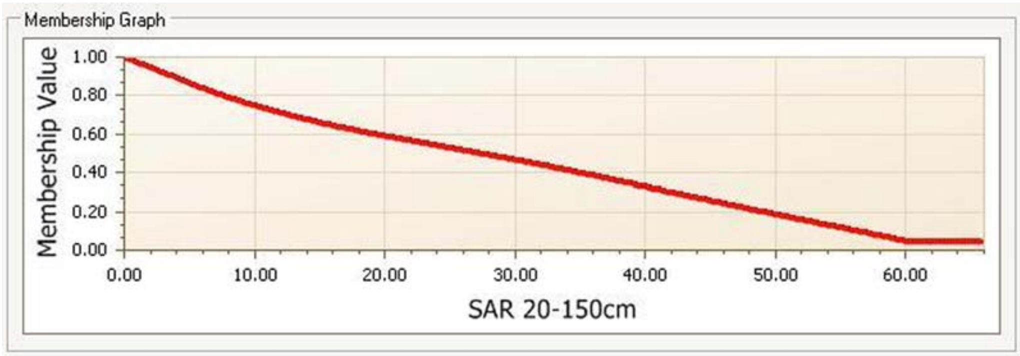
3b28.—Rock fragment volume 0-20 cm evaluation. Units are percent by volume.



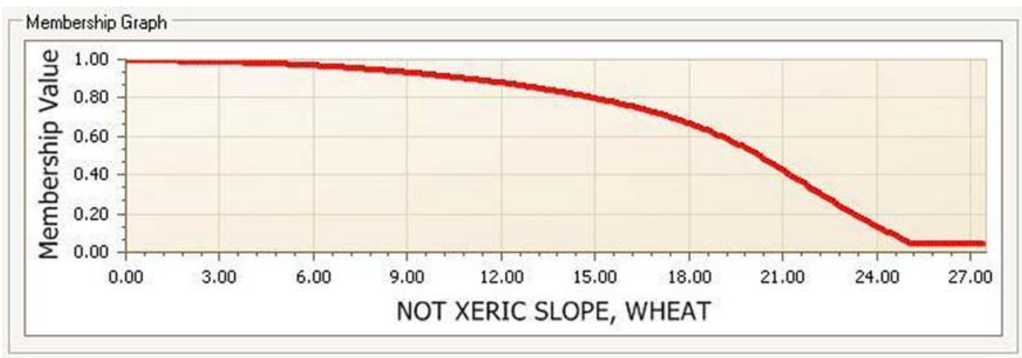
3b29.—Rock fragment volume 20-150 cm evaluation. Units are percent by volume.



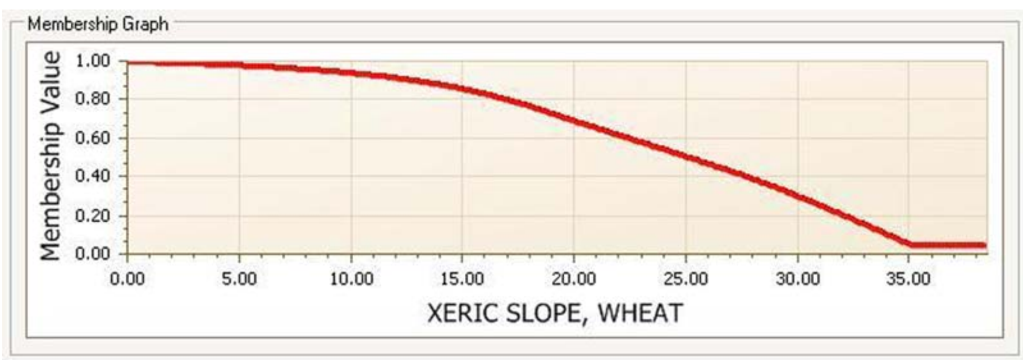
3b30.—SAR 0-20 cm evaluation. SAR is a unitless ratio.



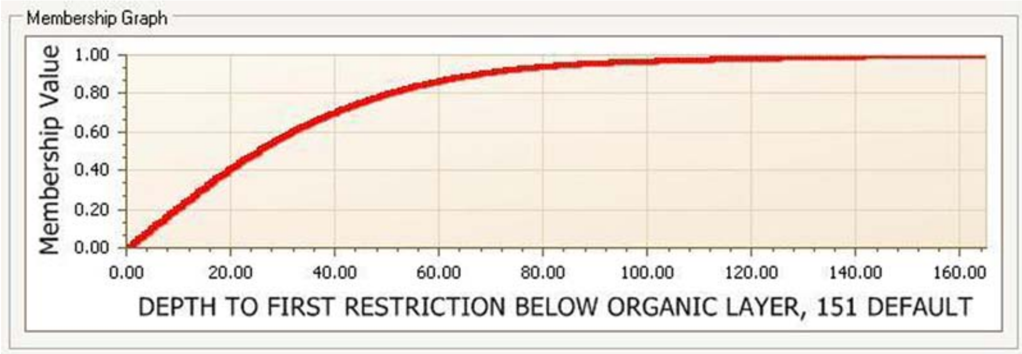
3b31.—SAR 20-150 cm evaluation. SAR is a unitless ratio.



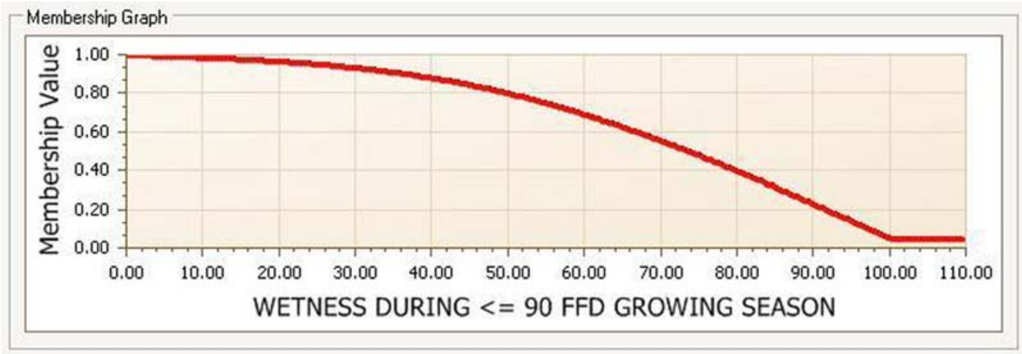
3b32.—Effective Slope, Not Xeric (Wheat) evaluation. Units are percent slope.



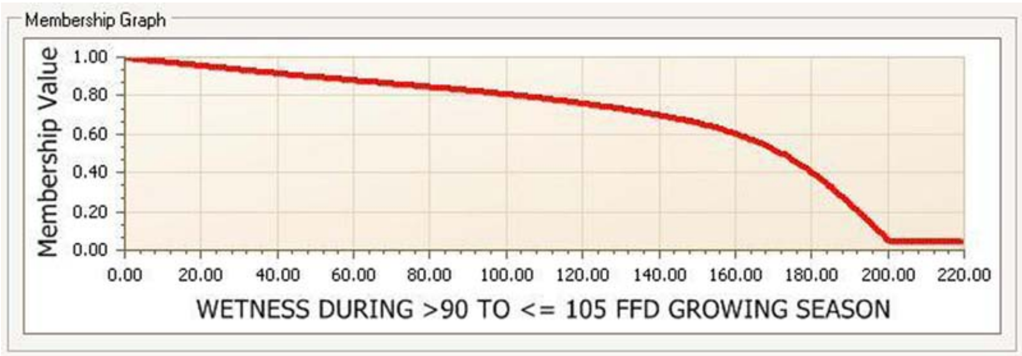
3b33.—Effective Slope, Xeric (Wheat) evaluation. Units are percent slope.



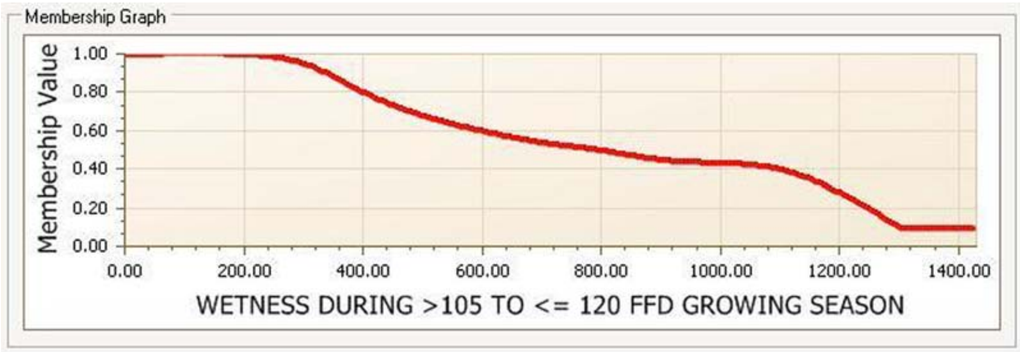
3b34.—Soil Depth evaluation (Wheat). Units are cm.



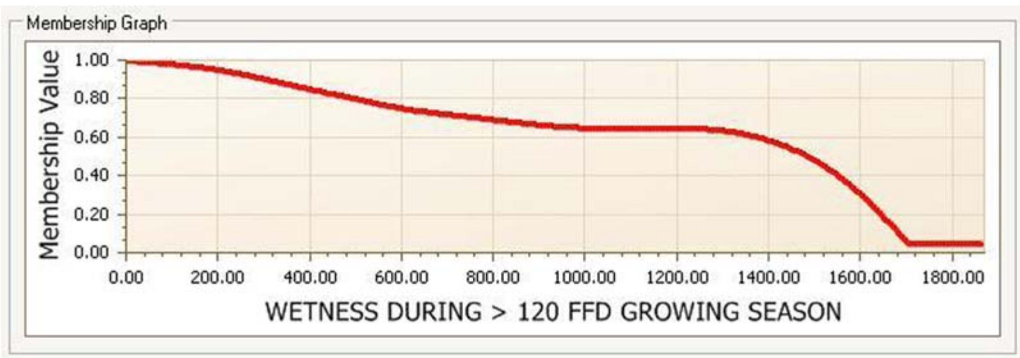
3b35.—Wetness During FFD <= 90 (Wheat) evaluation. Units are cm.



3b36.—Wetness During FFD >90 to <=105 (Wheat). Units are cm.

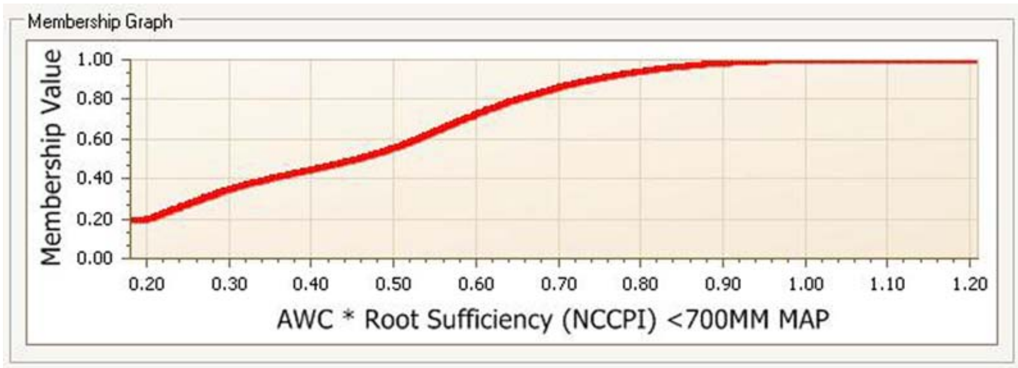


3b37.—Wetness During FFD >105 to <=120 (Wheat) evaluation. Units are cm.

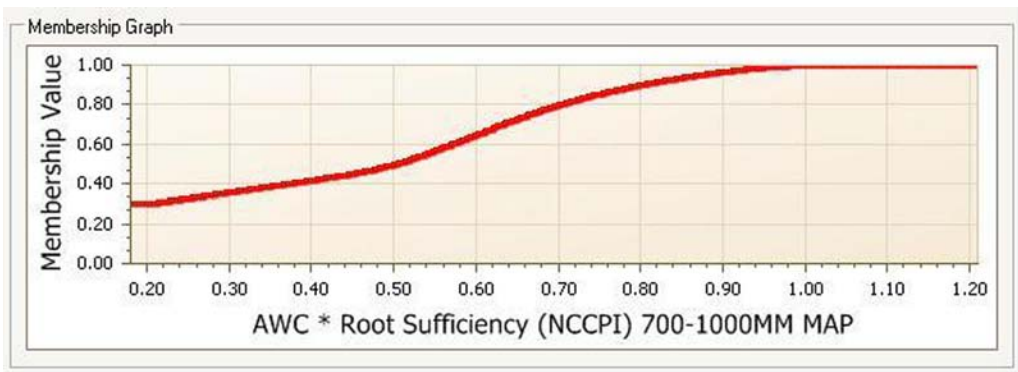


3b38.—Wetness During FFD >120 (Wheat) evaluation. Units are cm.

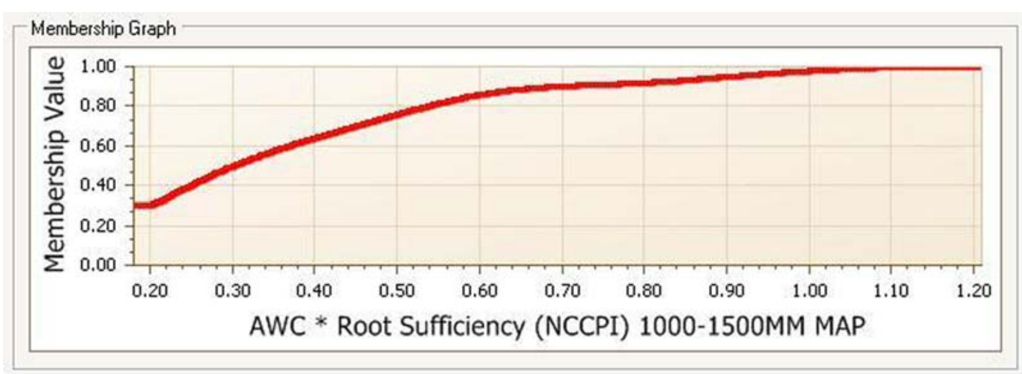
3c.—Cotton Submodel Evaluations for Soil Properties



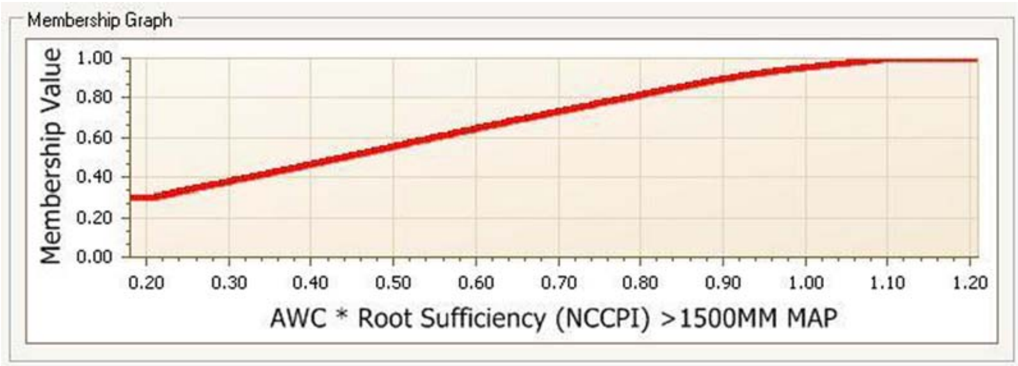
3c1a.—AWC Sufficiency <700 mm MAP (Cotton) evaluation. AWC is in cm.



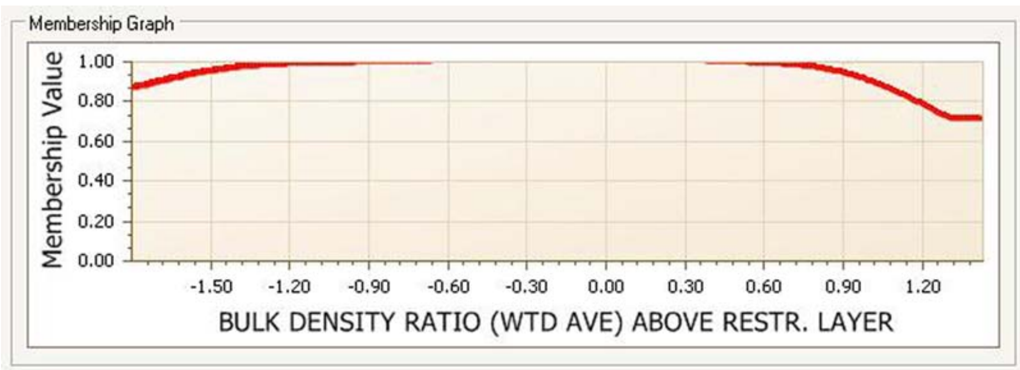
3c1b.—AWC Sufficiency 700-1000 mm MAP (Cotton) evaluation. AWC is in cm.



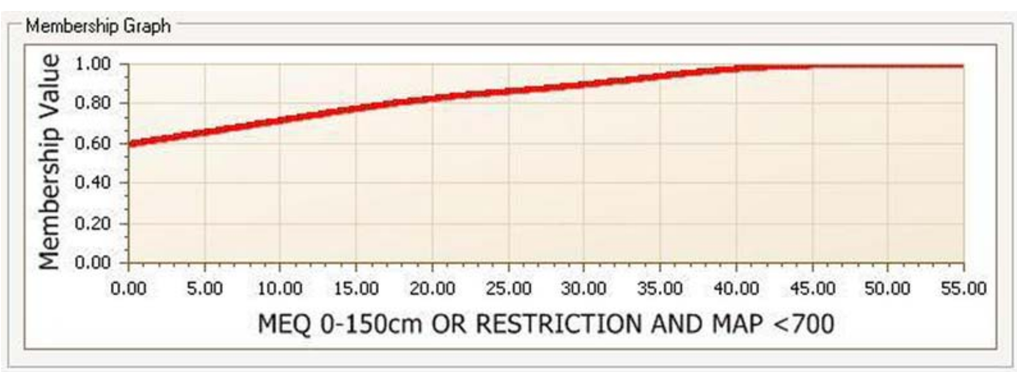
3c1c.—AWC Sufficiency 1000-1500 mm MAP (Cotton) evaluation. AWC is in cm.



3c1d.—AWC Sufficiency >1500 mm MAP (Cotton) evaluation. AWC is in cm.

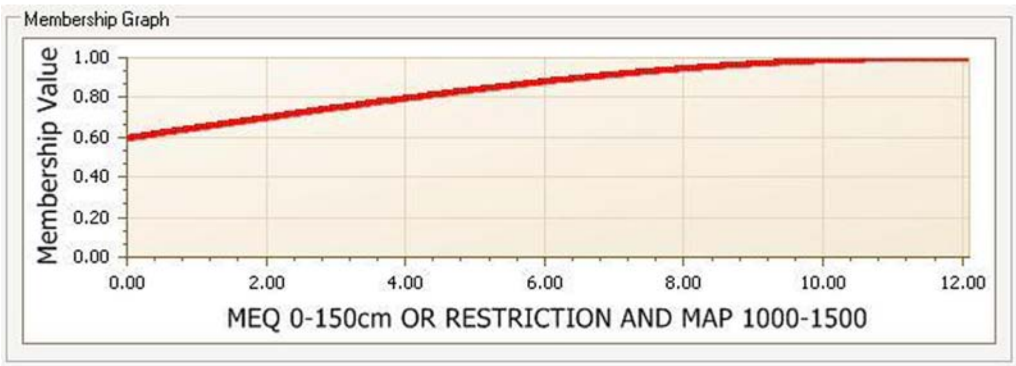


3c2.—Bulk Density Ratio evaluation. The units of the ratio are $g/cm^3/g/cm^3$.

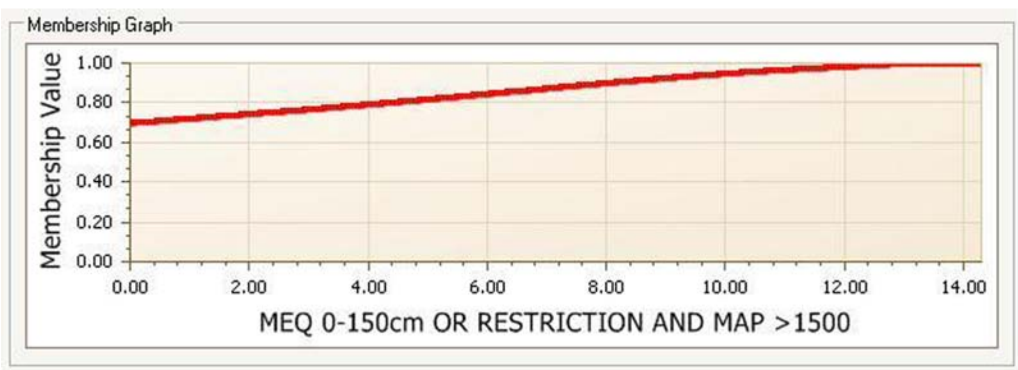


3c3a.—CEC MAP <700 mm (Cotton) evaluation. Units are meq/cm^2.

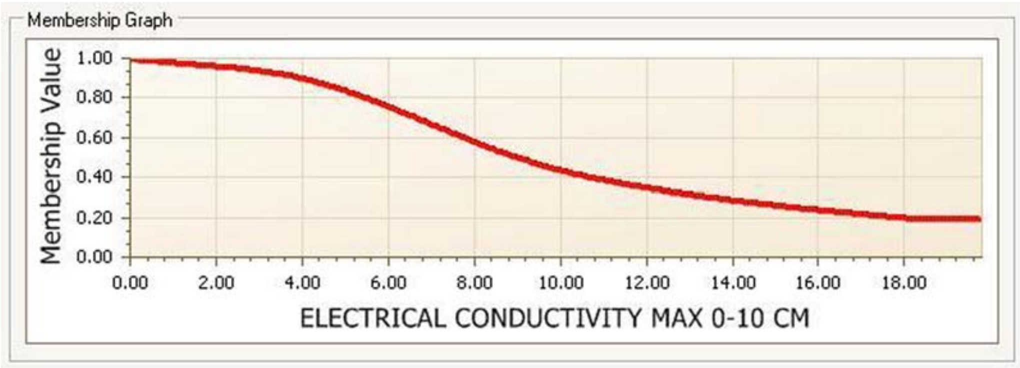
3c3b.—CEC MAP 700-1000 mm (Cotton) evaluation. Units are meq/cm².



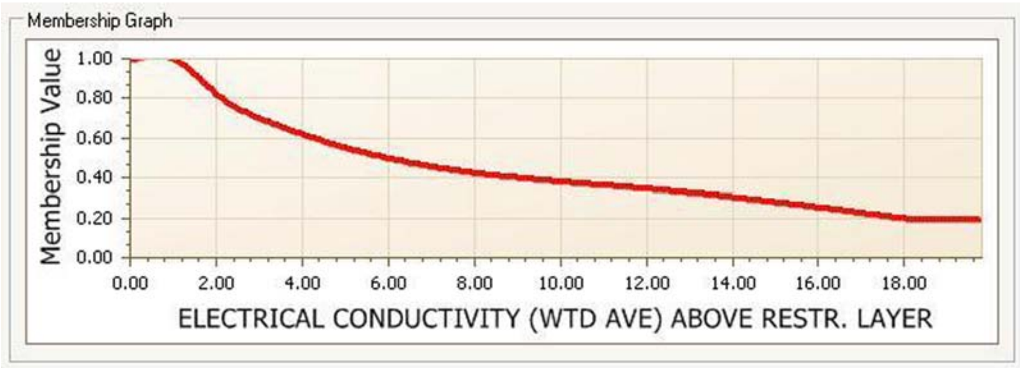
3c3c.—CEC MAP 1000-1500 mm (Cotton) evaluation. Units are meq/cm².



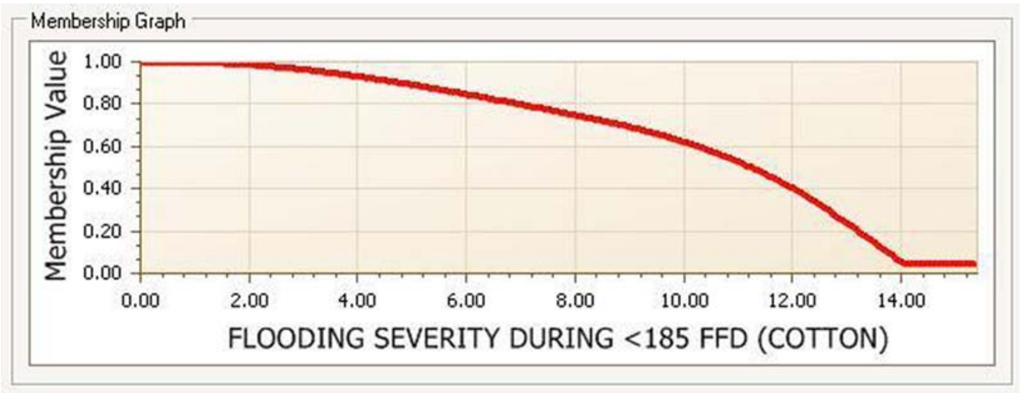
3c3d.—CEC MAP >1500 mm (Cotton) evaluation. Units are meq/cm².



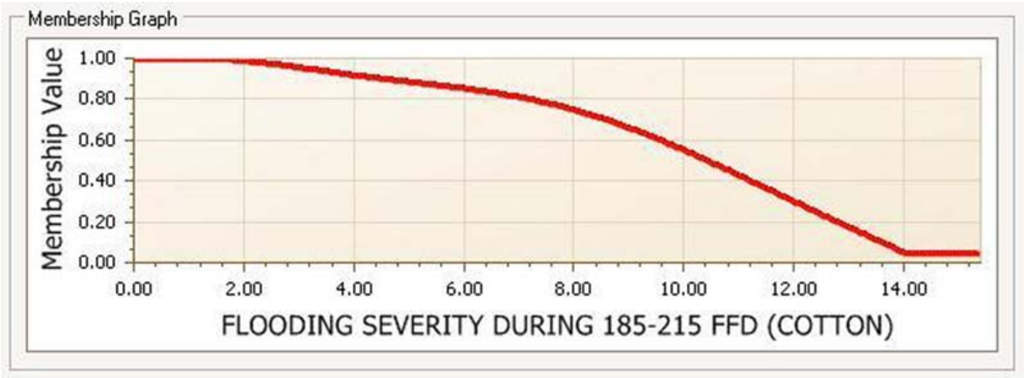
3c4.—Electrical Conductivity Adverse Germination (Cotton) evaluation. Units are mmhos/cm.



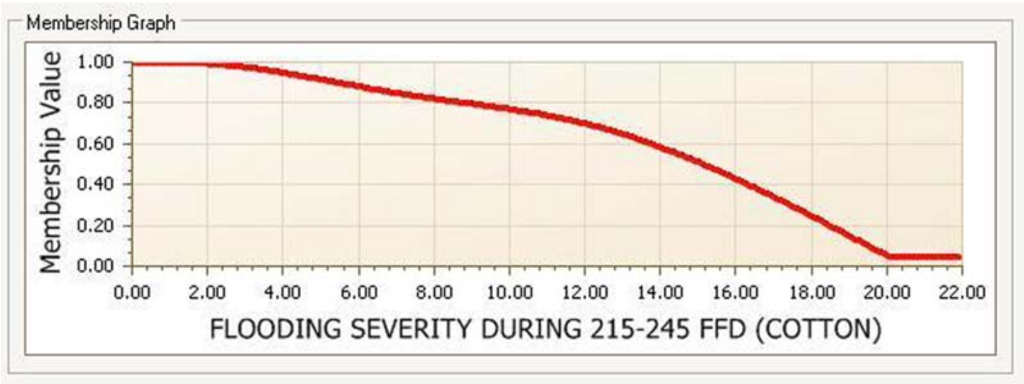
3c5.—Electrical Conductivity Adverse Growth (Cotton) evaluation. Units are mmhos/cm.



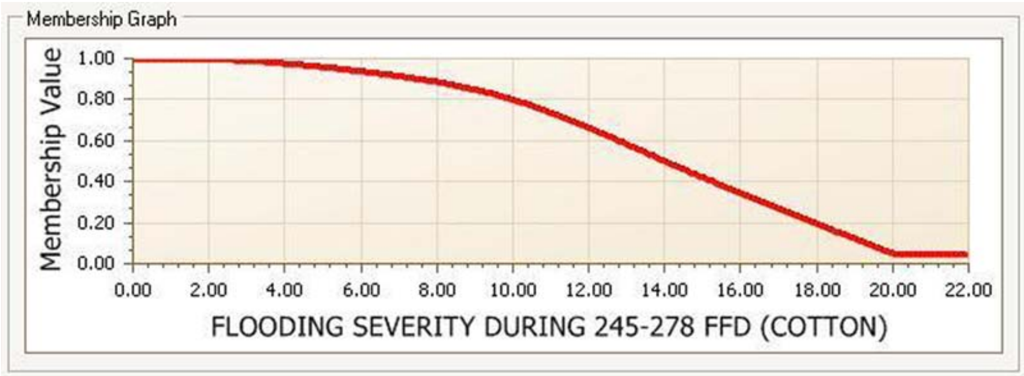
3c6a.—Flooding During <185 FFD evaluation. Units are (days)*(inundations/month)*(months).



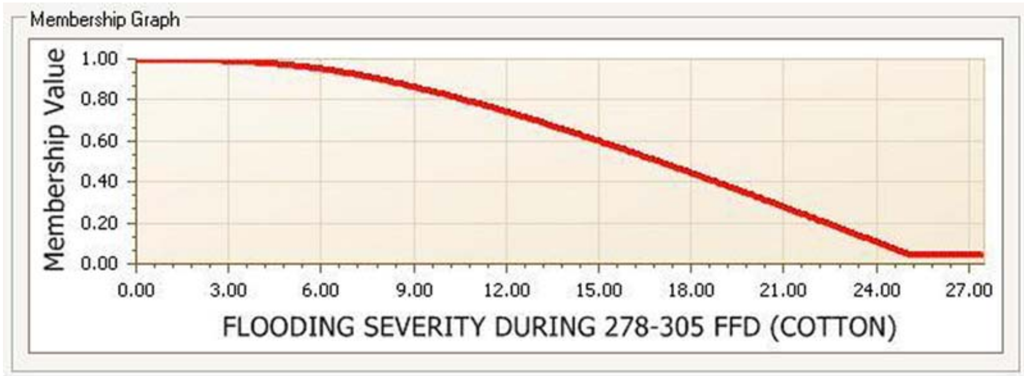
3c6b.—Flooding During 185-215 FFD evaluation. Units are (days)*(inundations/month)*(months).



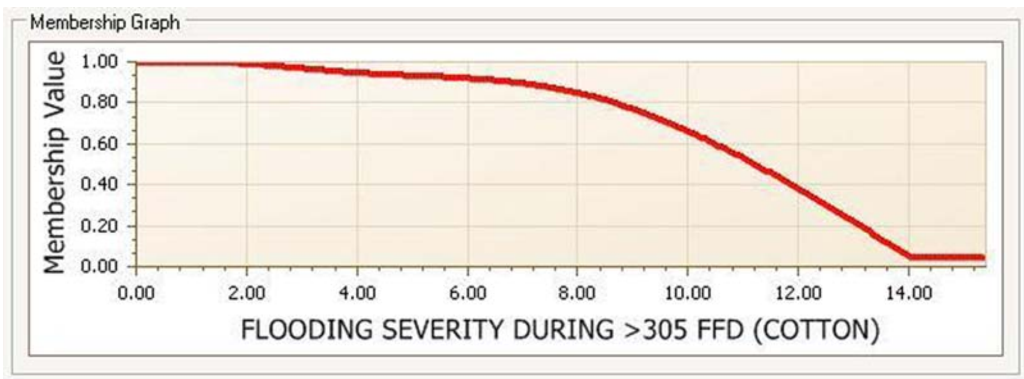
3c6c.—Flooding During 215 to 245 FFD evaluation. Units are (days)*(inundations/month)*(months).



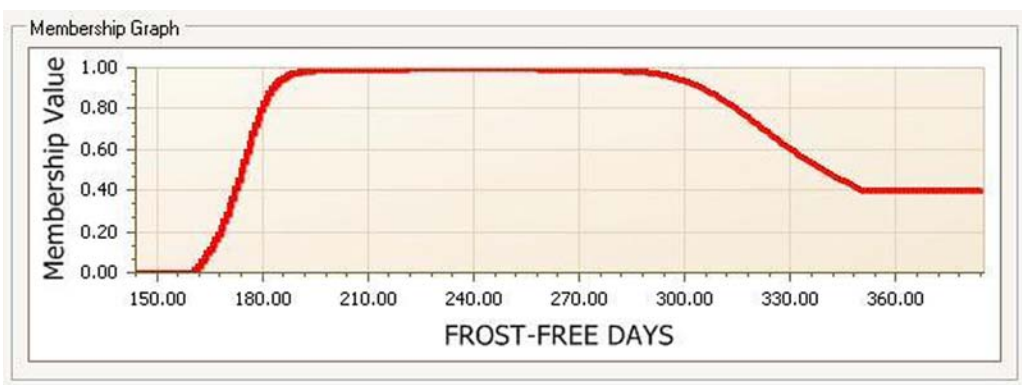
3c6d.—Flooding During 245-278 FFD evaluation. Units are (days)*(inundations/month)*(months).



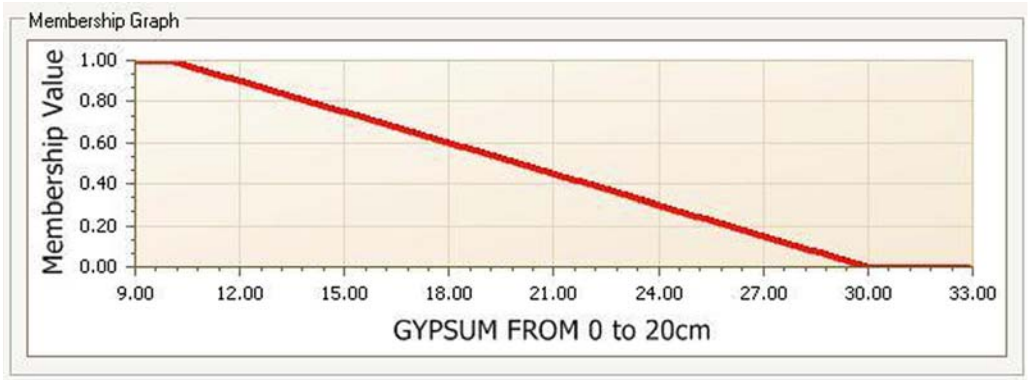
3c6e.—Flooding During the Growing Season evaluation. Units are (days)*(inundations/month)*(months).



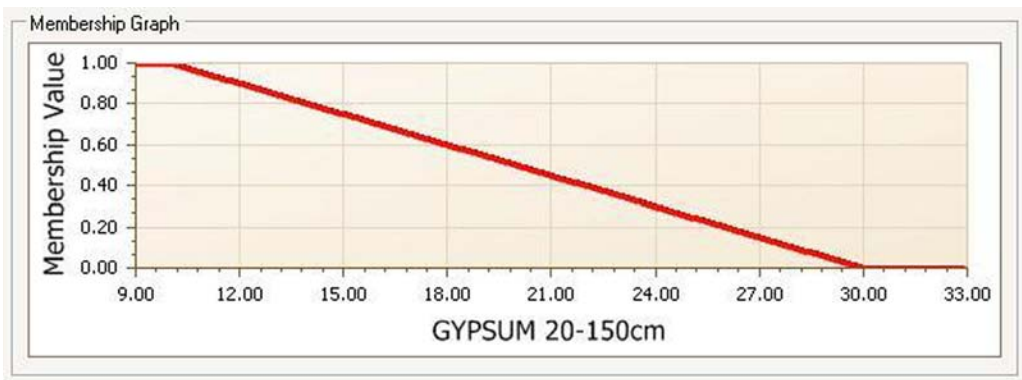
3c6f.—Flooding During the Growing Season evaluation. Units are (days)*(inundations/month)*(months).



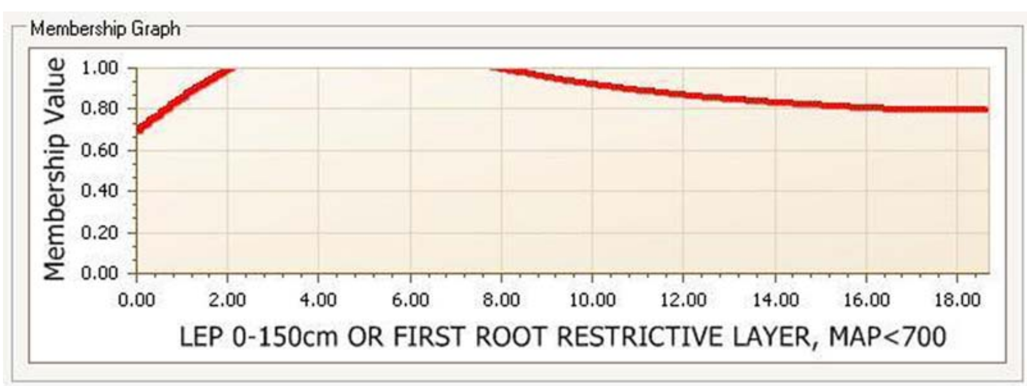
3c7.—Frost-Free Days (Cotton) evaluation. Units are frost-free days/year.



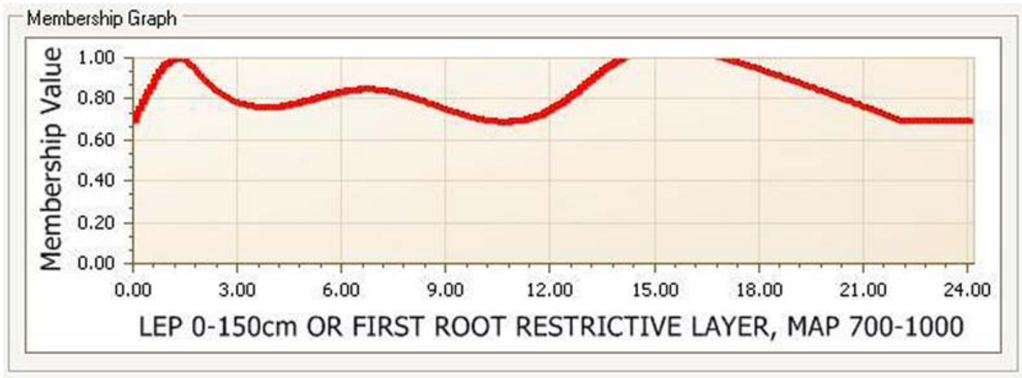
3c8.—Gypsum from 0-20 cm evaluation. Units are percent by weight of the less than 20 mm material.



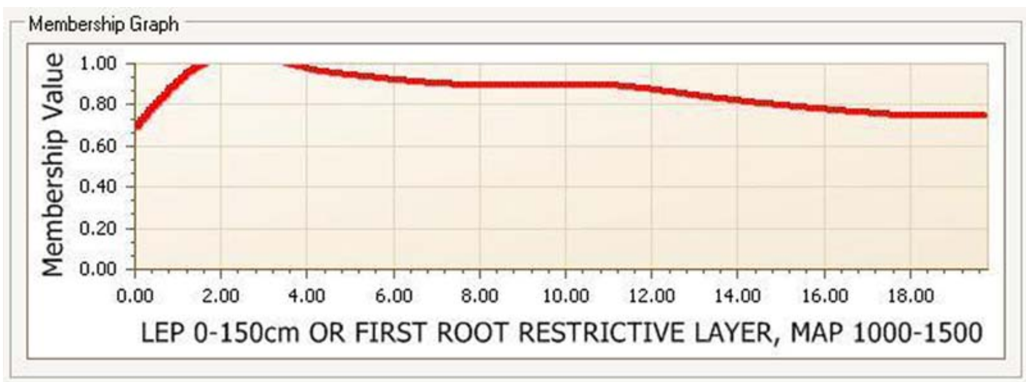
3c9.—Gypsum from 20 to 150 cm evaluation. Units are percent by weight of the less than 20 mm material.



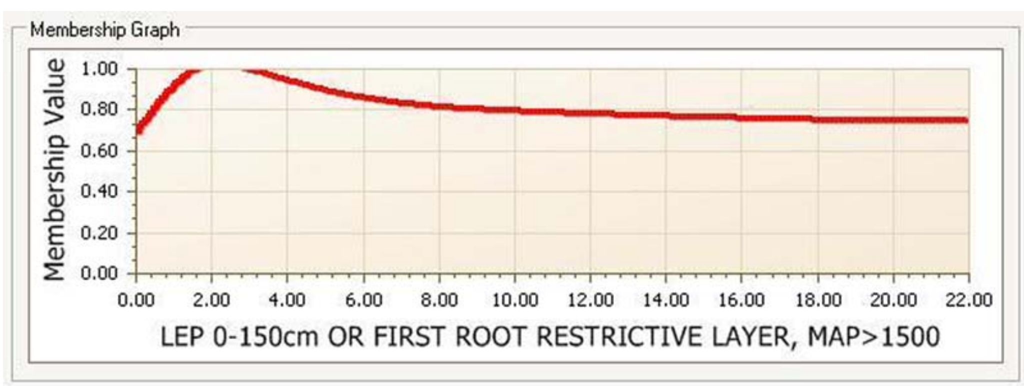
3c10a.—LEP from 0 to 150 cm <700 mm MAP (Cotton) evaluation. Units are cm^3/cm^3.



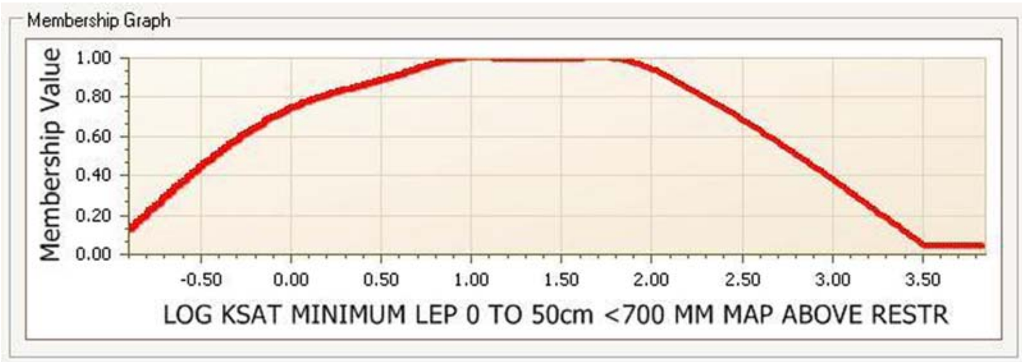
3c10b.—LEP from 0 to 150 cm 700-1000 mm MAP (Cotton) evaluation. Units are cm^3/cm^3.



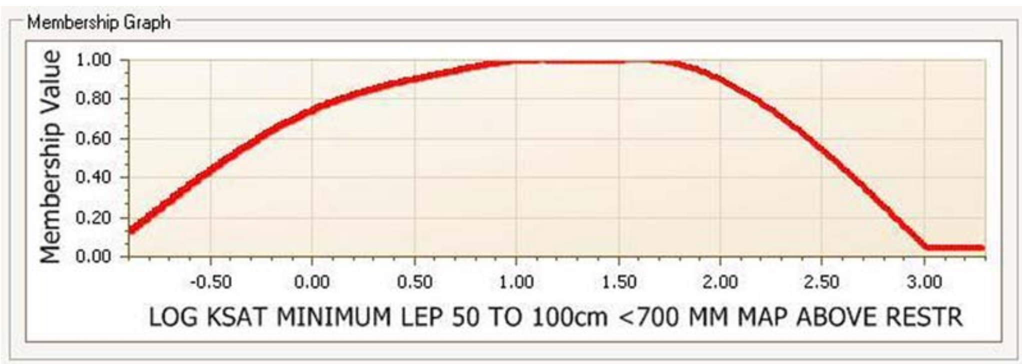
3c10c.—LEP from 0 to 150 cm 1000-1500 mm MAP (Cotton) evaluation. Units are cm^3/cm^3.



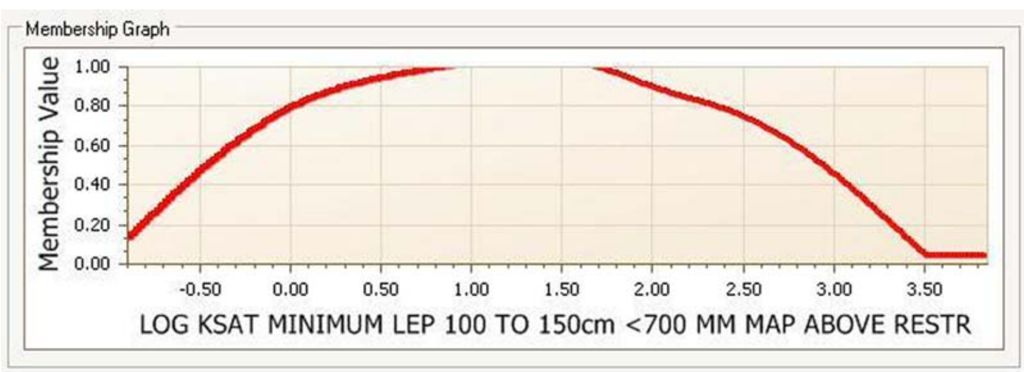
3c10d.—LEP from 0 to 150 cm >1500 mm MAP (Cotton) evaluation. Units are cm^3/cm^3.



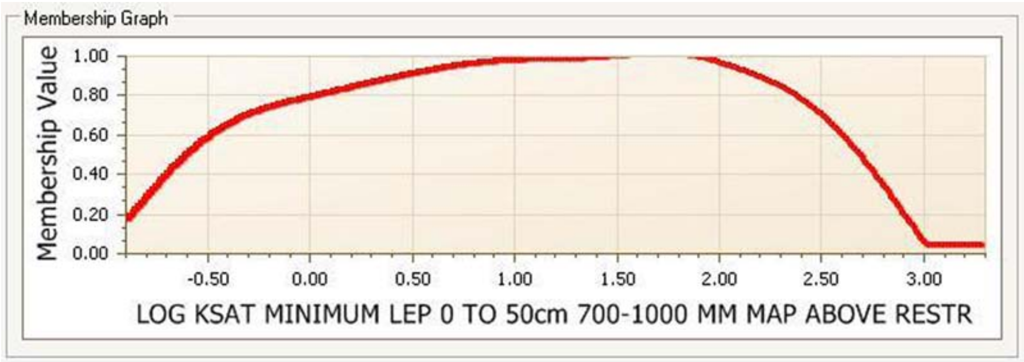
3c11a.—Log (Ksat X LEP) 0-50 cm, MAP <700 mm (Cotton) evaluation. Units are log(μ/sec).



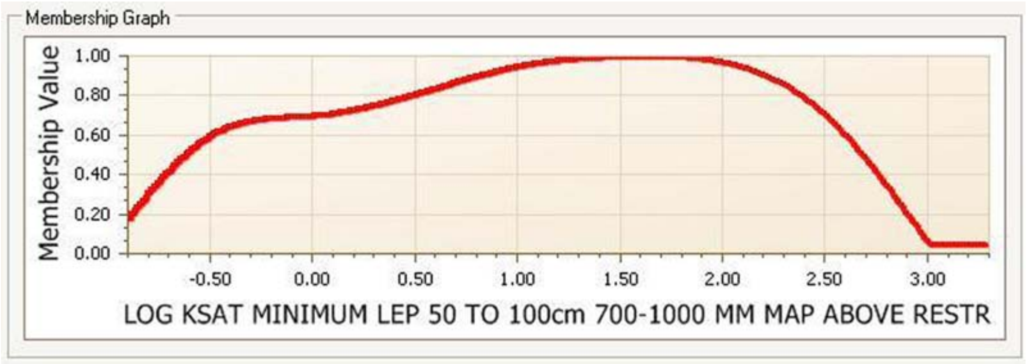
3c11b.—Log (Ksat X LEP) 50-100 cm, MAP <700 mm (Cotton) evaluation. Units are log(μ/sec).



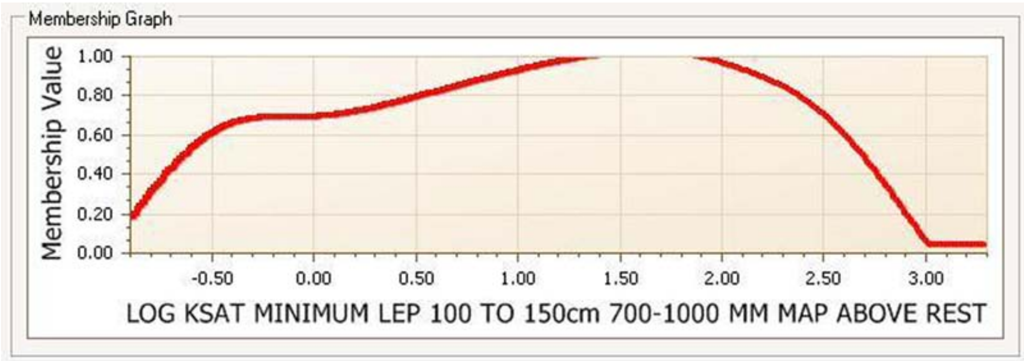
3c11c.—Log (Ksat X LEP) 100-150 cm, MAP <700 mm (Cotton) evaluation. Units are log(μ/sec).



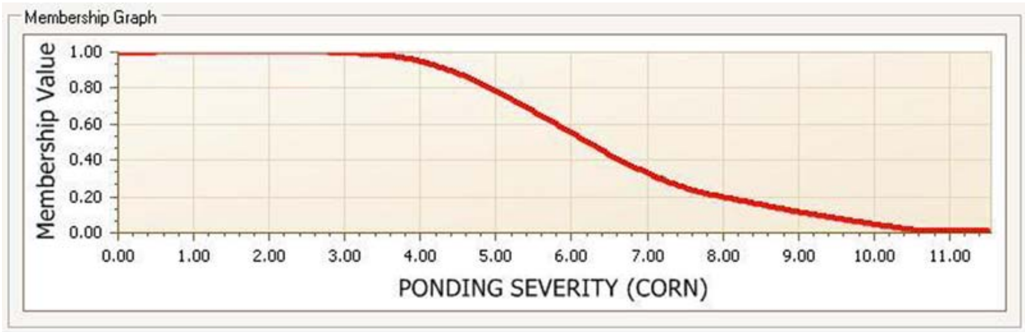
3c11d.—Log (Ksat X LEP) 0-50cm 700-1000 mm MAP (Cotton) evaluation. Units are log(μ/sec).



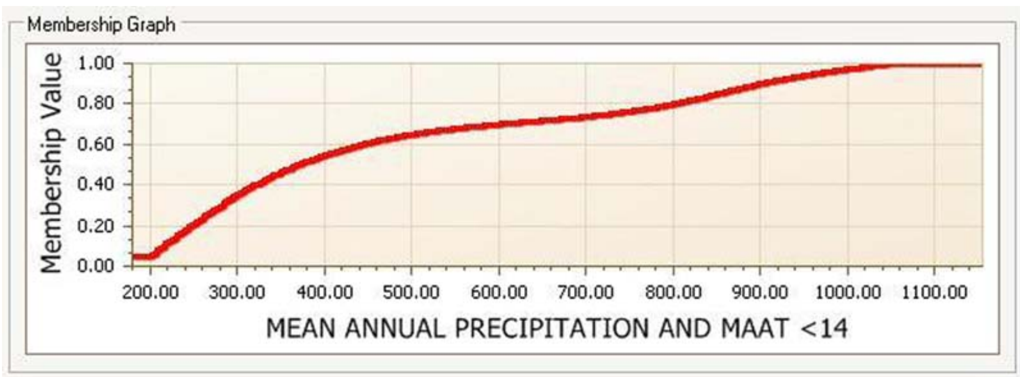
3c11e.—Log (Ksat X LEP) 50-100 cm 700-1000 mm MAP (Cotton) evaluation. Units are log(μ/sec).



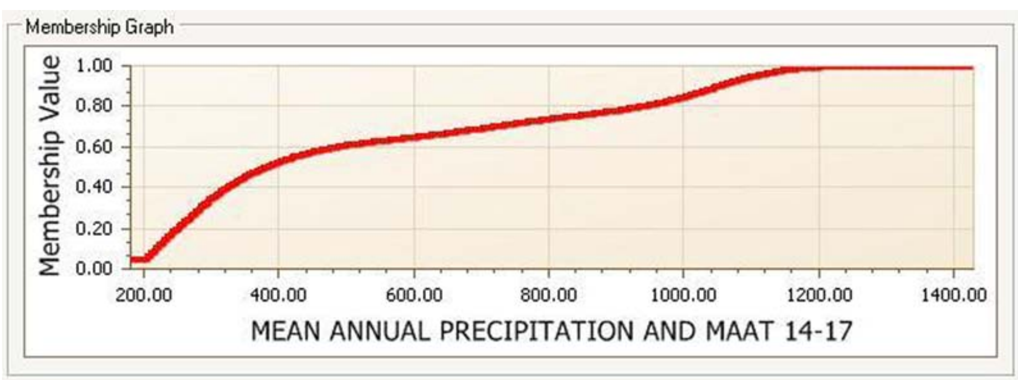
3c11f.—Log (Ksat X LEP) 100-150 cm 700-1000 mm MAP (Cotton) evaluation. Units are log(μ/sec).



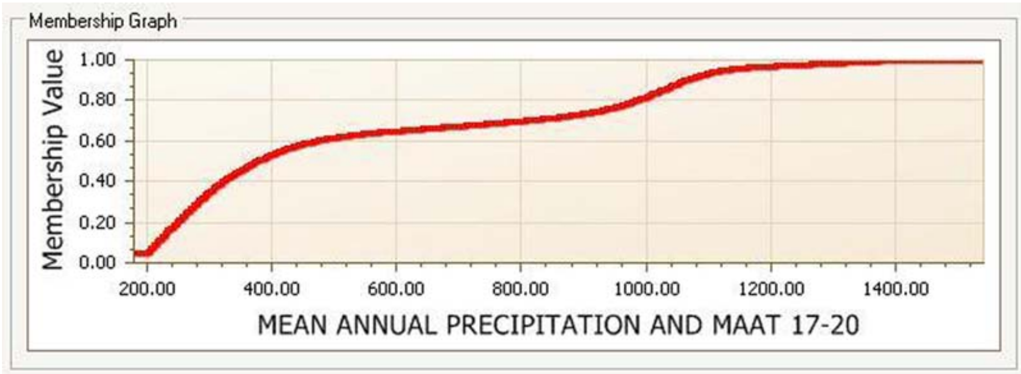
3c12.—Ponding During the Growing Season evaluation. Units are (days)*(inundations)*(months).



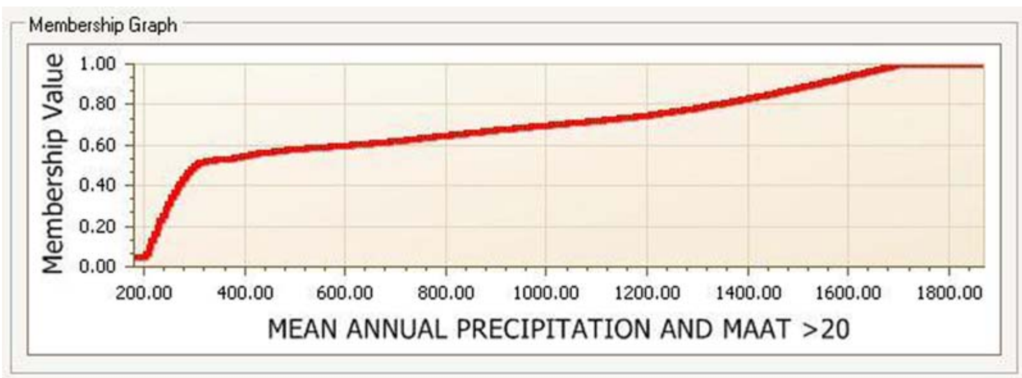
3c13a.—Precipitation (Cotton) and MAAT <14 °C evaluation. Units are mm/year.



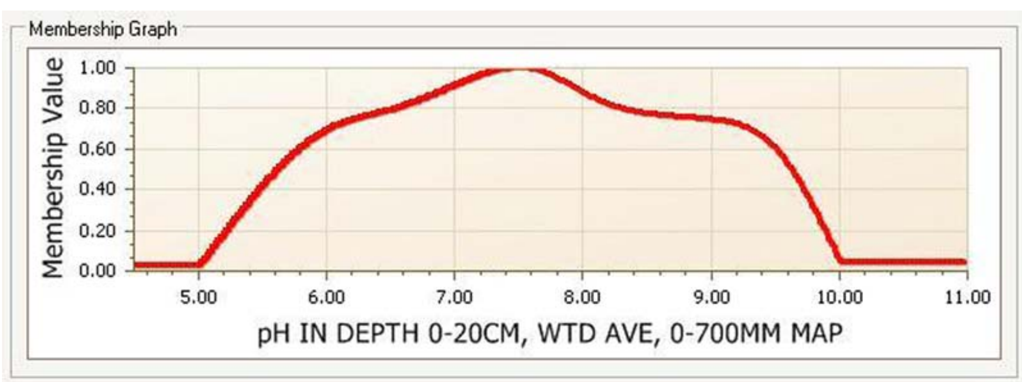
3c13b.—Precipitation (Cotton) and MAAT 14-17 °C evaluation. Units are mm/year.



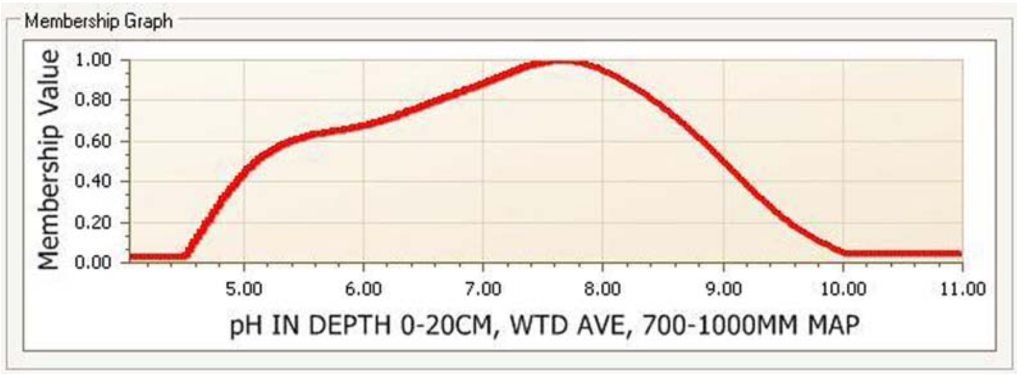
3c13c.—Precipitation (Cotton) and MAAT 17-20 °C evaluation. Units are mm/year.



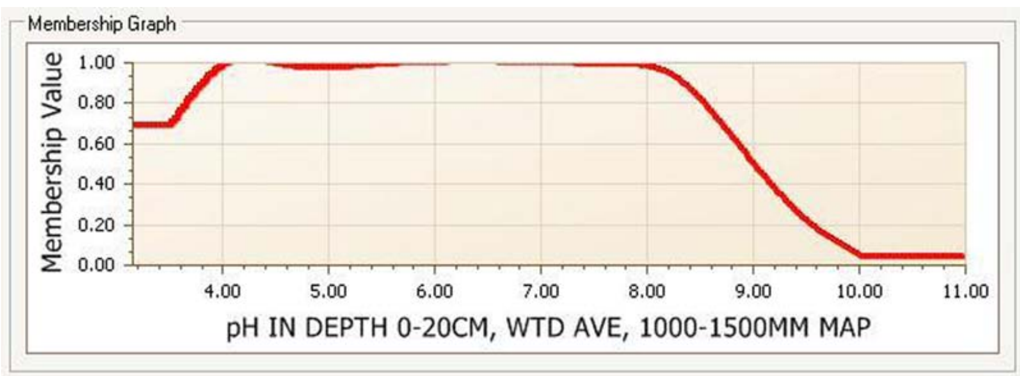
3c13d.—Precipitation (Cotton) and MAAT >20 °C evaluation. Units are mm/year.



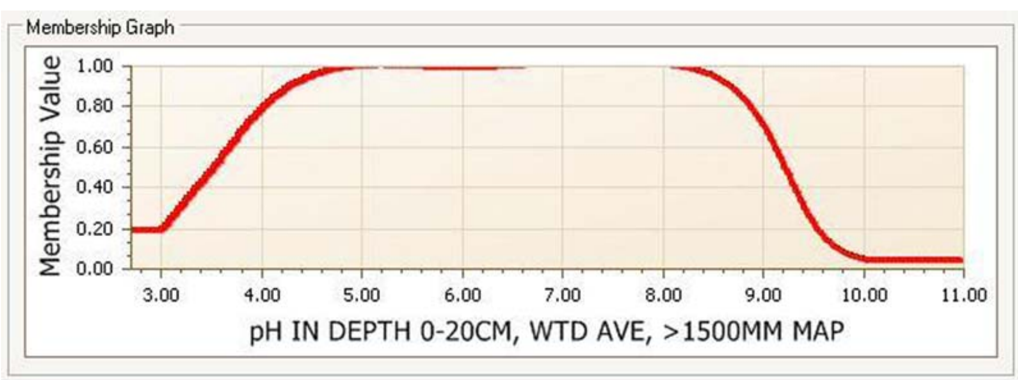
3c14a.—pH 0-20 cm (Cotton), <700 mm MAP evaluation (pH units).



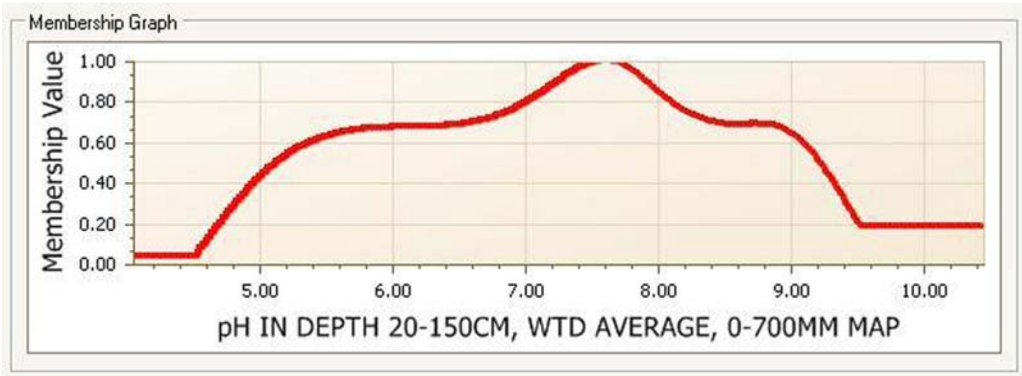
3c14b.—pH 0-20 cm (Cotton), 700-1000 mm MAP evaluation (pH units).



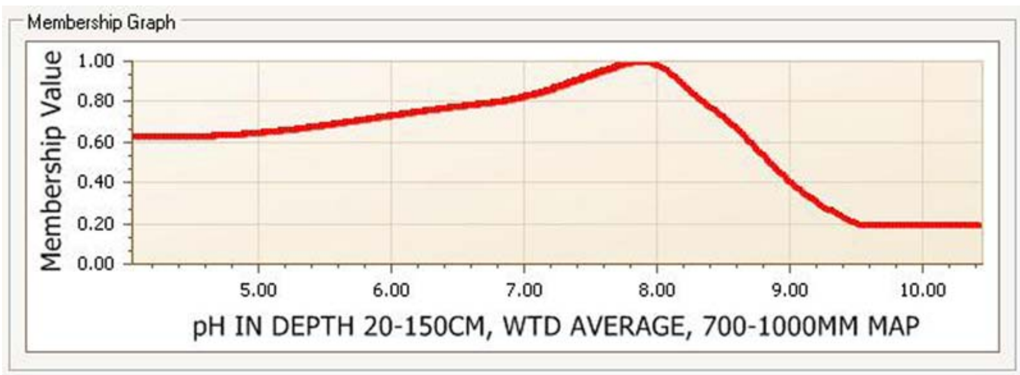
3c14c.—pH 0-20 cm (Cotton), 1000-1500 mm MAP evaluation (pH units).



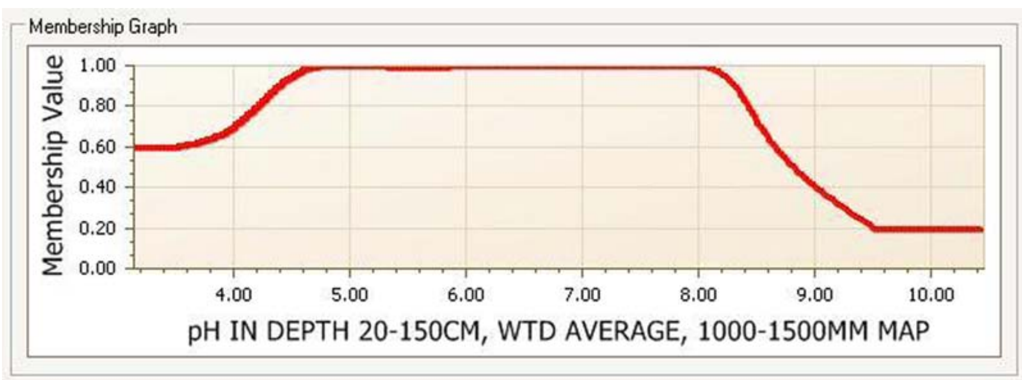
3c14d.—pH 0-20 cm (Cotton), >1500 mm MAP evaluation (pH units).



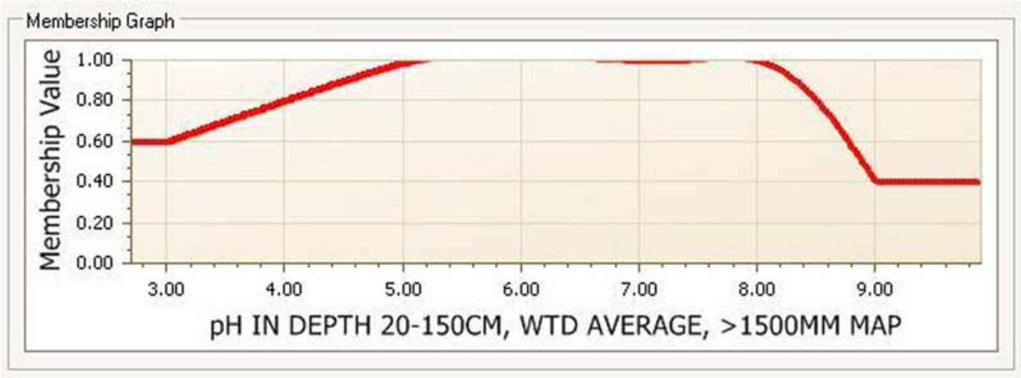
3c15a.—pH 20-150 cm (Cotton), <700 mm MAP evaluation (pH units).



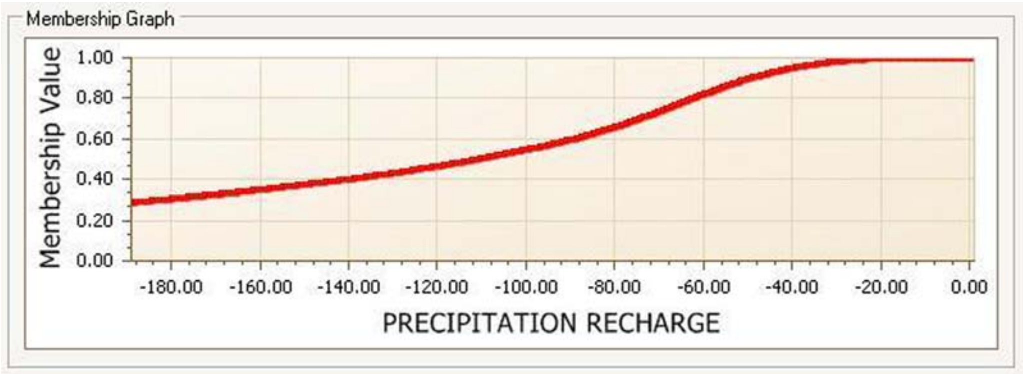
3c15b.—pH 20-150 cm (Cotton), 700-1000 mm MAP evaluation (pH units).



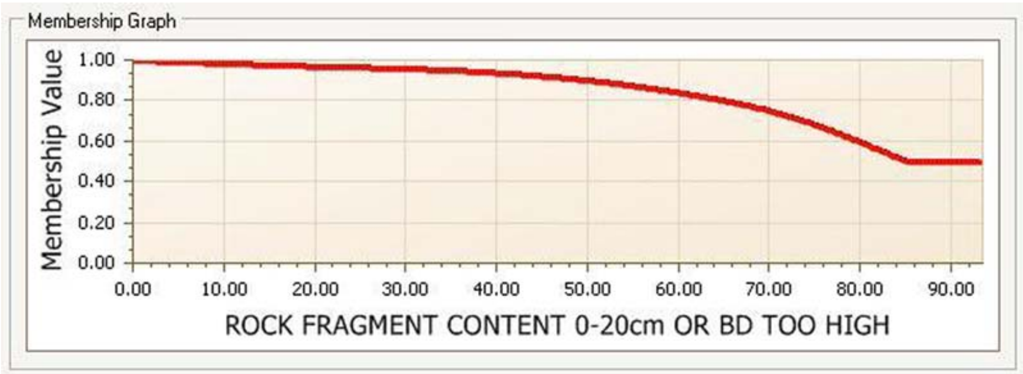
3c15c.—pH 20-150 cm (Cotton), 1000-1500 mm MAP evaluation (pH units).



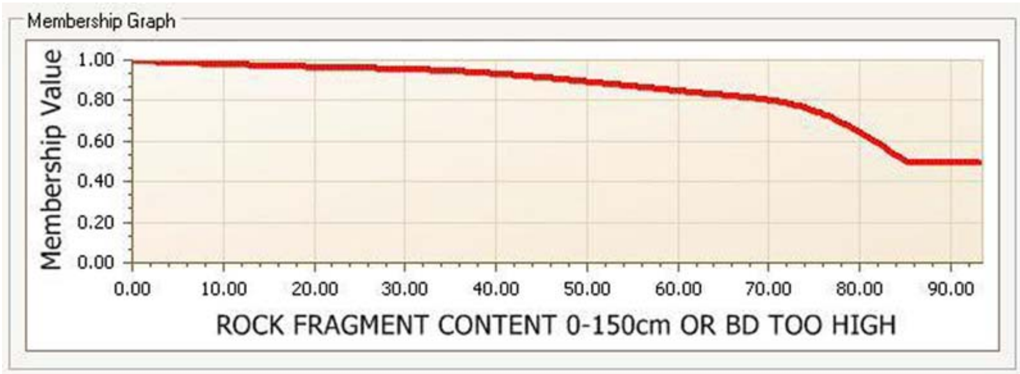
3c15d.—pH 20-150 cm (Cotton), >1500 mm MAP evaluation (pH units).



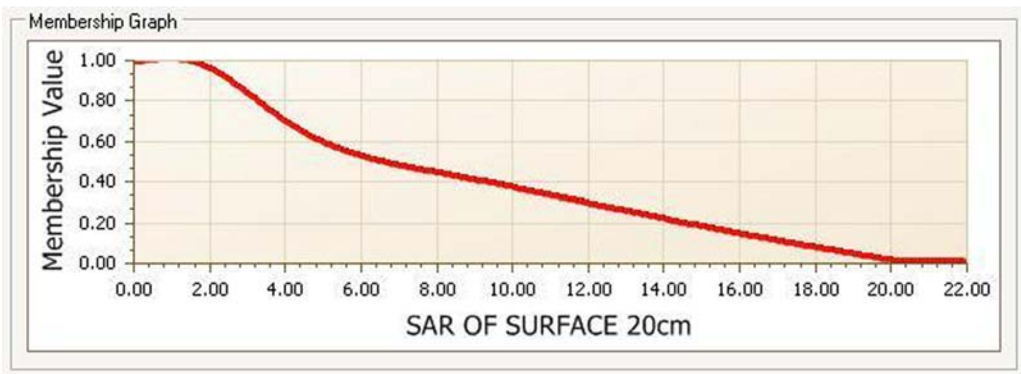
3c16.—Precipitation Recharge (Cotton) evaluation. Units are mm/year.



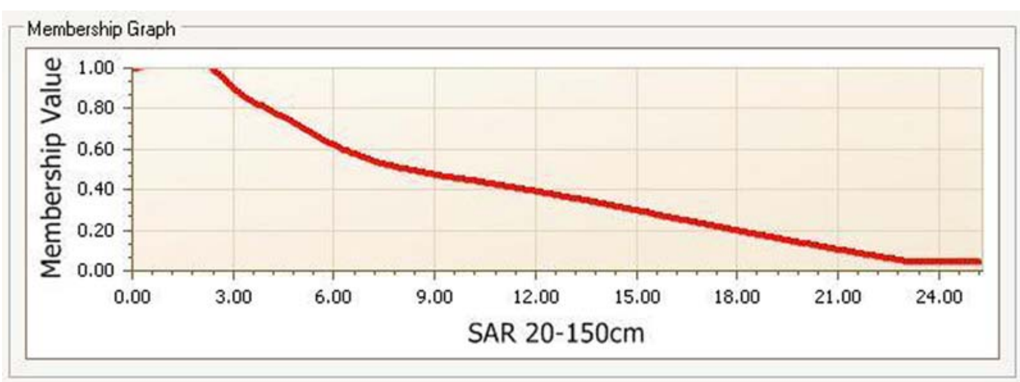
3c17.—Rock fragment volume 0-20 cm evaluation. Units are percent by volume.



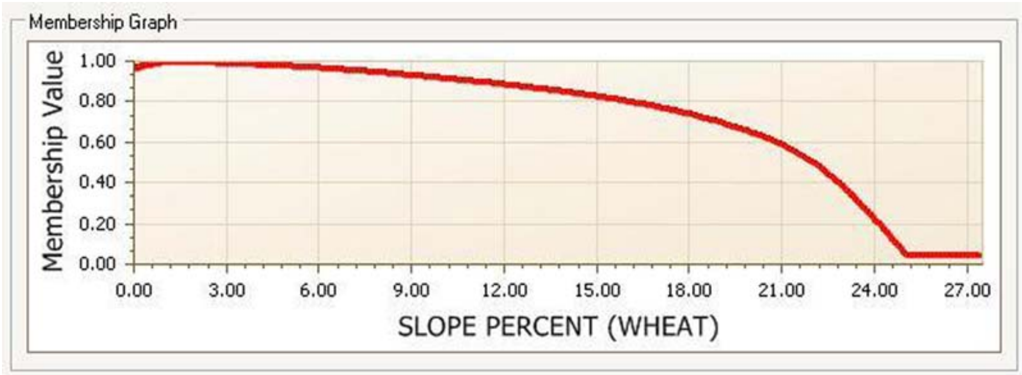
3c18.—Rock fragment volume 20-150 cm evaluation. Units are percent by volume.



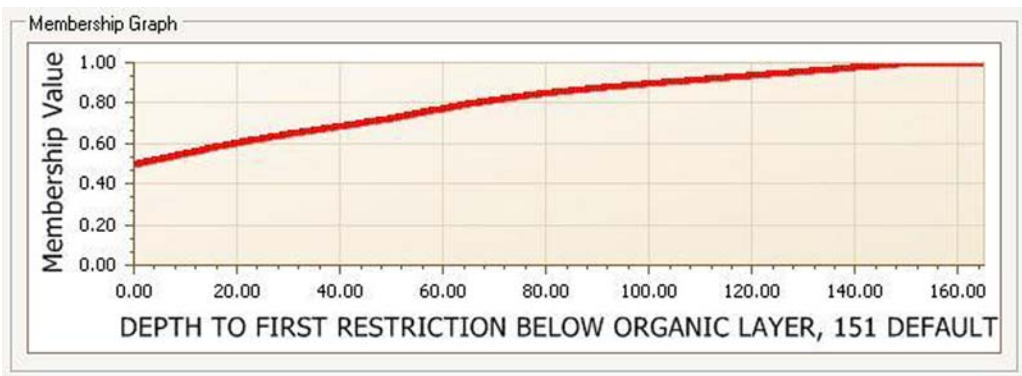
3c19.—SAR 0-20 cm evaluation. SAR is a unitless ratio.



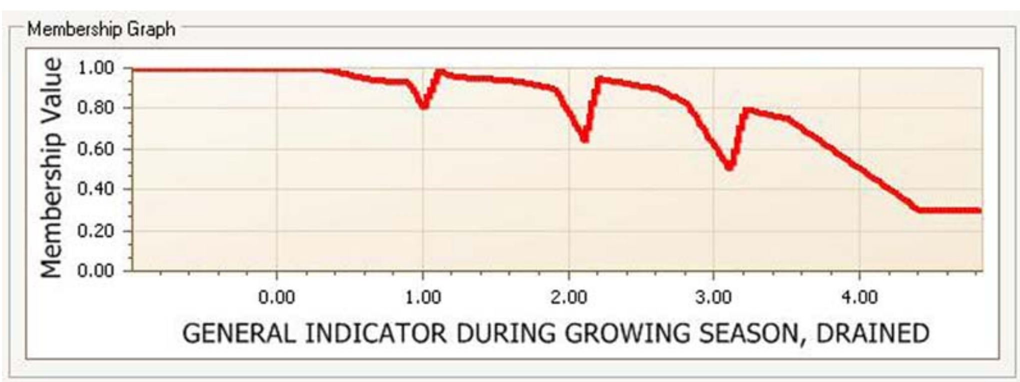
3c20.—SAR 20-150 cm evaluation. SAR is a unitless ratio.



3c21.—Slope (Cotton) evaluation. Units are percent slope.



3c22.—Soil Depth evaluation. Units are cm.



3c23.—Wetness Index During Growing Season (Cotton) evaluation (unitless).

Appendix 4.—Properties With a Possible Result of "Null Not Rated"

The representative value (rv) for each is used in the derivation of the index.

Slope

Map Unit Name

Frost-Free Days

Ksat

Mean Annual Precipitation

Mean Annual Air Temperature

Available Water-Holding Capacity

Bulk Density $^{1}/_{3}$ Bar

Linear Extensibility Percent

Organic Matter

pH 1:1 H_2O or $CaCl_2$

Sodium Adsorption Ratio

Percent Sand, Silt, and Clay

Electrical Conductivity

CEC

Appendix 5.—Root-Limiting Layers in NCCPI

The depth (and therefore volume) of soil that roots can exploit contributes significantly to soil productivity. Many calculations of soil capacity factors, such as AWC and cation-exchange capacity, stop at a root-limiting layer. Recognition of root-limiting layers involves not only physical but also chemical barriers to root growth. NCCPI recognizes four kinds of root-limiting layers. The first kind is the typical root-limiting layers populated in NASIS, including hard bedrock, soft bedrock, a fragipan, a duripan, sulfuric material, and a dense layer. The second kind is a layer having a pH of less than 3.5, and the third is a layer having an electrical conductivity of more than 12. The fourth kind is a possible dense layer determined through an examination of the differential between the populated bulk density of a layer and a theoretical optimum density. If the differential reaches a threshold, then the layer is considered to stop root growth. If no root-restricting zone is identified, a depth of 150 cm is used to approximate the maximum rooting depth.

Appendix 6.—Calculations Used To Manipulate Data

Typically, soil and site data are rated in the evaluations just as they occur in the database. In some cases, however, a more meaningful relationship between soil properties and soil productivity can be derived by combining some attributes or by performing some manipulation of the data. The relationships used in the model generally are the best fit found after a number of candidates have been considered. These cases are examined in this section.

Bulk Density

Bulk density is represented in the database as simply grams per cubic centimeter. Bulk density may limit root growth. A reasonable bulk density for a sandy soil might be 1.5 g/cm^3, and a clayey soil with the same bulk density would exhibit greatly reduced root growth. As a result, the calculation determines the difference between an “ideal” bulk density and the populated bulk density for the combination of sand, silt, and clay populated in the layer. Organic soils are currently considered to have an optimum bulk density.

```
#”idealbd” is a calculated “ideal” bulk density for various combinations of sand, silt,
    and clay.
#”delta” accounts for a sliding scale of differences between ideal and actual bulk
    density at various s, si, &c contents.
#”densrat” is the ratio of the observed density difference to that density difference
    that shows that the density is limiting.
# Sum the Bulk density by horizon and compute weighted average.

define isito       codename(desgnmaster). (identifies organic layers)
define organic     codename(taxorder). (identifies histosols)
define idealbd     (((sandtotal_r*1.75)/100)+((silttotal_r*1.40)/100)+((claytotal
    _r*1.30)/100)).
define delta       ((0.002081*sandtotal_r)+(0.003912*silttotal_r)+0.044351).


define differ      isnull(desgnmaster) then desgnmaster else
                   if isito == “O” then 0 else if
                   isito == “L” then 0 else ((dbthirdbar_r)-(idealbd)).

define densrat     (differ/delta).
define rv1         wtavg(densrat, layer_thickness).

define rv          if isnull(rv1) then rv1 else
                   if organic == “histosols” then 0 else rv1.
```

Cation-Exchange Capacity

Cation-exchange capacity is handled in a way analogous to root zone AWC. It is basically root zone CEC. The density of the layer and the content of rock fragments are accounted for as well as any root-limiting layer.

```
# Determine the depth to the first restrictive layer
DERIVE depth from rv using "NSSC Pangaea":"DEPTH TO FIRST RESTRICTION
    BELOW ORGANIC LAYER".
DERIVE o_thickness from rv using "NSSC Data":"SURFACE ORGANIC HORIZON
    THICKNESS, NOT HISTOSOL".

ASSIGN fragvol_r        REGROUP fragvol_r by hzname aggregate sum.
ASSIGN hzdept_r         REGROUP hzdept_r by hzname aggregate first.
ASSIGN hzdepb_r         REGROUP hzdepb_r by hzname aggregate first.
ASSIGN cec7_r           REGROUP cec7_r by hzname aggregate first.
ASSIGN ecec_r           REGROUP ecec_r by hzname aggregate first.
ASSIGN dbthirdbar_r     REGROUP dbthirdbar_r by hzname aggregate first.
ASSIGN hzname           REGROUP hzname by hzname aggregate first.

ASSIGN ecec_r           ecec_r/.6.

# Find minimum of restriction depth and 151cm.
DEFINE min_depth  depth < 151 and not isnull(depth) ? depth : 151.

# Find the thickness of each horizon between 0-151cm.
define top_in_range     hzdept_r > min_depth ? min_depth : hzdept_r - o_thickness.
define bottom_in_range  hzdepb_r > min_depth ? min_depth : hzdepb_r - o_
    thickness.
define layer_thickness  bottom_in_range - top_in_range.

#Use ecec_r if it is populated, else use cec7_r.
define horcec    ISNULL(cec7_r) then ecec_r else cec7_r.

#If the horizon lacks frags (is null) we want a zero for the horizon frags.
define horfrag    ISNULL(fragvol_r) then 0 else fragvol_r.

#The cec capacity of a horizon, adjusted downward for rock fragment content.
define ceccap    (horcec/100)*(dbthirdbar_r)*(1-(horfrag/100)).

# Compute the total CEC for 1 cm2 x rooting depth volume of the component.
DEFINE rv    arraysum(ceccap * layer_thickness).
```

Saturated Hydraulic Conductivity

Saturated hydraulic conductivity is measured when the soil is saturated by water. In the case of Vertisols, this measurement pushes the Ksat to an unrealistically low level, in terms of what a growing root senses. These soils are expansive and allow aeration and water movement primarily by cracking. A better measure of aeration is provided by multiplying the Ksat by the linear extensibility rather than the Ksat by itself. Using the log10 of the product also helps in graphing a value that crosses several orders of magnitude.

```
# Determine the depth to RESTRICTIVE LAYER.
DERIVE depth from rv using “NSSC Pangaea”:”DEPTH TO FIRST RESTRICTION
    BELOW ORGANIC LAYER”.

#zero ksats cause trouble
ASSIGN ksat_l  ksat_l+.0001.
ASSIGN ksat_r  ksat_r+.0001.
ASSIGN ksat_h  ksat_h+.0001.

#LEP may be null or low
ASSIGN lep_r   if isnull(lep_r) then 1 else if lep_r <= 1 then 1 else lep_r.


define lepksat_r          lep_r*ksat_r.
define lepksat_l          lep_r*ksat_l.
define lepksat_h          lep_r*ksat_h.

# Find minimum of restriction depth and 150cm
DEFINE min_depth  depth < 49 and not isnull(depth) ? depth : 50.
DEFINE in_range   isnull (hzdept_r) ? hzdept_r :
                  (hzdept_r < min_depth ? 1 :0).

# Find the ksat values in the min_depth.
DEFINE low1   arraymin (lookup(1, in_range, lepksat_l)).
DEFINE high1  arraymin (lookup(1, in_range, lepksat_h)).
DEFINE rv1    arraymin (lookup(1, in_range, lepksat_r)).

define low      log10(low1).
define rv       log10(rv1).
define high     log10(high1).
```

Flooding

Flooding presents a problem of duration, frequency, and timing. Flooding during the time of year when the crop is in the ground is detrimental. Flooding while the ground is idle is less detrimental. A month of flooding during a 200-day growing season is less detrimental than a month of flooding during a 90-day growing season. Rare flooding during the growing season is less detrimental than frequent flooding during the growing season. An index that integrates the timing, frequency, and duration of flooding, called Flooding Severity, is used to assess the impact of flooding on productivity. In the following examples, wheat in a 90- to 105-day growing season is the crop of interest.

Flooding Duration

```
FLOODING DURATION CLASS - WHEAT GROWING SEASON, MAX

# Get flooding duration classes

exec sql select floddurcl
from component, comonth
where join component to comonth and
((taxtempregime in (“pergelic”) and comonth.month in (“jul”, “aug”))
or (taxtempregime in (“cryic”) and comonth.month in (“jun”, “jul”, “aug”))
or (taxtempregime in (“frigid”) and comonth.month in (“apr”, “may”, “jun”, “jul”, “aug”,
    “sep”))
or (taxtempregime in (“mesic”) and comonth.month in (“mar”, “apr”, “may”, “jun”,
    “aug”, “sep”, “oct”))
or (taxtempregime in (“thermic”) and comonth.month in (“mar”, “apr”, “may”, “jun”,
    “sep”, “oct”))
or (taxtempregime in (“isothermic”, “isohyperthermic”, “isomesic”) and comonth.
    month in (“feb”, “mar”, “apr”, “may”, “jun”, “sep”, “oct”, “nov”, “dec”))
or (taxtempregime in (“hyperthermic”) and comonth.month in (“feb”, “mar”, “apr”,
    “may”, “jun”, “sep”, “oct”, “nov”, “dec”))
or (taxtempregime in (“isofrigid”) and comonth.month in (“may”, “jun”, “jul”, “sep”,
    “oct”)));

aggregate column floddurcl max.

define rv       ISNULL(floddurcl) then 1 else
                if floddurcl == 1 then 2 else
                if floddurcl == 2 then 3 else
                if floddurcl == 3 then 4 else
                if floddurcl == 4 then 5 else “”.
```

Flooding Frequency

```
FLOODING FREQUENCY CLASS - WHEAT GROWING SEASON, MAX

# Get flooding frequency classes

exec sql select flodfreqcl
from component, comonth
where join component to comonth and
((taxtempregime in (“pergelic”) and comonth.month in (“jul”, “aug”))
or (taxtempregime in (“cryic”) and comonth.month in (“jun”, “jul”, “aug”))
or (taxtempregime in (“frigid”) and comonth.month in (“apr”, “may”, “jun”, “jul”, “aug”,
    “sep”))
or (taxtempregime in (“mesic”) and comonth.month in (“mar”, “apr”, “may”, “jun”,
    “aug”, “sep”, “oct”))
or (taxtempregime in (“thermic”) and comonth.month in (“mar”, “apr”, “may”, “jun”,
    “sep”, “oct”, “nov”))
or (taxtempregime in (“isothermic”, “isohyperthermic”, “isomesic”) and comonth.
    month in (“feb”, “mar”, “apr”, “may”, “jun”, “oct”, “nov”, “dec”))
or (taxtempregime in (“hyperthermic”) and comonth.month in (“feb”, “mar”, “apr”,
    “may”, “jun”, “sep”, “oct”, “nov”, “dec”))
or (taxtempregime in (“isofrigid”) and comonth.month in (“may”, “jun”, “jul”, “sep”,
    “oct”)));.


define freqarray        ISNULL(flodfreqcl) then 1 else
                        if flodfreqcl == 1 then 1 else
                        if flodfreqcl == 5 then 1 else
                        if flodfreqcl == 2 then 1 else
                        if flodfreqcl == 3 then 2 else
                        if flodfreqcl == 4 then 3 else
                        if flodfreqcl == 6 then 4 else “”.


define rv arraymax(freqarray).
```

Months of Flooding During the Growing Season

```
FLOODING DURATION MONTHS - WHEAT GROWING SEASON, MAX

# Get the number of flooding months

exec sql select floddurcl
from component, comonth
where join component to comonth and
((taxtempregime in (“pergelic”) and comonth.month in (“jul”, “aug”))
or (taxtempregime in (“cryic”) and comonth.month in (“jun”, “jul”, “aug”))
or (taxtempregime in (“frigid”) and comonth.month in (“apr”, “may”, “jun”, “jul”, “aug”,
    “sep”))
or (taxtempregime in (“mesic”) and comonth.month in (“mar”, “apr”, “may”, “jun”,
    “aug”, “sep”, “oct”))
or (taxtempregime in (“thermic”) and comonth.month in (“mar”, “apr”, “may”,
    “jun”,”sep”, “oct”, “nov”))
or (taxtempregime in (“isothermic”, “isohyperthermic”, “isomesic”) and comonth.
    month in (“feb”, “mar”, “apr”, “may”, “jun”,  “sep”, “oct”, “nov”, “dec”))
or (taxtempregime in (“hyperthermic”) and comonth.month in (“feb”, “mar”, “apr”,
    “may”, “jun”, “jul”, “aug”, “sep”, “oct”, “nov”, “dec”))
or (taxtempregime in (“isofrigid”) and comonth.month in (“may”, “jun”, “jul”,”sep”,
    “oct”)));

aggregate column floddurcl none.

define wetmo    ARRAYCOUNT(floddurcl).

define rv       isnull(wetmo) ? 0 : wetmo.
```

Flooding Severity

```
exec sql
select mean_annual_frost_free_days_r
from component where ((mean_annual_frost_free_days_r > 90) and (mean_annual_
frost_free_days_r <= 105));.


derive duration from rv using “NSSC Data”:”FLOODING DURATION CLASS -
WHEAT GROWING SEASON, MAX”.
derive frequency from rv using “NSSC Data”:”FLOODING FREQUENCY CLASS -
WHEAT GROWING SEASON, MAX”.
derive months from rv using “NSSC Data”:”FLOODING DURATION MONTHS -
WHEAT GROWING SEASON, MAX”.

define rv1      (duration*frequency*months)/10. (Flooding Severity Calculation)

define rv       isnull(mean_annual_frost_free_days_r) ? mean_annual_frost_free_
days_r : rv1.
```

Ponding

Like flooding, ponding presents a problem of duration, frequency, and timing. Ponding during the time of year when the crop is in the ground is detrimental. Ponding while the ground is idle is less detrimental. A month of ponding during a 200-day growing season is less detrimental than a month of ponding during a 90-day growing season. Rare ponding during the growing season is less detrimental than frequent ponding during the growing season. An index that integrates the timing, frequency, and duration of ponding, called Ponding Severity, is used to assess the impact of ponding on productivity. In the following examples, wheat in a 90- to 105-day growing season is the crop of interest.

Ponding Duration

```
PONDING DURATION CLASS - WHEAT GROWING SEASON, MAX

# Get ponding duration classes

exec sql select ponddurcl
from component, comonth
where join component to comonth and
((taxtempregime in (“pergelic”) and comonth.month in (“jul”, “aug”))
or (taxtempregime in (“cryic”) and comonth.month in (“jun”, “jul”, “aug”))
or (taxtempregime in (“frigid”) and comonth.month in (“apr”, “may”, “jun”, “jul”, “aug”,
    “sep”))
or (taxtempregime in (“mesic”) and comonth.month in (“mar”, “apr”, “may”, “jun”, “jul”,
    “aug”, “sep”, “oct”))
or (taxtempregime in (“thermic”) and comonth.month in (“feb”, “mar”, “apr”, “may”,
    “jun”, “jul”, “aug”, “sep”, “oct”))
or (taxtempregime in (“isothermic”, “isohyperthermic”, “isomesic”) and comonth.
    month in (“jan”, “feb”, “mar”, “apr”, “may”, “jun”, “jul”, “aug”, “sep”, “oct”, “nov”,
    “dec”))
or (taxtempregime in (“hyperthermic”) and comonth.month in (“feb”, “mar”, “apr”,
    “may”, “jun”, “jul”, “aug”, “sep”, “oct”, “nov”, “dec”))
or (taxtempregime in (“isofrigid”) and comonth.month in (“apr”, “may”, “jun”, “jul”,
    “aug”, “sep”, “oct”)));

aggregate column ponddurcl max.

#Convert class to a number

define rv       ISNULL(ponddurcl) then 1 else
                if ponddurcl == 1 then 2 else
                if ponddurcl == 2 then 3 else
                if ponddurcl == 3 then 4 else
                if ponddurcl == 4 then 5 else “”.
```

Ponding Frequency

```
PONDING FREQUENCY CLASS - WHEAT GROWING SEASON, MAX

# Get ponding frequency classes

exec sql select pondfreqcl
from component, comonth
where join component to comonth and
((taxtempregime in (“pergelic”) and comonth.month in (“jul”, “aug”))
or (taxtempregime in (“cryic”) and comonth.month in (“jun”, “jul”, “aug”))
or (taxtempregime in (“frigid”) and comonth.month in (“apr”, “may”, “jun”, “jul”, “aug”,
    “sep”))
or (taxtempregime in (“mesic”) and comonth.month in (“mar”, “apr”, “may”, “jun”,
    “aug”, “sep”, “oct”))
or (taxtempregime in (“thermic”) and comonth.month in (“feb”, “mar”, “apr”, “may”,
    “sep”, “oct”))
or (taxtempregime in (“isothermic”, “isohyperthermic”, “isomesic”) and comonth.
    month in (“jan”, “feb”, “mar”, “apr”, “may”, “jun”, “jul”, “oct”, “nov”, “dec”))
or (taxtempregime in (“hyperthermic”) and comonth.month in (“feb”, “mar”, “apr”,
    “may”, “jun”, “oct”, “nov”, “dec”))
or (taxtempregime in (“isofrigid”) and comonth.month in (“apr”, “may”, “jun”, “jul”,
    “aug”, “sep”, “oct”)));

aggregate column pondfreqcl max.

define rv       ISNULL(pondfreqcl) then 1 else
                if pondfreqcl == 1 then 1 else
                if pondfreqcl == 2 then 2 else
                if pondfreqcl == 3 then 3 else
                if pondfreqcl == 4 then 4 else
                if pondfreqcl == 5 then 5 else 1.
```

Months of Ponding During the Growing Season

```
PONDING DURATION MONTHS - WHEAT GROWING SEASON, MAX

# Get ponding duration classes

exec sql select ponddurcl
from component, comonth
where join component to comonth and
((taxtempregime in (“pergelic”) and comonth.month in (“jul”, “aug”))
or (taxtempregime in (“cryic”) and comonth.month in (“jun”, “jul”, “aug”))
or (taxtempregime in (“frigid”) and comonth.month in (“apr”,”may”, “jun”, “jul”, “aug”,
    “sep”))
or (taxtempregime in (“mesic”) and comonth.month in (“mar”, “apr”, “may”, “jun”, “jul”,
    “aug”, “sep”, “oct”))
or (taxtempregime in (“thermic”) and comonth.month in (“feb”, “mar”, “apr”, “may”,
    “jun”, “jul”, “aug”, “sep”, “oct”))
or (taxtempregime in (“isothermic”, “isohyperthermic”, “isomesic”) and comonth.
    month in (“jan”, “feb”, “mar”, “apr”, “may”, “jun”, “jul”, “aug”, “sep”, “oct”, “nov”,
    “dec”))
or (taxtempregime in (“hyperthermic”) and comonth.month in (“feb”, “mar”, “apr”,
    “may”, “jun”, “jul”, “aug”, “sep”, “oct”, “nov”, “dec”))
or (taxtempregime in (“isofrigid”) and comonth.month in (“apr”, “may”, “jun”, “jul”,
    “aug”, “sep”, “oct”)));

aggregate column ponddurcl none.

define wetmo    ARRAYCOUNT(ponddurcl).

define rv       isnull(wetmo) ? 0 : wetmo.
```

Ponding Severity

```
exec sql
select mean_annual_frost_free_days_r
from component where ((mean_annual_frost_free_days_r > 90) and (mean_annual_
    frost_free_days_r <= 105));.


derive duration from rv using “NSSC Data”:”PONDING DURATION CLASS - WHEAT
    GROWING SEASON, MAX”.
derive frequency from rv using “NSSC Data”:”PONDING FREQUENCY CLASS -
    WHEAT GROWING SEASON, MAX”.
derive months from rv using “NSSC Data”:”PONDING DURATION MONTHS -
    WHEAT GROWING SEASON, MAX”.

define rv1      (duration*frequency*months)/10.
define rv       isnull(mean_annual_frost_free_days_r) ? mean_annual_frost_free_
days_r : rv1.
```

Water Tables

Water table depth, duration, and timing are synthesized into a single number called the “General Indicator of Soil Wetness” for various lengths of growing season.

```
exec sql
select comonth.month, soimoistdept_r, coiid, localphase, otherph
from component, comonth, cosoilmoist
where join component to comonth and
join comonth to cosoilmoist and
soimoiststat in (“wet”)
and (taxtempcl in (“hypergelic”, “pergelic”, “subgelic”)
and (comonth.month in (“jul”, “aug”))
or (taxtempregime in (“thermic”)
and comonth.month in (“feb”, “mar”, “apr”, “may”, “jun”, “jul”, “aug”, “sep”, “oct”))
or (taxtempregime in (“mesic”)
and comonth.month in (“mar”, “apr”, “may”, “jun”, “jul”, “aug”, “sep”, “oct”))
or (taxtempregime in (“cryic”)
and comonth.month in (“jun”, “jul”, “aug”))
or (taxtempregime in (“frigid”, “isofrigid”)
and comonth.month in (“may”, “jun”, “jul”, “aug”, “sep”))
or (taxtempregime in (“hyperthermic”)
and comonth.month in (“feb”, “mar”, “apr”, “may”, “jun”, “jul”, “aug”, “sep”, “oct”, “nov”,
    “dec”))
or (taxtempregime in (“isothermic”, “isohyperthermic”, “isomesic”)
and comonth.month in (“jan”, “feb”, “mar”, “apr”, “may”, “jun”, “jul”, “aug”, “sep”, “oct”,
    “nov”, “dec”)));
aggregate column coiid none, comonth.month none, soimoistdept_r none.

define wetdepth_r       if isnull(soimoistdept_r) then soimoistdept_r else if
                        (localphase imatches “drained*”)then 160 else
soimoistdept_r.

define monthindex       if isnull(soimoistdept_r) then .08 else
                        if wetdepth_r < 15 then 1888 else
                        if ((wetdepth_r >=15)and(wetdepth_r <50)) then 157 else
                        if ((wetdepth_r >=50)and(wetdepth_r <100)) then 13 else
                        if ((wetdepth_r >=100)and(wetdepth_r <200)) then 1 else
                        if wetdepth_r >= 200 then .08 else 0.08.

define yearindex        arraysum(monthindex).
define rv               log10(yearindex).
```

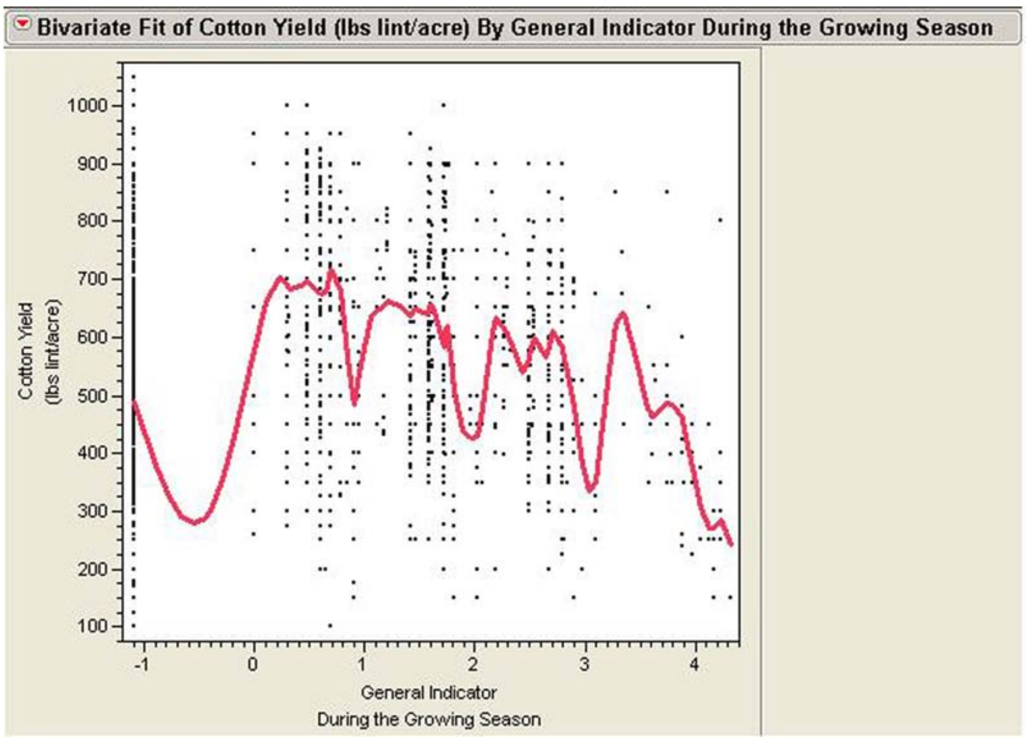
An instance of saturation during the growing season at a depth is given a rating according to this table:

Saturation depth (cm)	*Monthly Rating*
>200cm	0.08
100-200	1.0
50-100	13
15-50	157
0-15	1888

The monthly ratings are summed to calculate the yearly index, and the logarithm of the yearly index is the indicator of soil wetness. Thus a soil that does not become saturated within depth of 200 cm during a 6-month growing season would have an index of:

$$\text{Log}_{10}(6*0.08)=-0.319.$$

This index was developed to create a relatively simple way to sum the depths of the water tables (actually, the thickness of dry soil) over time without getting the same result for several moderately wet months as for one very wet month. A soil that is saturated to the surface for 2 months of a 7-month growing season but is otherwise dry returns an index of 3.58, whereas a soil that is saturated at a depth of 75 cm for the entire 7-month growing season returns an index of 1.96. Depending on the physiology of the crop and on its required length of growing season, an index of 1.96 may be more limiting than an index of 3.58, and the associated evaluation can be constructed to indicate that relationship. The evaluations using the General Indicator often have a "sawtooth" look (see 3a31, for example).



Plot of cotton yield versus the General Indicator.

The figure above shows a spline curve fitted through cotton yield plotted against the General Indicator. The fine structure of the curve shows the relationship of increasing wetness to yield even while the water table is relatively deep. This curve was used to create the evaluation depicted in 3c22.

Precipitation Recharge

Different crops have differing water-use patterns. Small grains are sufficiently different from corn, cotton, and soybeans for the relatively insensitive data available in NASIS to allow a different calculation of the effect of rainfall during the growing season.

Small Grains, Primarily Fall Sown

```
exec sql
select mean_annual_precipitation_r precip, mean_annual_air_temperature_r temp,
      taxsuborder, taxsubgrp

from component;.

derive xericclim from rv using “NSSC Data”:”XERIC CLIMATE”.

define recharge          ((precip-(300+(2*temp)))-(3*(temp**2)))/10.

define xercharg          ((precip-(300+(temp)))-(2*(temp**2)))/10.

define rv         isnull(recharge) then recharge else
                  if xericclim == “Y” then xercharg else recharge.

define low        isnull(recharge) then recharge else
                  if xericclim == “Y” then xercharg else recharge.

define high       isnull(recharge) then recharge else
                  if xericclim == “Y” then xercharg else recharge.
```

Corn, Cotton, Soybeans

```
exec sql
select mean_annual_precipitation_r precip, mean_annual_air_temperature_r temp,
      taxsuborder, taxsubgrp

from component;.

define recharge          ((precip-(300+(2*temp)))-(3*(temp**2)))/10.

define rv         isnull(recharge) then recharge else
                  if taxsuborder matches “*xeri*” then 0 else
                  if taxsubgrp matches “*xer*” then 0 else recharge.
```

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Storie, R.E. 1978. Storie index soil rating (revised). Special Publication 3203, Division of Agricultural Science, University of California, Berkeley.

Thornthwaite, C.W. 1948. An approach toward a rational classification of climate. Geographic Review 38: 55–94.

Glossary

Available water capacity (AWC). The capacity of soils to hold water available for use by most plants. It is commonly defined as the difference between the amount of soil water at field moisture capacity and the amount at wilting point. It is commonly expressed as inches of water per inch of soil. The capacity, in inches, in a 60-inch profile or to a limiting layer is expressed as:

Very low	0 to 3
Low	3 to 6
Moderate	6 to 9
High	9 to 12
Very high	more than 12

Bulk density. Soil bulk density is the ratio of the mass of dry solids to the bulk volume of the soil occupied by those dry solids. Bulk density is an important site characterization parameter because it varies with the structural condition of the soil, particularly that related to packing.

Cation-exchange capacity (CEC). The total amount of exchangeable cations that can be held by the soil, expressed in terms of milliequivalents per 100 grams of soil at neutrality (pH 7.0) or at some other stated pH value. The term, as applied to soils, is synonymous with base-exchange capacity but is more precise in meaning.

Clay. As a soil separate, the mineral soil particles less than 0.002 millimeter in diameter. As a soil textural class, soil material that is 40 percent or more clay, less than 45 percent sand, and less than 40 percent silt.

Electrical conductivity. A measure of the concentration of water-soluble salts in soils. It is used to indicate saline soils. High concentrations of neutral salts, such as sodium chloride and sodium sulfate, may interfere with the absorption of water by plants because the osmotic pressure in the soil solution is nearly as high as or higher than that in the plant cells. Salts may also interfere with the exchange capacity of nutrient ions, thereby resulting in nutritional deficiencies in plants.

Frost-free days. The expected number of days between the last freezing temperature (0 degrees C) in spring (January-July) and the first freezing temperature in fall (August-December). The number of days is based on the probability that the values for the standard “normal” period of 1971 to 2000 will be exceeded in 5 years out of 10.

Fuzzy system. A method of modeling that uses the degree of membership in a set as a membership function between 0 and 1 to quantify the impact of independent variables on dependent variables. This method is particularly useful when complex nonlinear relationships are modeled.

Gypsum. A mineral that is partially soluble in water and can be dissolved and removed by water. Soils with more than 10 percent gypsum may collapse if the gypsum is removed by percolating water. Dissolved gypsum reduces the amount of water available to plants by increasing the osmotic pressure of the soil solution.

Linear extensibility percentage (LEP). Refers to the change in length of an unconfined clod as moisture content is decreased from a moist to a dry state. Linear extensibility is used to determine the shrink-swell potential of soils. It is an expression of the volume change between the water content of the clod at $^1/_3$- or

$^{1}/_{10}$-bar tension (33-kPa or 10-kPa tension) and oven dryness. Volume change is influenced by the amount and type of clay minerals in the soil. The volume change is the percent change for the whole soil. If it is expressed as a fraction, the resulting value is COLE, coefficient of linear extensibility.

Loess. Material transported and deposited by wind and consisting dominantly of silt-sized particles.

Miscellaneous area. A kind of map unit that has little or no natural soil and supports little or no vegetation.

Organic matter. Plant and animal residue in the soil in various stages of decomposition. The content of organic matter in the surface layer is described as follows:

Very low	less than 0.5 percent
Low	0.5 to 1.0 percent
Moderately low	1.0 to 2.0 percent
Moderate	2.0 to 4.0 percent
High	4.0 to 8.0 percent
Very high	more than 8.0 percent

Parent material. The unconsolidated organic and mineral material in which soil forms.

pH value. A numerical designation of acidity and alkalinity in soil.

Ponding. Standing water on soils in closed depressions. Unless the soils are artificially drained, the water can be removed only by percolation or evapotranspiration.

Productivity, soil. The capability of a soil for producing a specified plant or sequence of plants under specific management.

Rock fragments. Rock or mineral fragments having a diameter of 2 millimeters or more; for example, pebbles, cobbles, stones, and boulders.

RZ AWC. Available water capacity in the root zone.

Sand. As a soil separate, individual rock or mineral fragments from 0.05 millimeter to 2.0 millimeters in diameter. Most sand grains consist of quartz. As a soil textural class, a soil that is 85 percent or more sand and not more than 10 percent clay.

Saturated hydraulic conductivity (Ksat). The quality of the soil that enables water to move through the profile. Ksat is the reciprocal of the resistance of soil to water movement. As the resistance increases, the hydraulic conductivity decreases. Resistance to water movement in saturated soil is primarily a function of the arrangement and size distribution of pores.

Silt. As a soil separate, individual mineral particles that range in diameter from the upper limit of clay (0.002 millimeter) to the lower limit of very fine sand (0.05 millimeter). As a soil textural class, soil that is 80 percent or more silt and less than 12 percent clay.

Slope. The inclination of the land surface from the horizontal. Percentage of slope is the vertical distance divided by horizontal distance, then multiplied by 100. Thus, a slope of 20 percent is a drop of 20 feet in 100 feet of horizontal distance.

Sodium adsorption ratio (SAR). A measure of the amount of sodium (Na) relative to calcium (Ca) and magnesium (Mg) in the water extract from saturated soil paste. It is the ratio of the Na concentration divided by the square root of one-half of the Ca + Mg concentration.

Water-gathering surface. A concave part of the landscape where runoff can accumulate.

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