



United States  
Department of  
Agriculture



Natural  
Resources  
Conservation  
Service

# User Guide for the National Commodity Crop Productivity Index (NCCPI) Version 3.0, 2022



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## **Cover Images**

Clockwise from upper left: Corn, soybeans, and wheat fields and harvesting of cotton. Photos courtesy of USDA-FPAC Business Center.

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# Preface

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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, which provides data to the public interfaces Web Soil Survey and Soil Data Access. It presently pertains to only nonirrigated crops. Eventually, it will be expanded to include irrigated crops, rangeland, and forestland productivity.

The NCCPI, version 3.0, 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 rule-based, fuzzy logic 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. For example, extreme erosion, compaction, land leveling, and salinization could cause such changes.

Traditional steps in creating soil survey interpretations are:

1. Study an array of soils having known, documented performance.
2. Construct conceptual and mathematical relationships that predict soil performance.
3. Use the National Cooperative Soil Survey (NCSS) soil database (NASIS) to generate predictions on a wider array of soils.
4. Test 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 to rate 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.

The NASIS database provides information and soil data for nearly all 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, soil parent material, and taxonomic classes.

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.

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.

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.

As the NCCPI continues in development 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 better understood, new information will be added and used to refine aspects of the model.

## **Present Applicability**

In version 3.0 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 in 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.



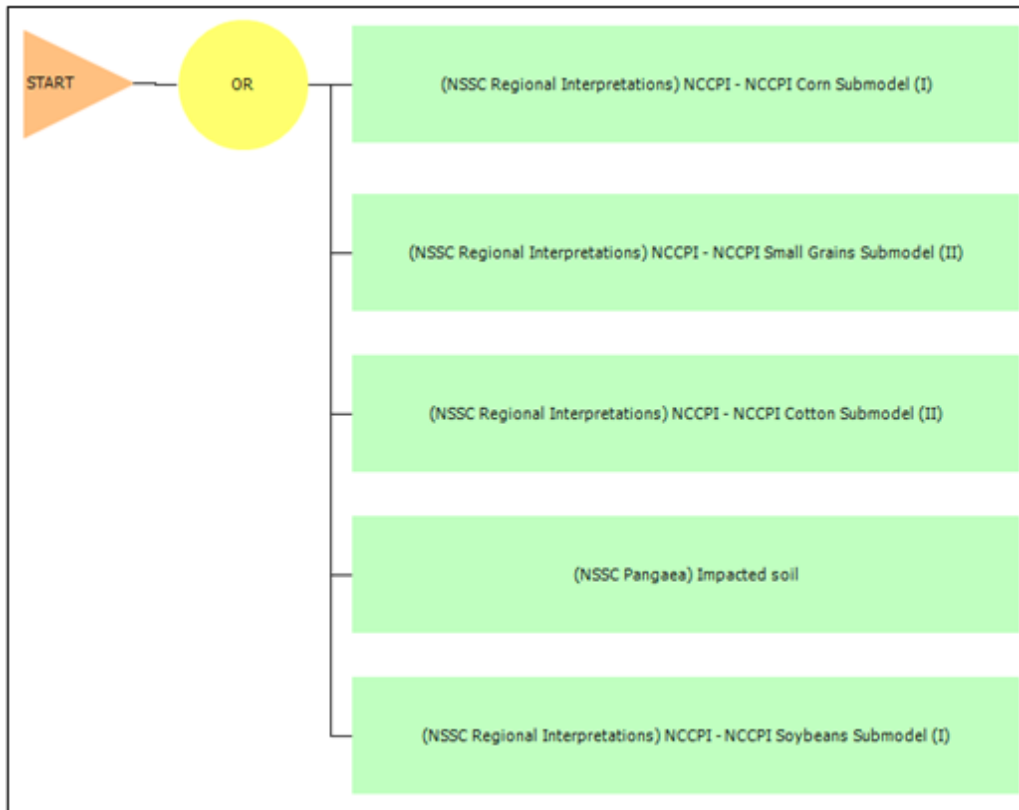


# User Guide for the National Commodity Crop Productivity Index (NCCPI), Version 3.0

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The National Commodity Crop Productivity Index is a national interpretation in the National Soil Information System (NASIS). It is not intended to replace models that are developed and maintained by individual States, such as the Iowa Corn Suitability Rating or the Storie Index. 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 rule-based fuzzy logic system 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.



**Figure 1.—The main model of NCCPI, version 3.0.**

The structure of the model consists of four 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 four 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 four current submodels (categories) are Corn, Soybeans, Small Grains, and Cotton. These categories represent four major divisions of commodity crops, in terms of climatic, landscape, and soil adaptation. Each of the four submodels will be examined in this publication. While the overall look of the four submodels is similar, the inner workings are somewhat different.

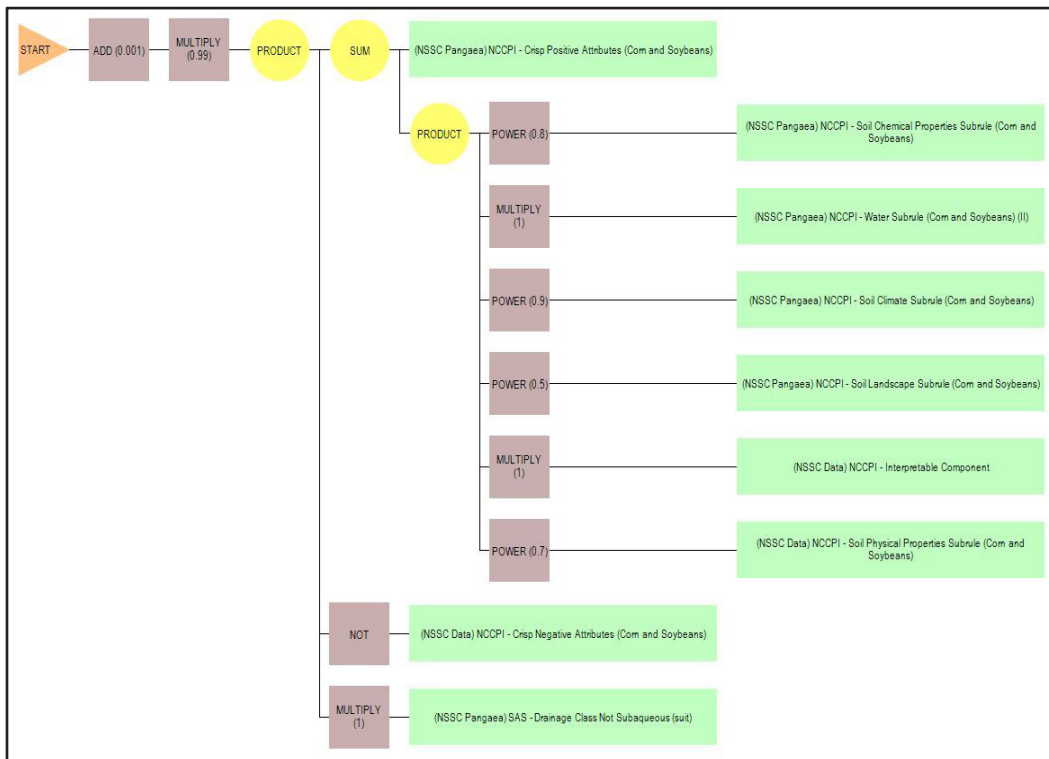
A fifth model has been added to identify Impacted Soil. Impacted soils are soils affected by surface mining and smelting activities, rendering them unable to support the production of commodity crops. This model will ensure impacted soils do not receive a rating for the NCCPI.

### **Overall Crop Submodel Design**

Figures 2 through 5 illustrate the different crop submodels. The overall design of each crop submodel is very similar. Five of the subrules in these submodels have reasonable fuzzy logic relationships, whereas the remaining subrules use crisp relationships. Crisp

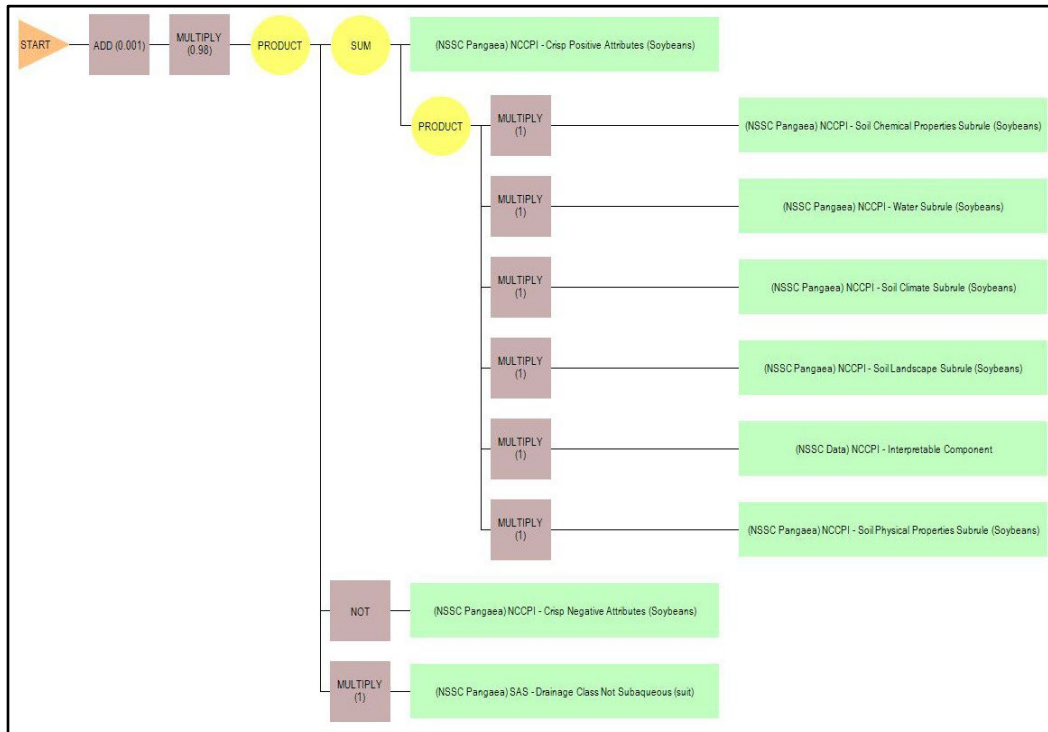
relationships are used because the data available for specific parameters, such as those for erosion, are not of a continuous nature but rather are class data. This information is not of sufficient quality for the development of a fuzzy relationship, since the quantitative impact of an erosion class on crop productivity is generally unknown. 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.

In the calculation of the crop 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 Interpretable Component Subrule occurs in all four 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 classed as “not rated.” Similarly, the Drainage Class Not Subaqueous Subrule ensures that subaqueous soils are not given ratings for subaerial soils and vice versa.

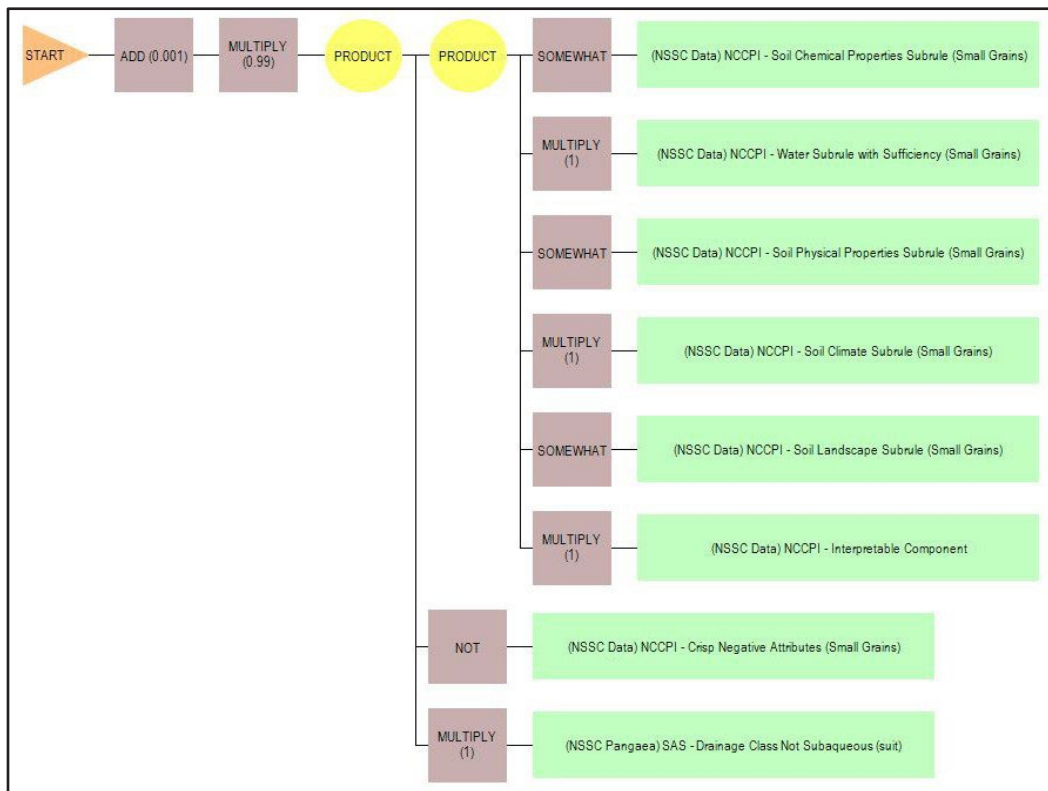


**Figure 2.—The Corn Submodel. Many of the subrules in this submodel retain legacy naming conventions from the NCCPI, Version 2.0, Corn and Soybeans Submodel.**

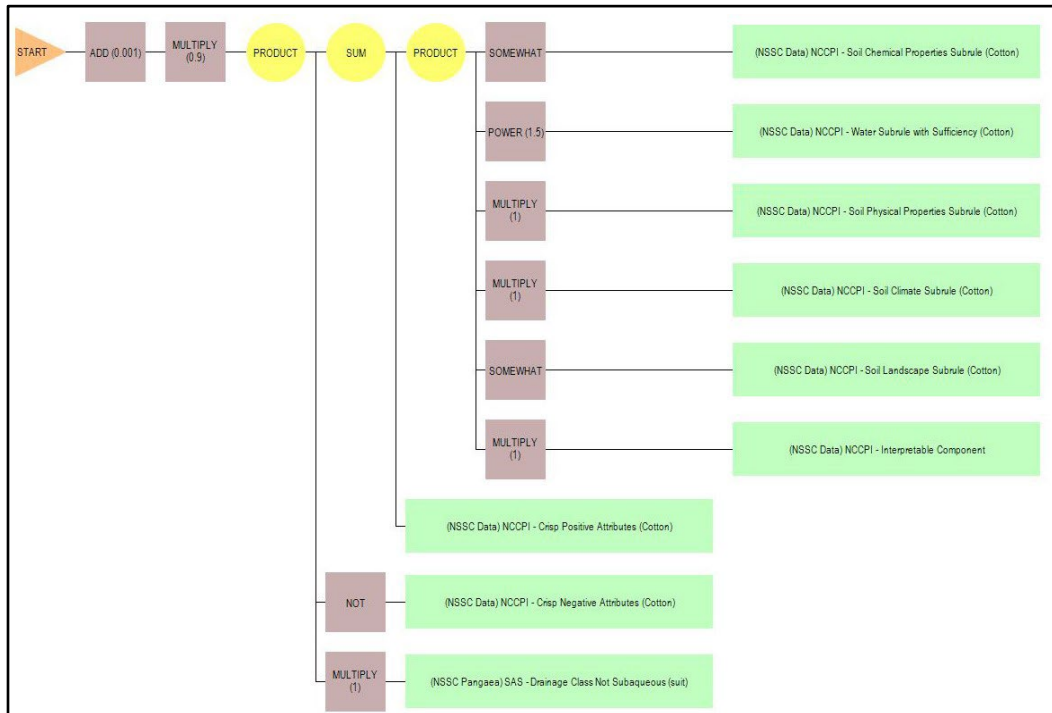
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**Figure 3.—The Soybeans Submodel. It is most similar to the Corn Submodel.**



**Figure 4.—The Small Grains Submodel. It lacks a Crisp Positive Attributes Subrule.**



**Figure 5.—The Cotton Submodel.**

## History and Differences Between the Models

Initially, three crop models were used for the NCCPI to represent the variation of nonirrigated crops grown across the continental US: Corn and Soybeans, Small Grains, and Cotton. There has been extensive work to develop land productivity ratings using corn and soybeans in the midwestern States. Small grains provide an analogous crop for cooler, drier climates and shorter growing seasons. 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.

Feedback from northern tier States indicated that the three-model NCCPI was disproportionately downgrading their soils. While corn production followed the model ratings fairly well, soybeans performed better than predicted because the longer daylight hours partially compensated for the shorter growing season. The fourth crop model, new in version 3.0, separates out soybeans to address this variation.

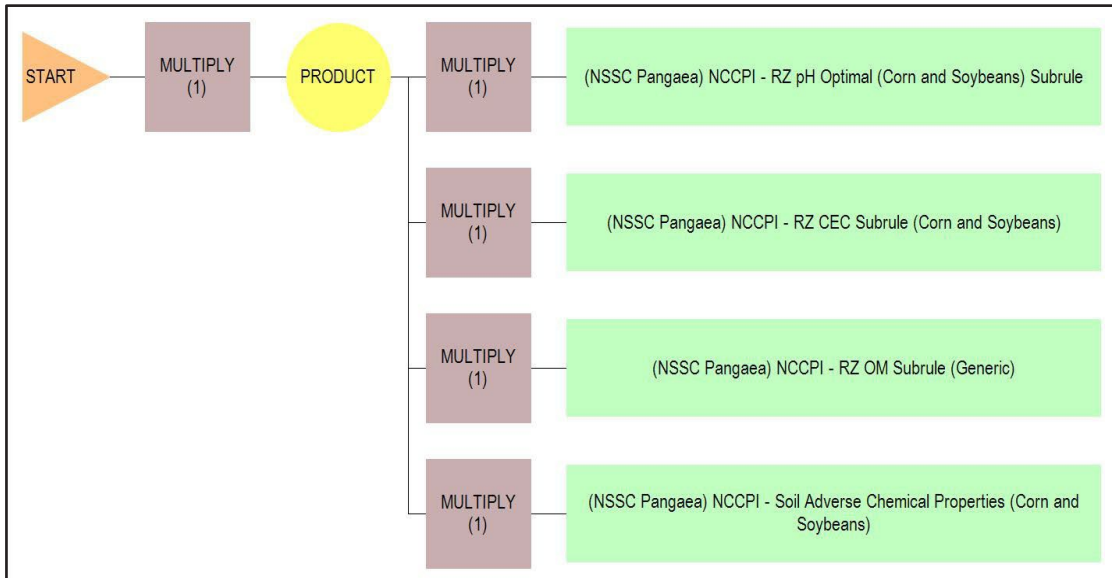
Rather than discussing each crop model independently, this guide presents the models by their constituent subrules. Each subrule section discusses the different properties used by the rules depending on the importance of the property for crop production.

## **Fuzzy Logic Subrules**

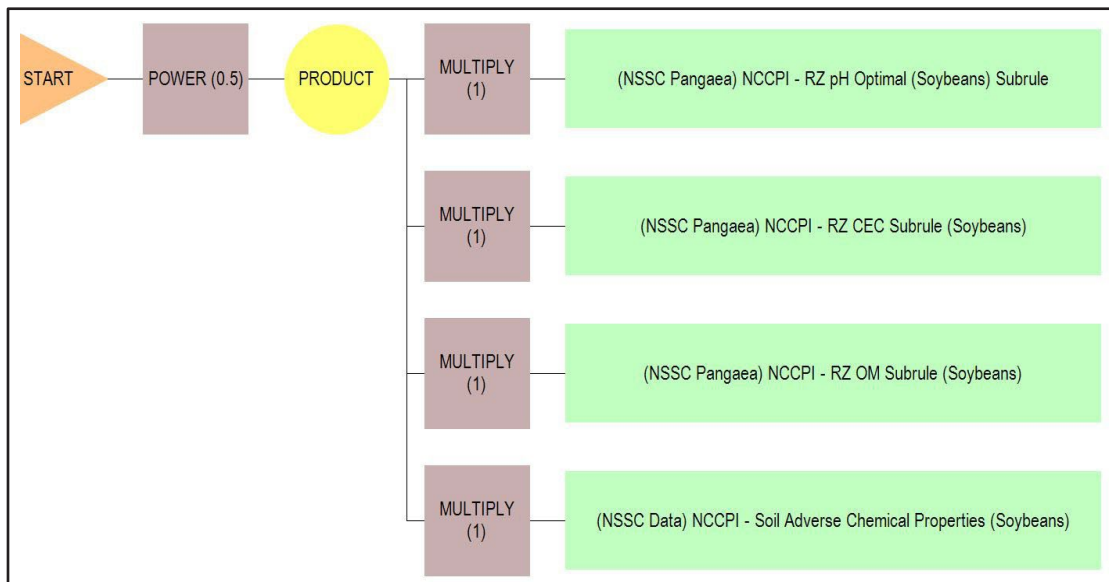
### **Soil Chemical Properties Subrule**

Figures 6 through 9 display the Soil Chemical Properties Subrules for each submodel. The Corn, Soybeans, and Small Grains Submodels all quantify the effects of pH, CEC (cation-exchange capacity), organic matter, and adverse chemical properties in the root zone (i.e., from the soil surface to a depth of 150 cm or to a restrictive layer). 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. Root-limiting layers are identified by a physical restriction, electrical conductivity greater than 8 decisiemens per meter, pH less than 3.5, or high bulk densities for the texture class of the soil. Horizon CEC, rock fragment content, and bulk density are used in the calculation. A small input of CEC is allowed for soils that have a water table.

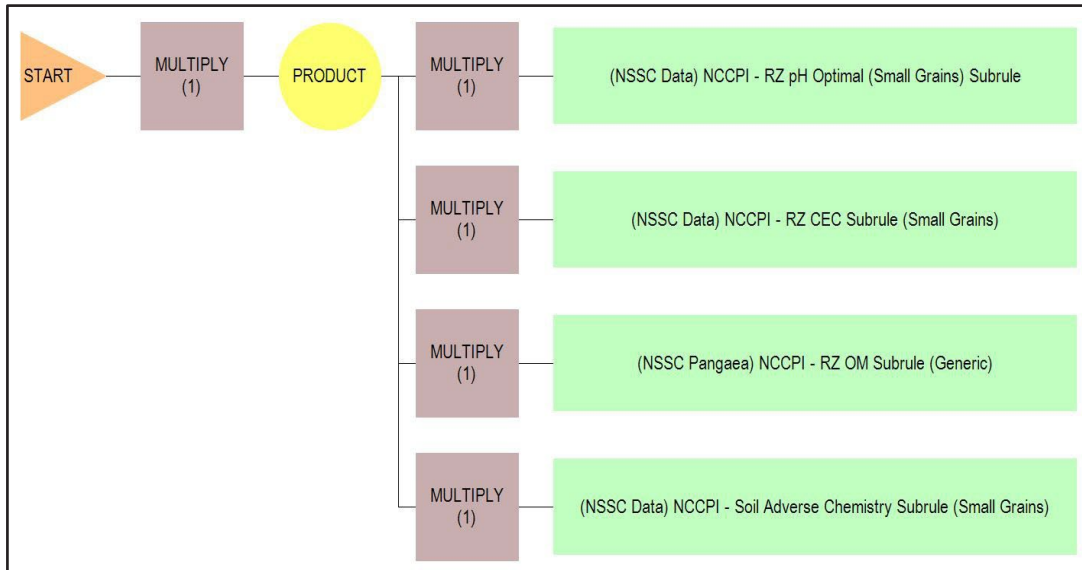
Since cotton is often grown in low CEC soils, management techniques largely mask responses related to clay activity. The effects of pH are considered for depths of 0 to 20 cm and 20 to 150 cm. The most limiting of the two scores is used for the calculation. The pH adaptation for cotton is broader than that for the submodel for corn and soybeans or for small grains and considers mean annual precipitation when evaluating the influence of pH. Organic matter also is considered for the depth ranges of 0 to 20 cm and 20 to 150 cm; the average condition is then used in the calculation. The Cotton Submodel does not include organic matter. Adverse chemical properties, namely, sodium adsorption ratio (SAR), electrical conductivity (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 salinity tolerance of cotton is broader than that of corn and soybeans.



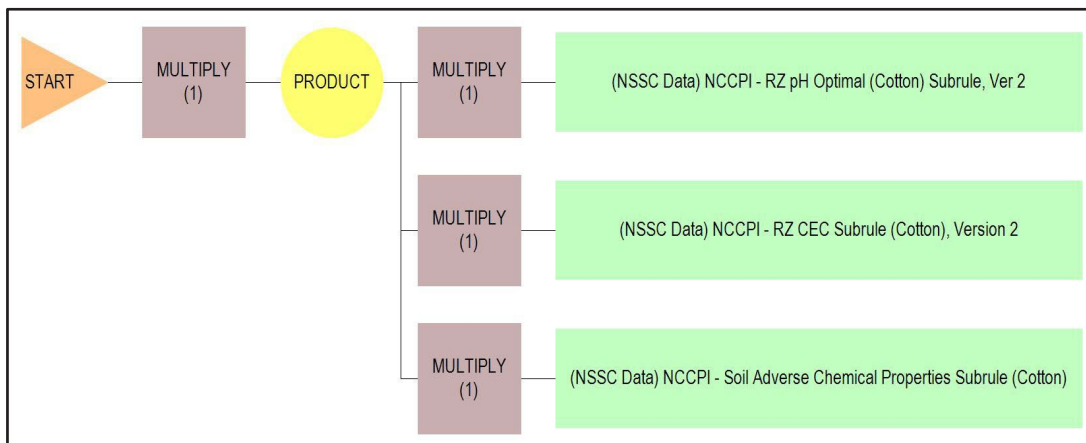
**Figure 6.—The Corn Submodel – Soil Chemical Properties Subrule (Corn and Soybeans).**



**Figure 7.—The Soybeans Submodel – Soil Chemical Properties Subrule (Soybeans).**



**Figure 8.—The Small Grains Submodel – Soil Chemical Properties Subruler (Small Grains).**



**Figure 9.—The Cotton Submodel – Soil Chemical Properties Subruler (Cotton).**

**Water Subruler**

The Water Subruler, depicted in figures 10 through 13 for all four submodels, quantifies the capability of the soil, climate, and landscape to supply water for crop growth. Four sources of water are considered for the Corn, Soybeans, and Small Grains Submodels: 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). The Cotton Submodel does not consider surface contributions. This calculation uses the sum of a proportion of each of the four factors for the Corn and Soybeans Submodels and a sum of a proportion of three factors for the Small Grains and Cotton Submodels.

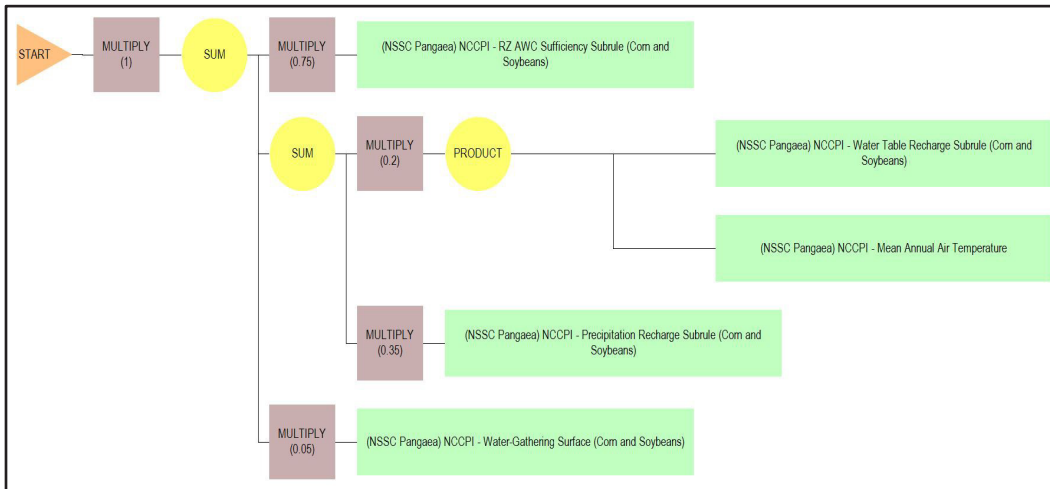


RZ AWC is the amount of plant-available water a soil can store between the surface and a depth of 200 cm. Water Table Recharge quantifies effects of a saturated zone deep within the root zone where roots can access water during summer or during other parts of the growing season. Water-Gathering Surface accounts for additions of water (run-on) resulting from the position of the soil on the landform.

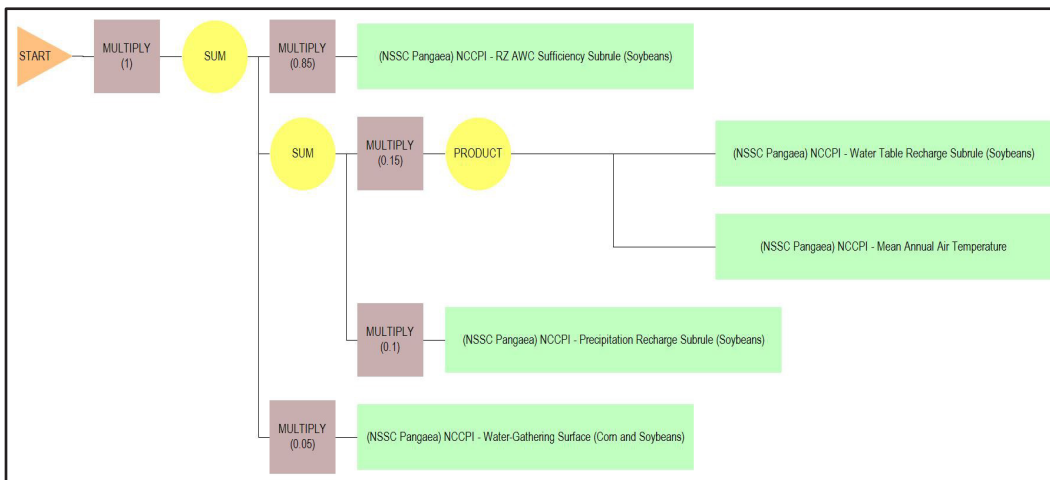
Precipitation Recharge is intended to represent the effect of rainfall during the growing season. The amount of rainfall indicated for a component in the database is decreased because of the effects of temperature, and a proportion is assigned for crop use. For example, consider two soils, both receiving 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.

In the Small Grains Submodel, the various subrule components are tailored to the response of small grains to water. This calculation uses the highest score of either the water table or precipitation recharge, unlike the Corn and Soybeans Submodels, which combine both water table and recharge influences. 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.

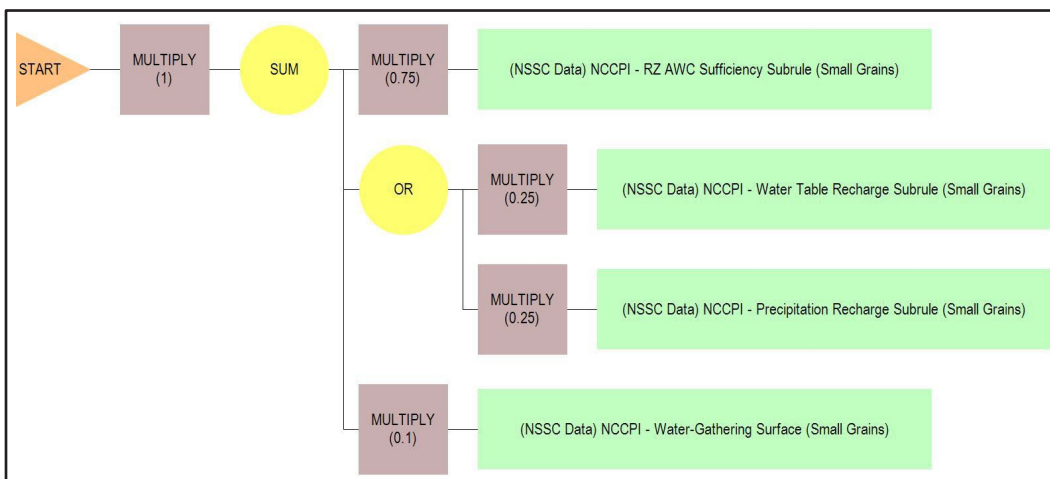
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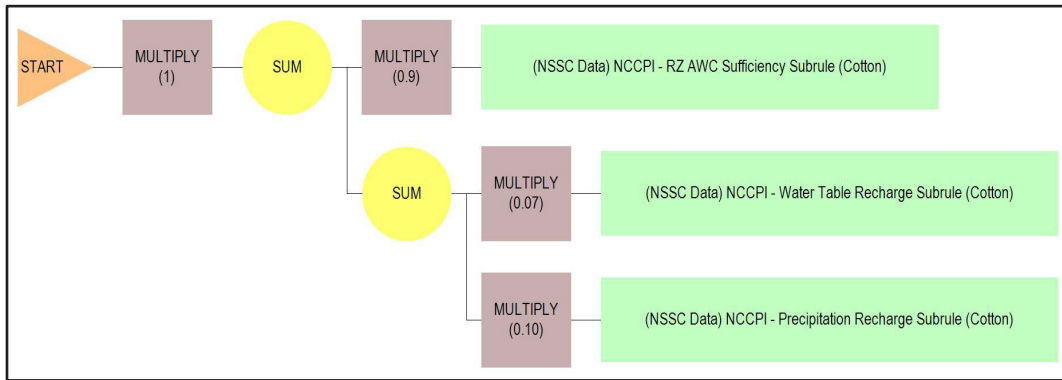
**Figure 10.—The Corn Submodel – The Water Subrule (Corn and Soybeans).**



**Figure 11.—The Water Subrule (Soybeans).**



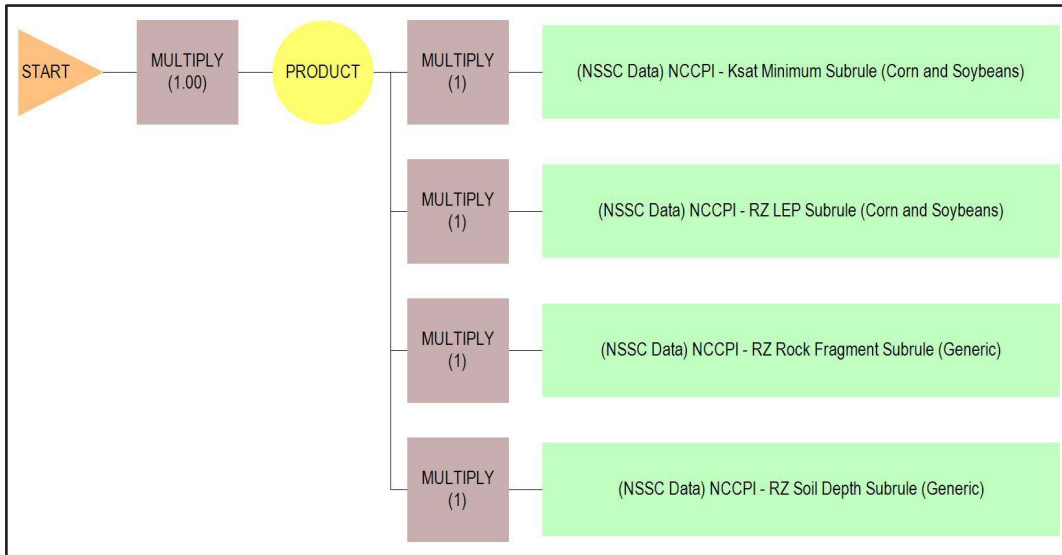
**Figure 12.—The Water Subrule (Small Grains).**



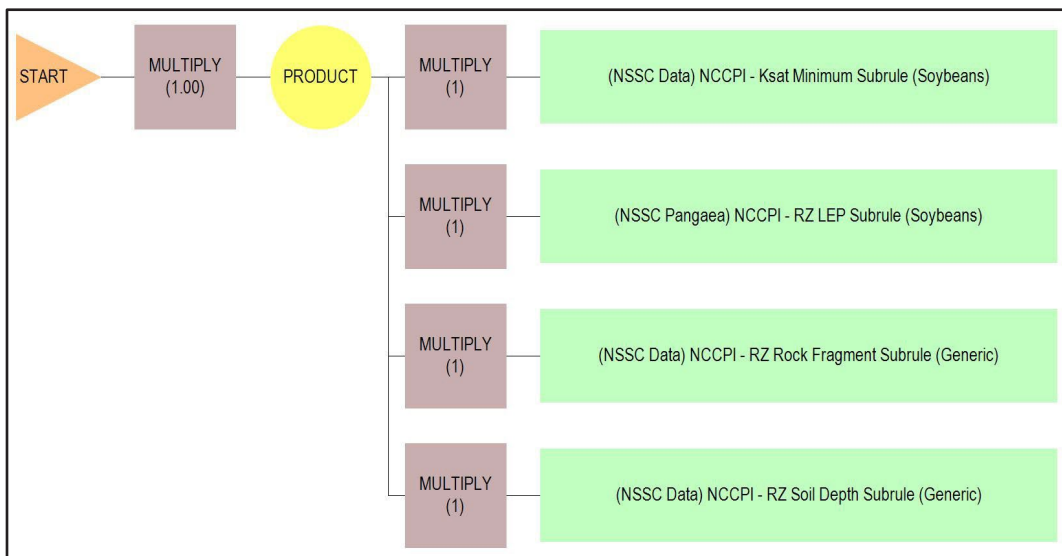
**Figure 13.—The Water Subrule (Cotton).**

### Soil Physical Properties Subrule

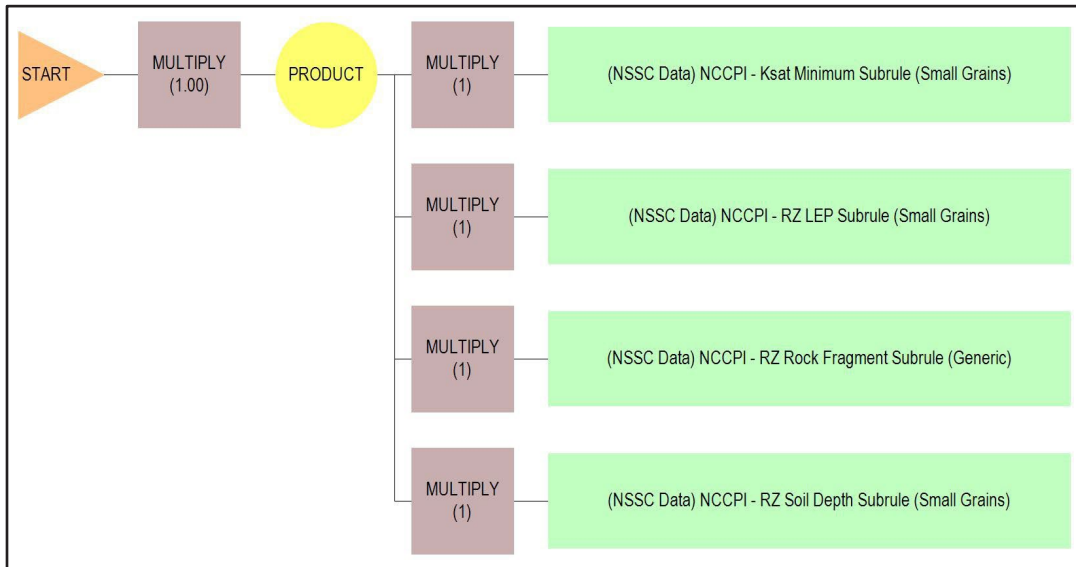
Figures 14 through 17 show the Soil Physical Properties Subrule for each of the four crop submodels, which quantify the effects of saturated hydraulic conductivity ( $K_{sat}$ ), linear extensibility percent (LEP), content of rock fragments, and soil depth on soil productivity. The actual entity used in the  $K_{sat}$  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 materials between depths of 0 to 50 cm, 50 to 100 cm, and 100 to 150 cm that are not root-limiting. The populated LEP value is used for the calculation of the LEP Subrule. 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 in the root zone, with greater emphasis on the 0 to 20 cm depth. The Soil Depth Subrule examines the thickness of soil material over a root-restricting horizon (see appendix 2 for the data elements used in the subrule and appendix 5 for a discussion of other root-limiting layers).



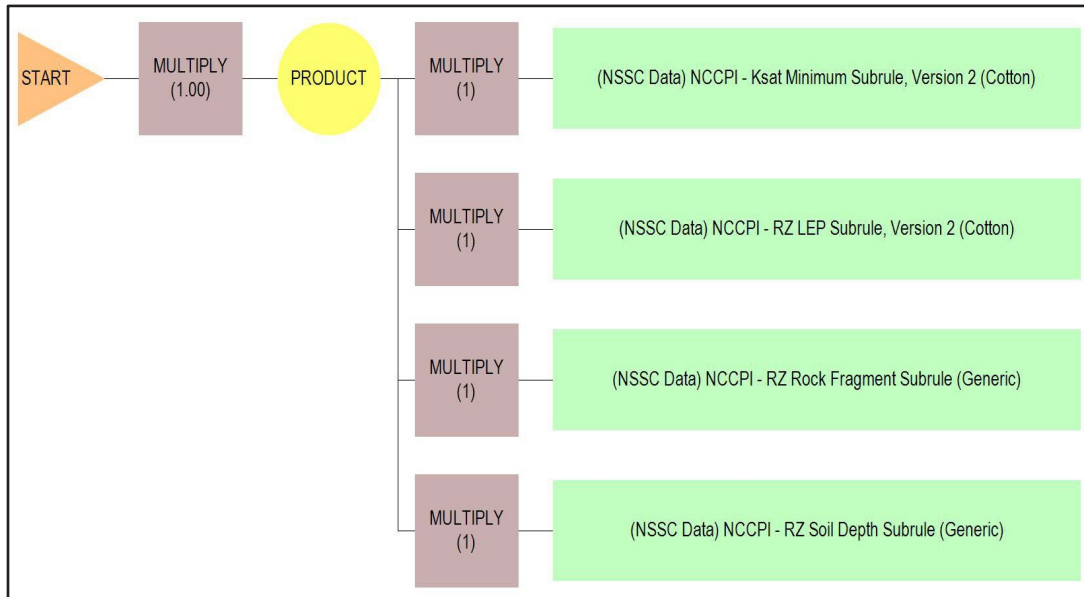
**Figure 14.—The Soil Physical Properties Subrule (Corn and Soybeans).**



**Figure 15.—The Soil Physical Properties Subrule (Soybeans).**



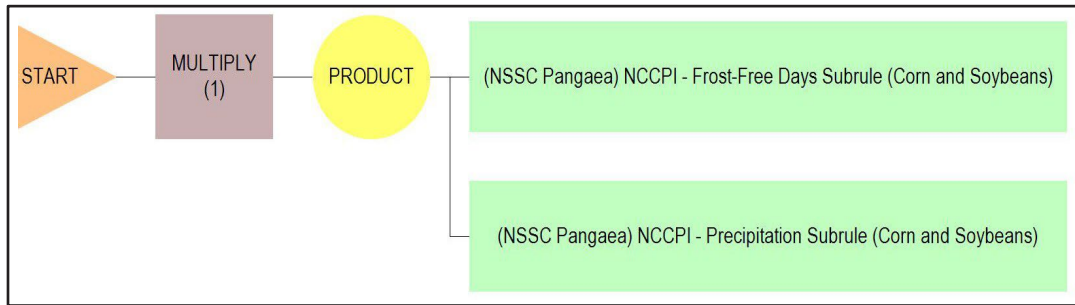
**Figure 16.—The Soil Physical Properties Subrule (Small Grains).**



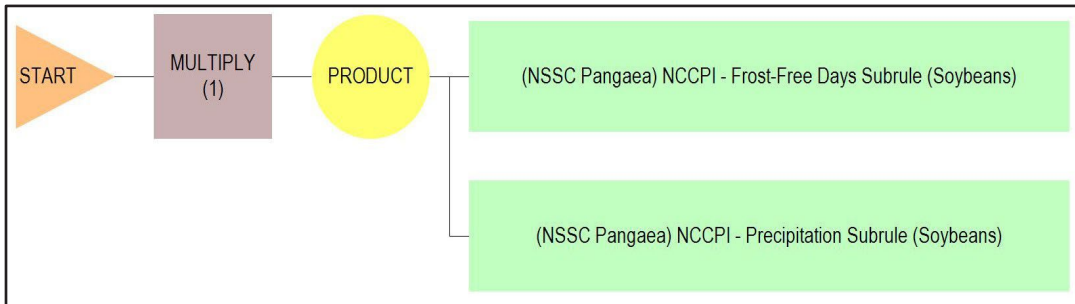
**Figure 17.—The Soil Physical Properties Subrule (Cotton).**

### Soil Climate Subrule

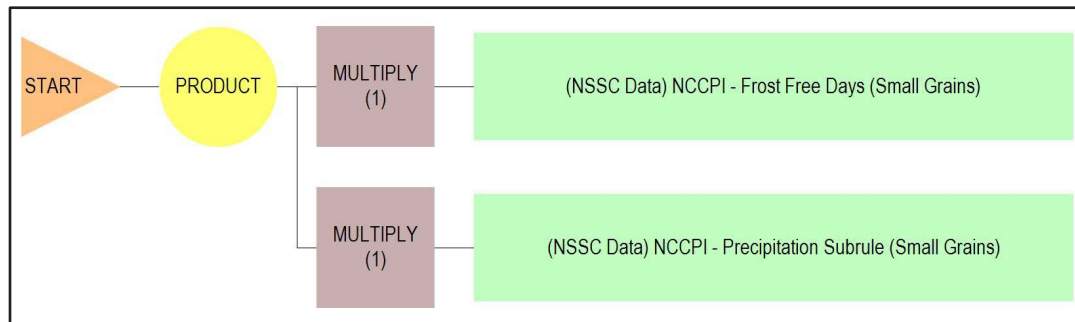
In the Soil Climate Subrule, depicted in figures 18 through 21, two major aspects of soil climate are considered: frost-free days and precipitation. Data for both of these are extracted from the Component Table of NASIS. Multiplying the scores together determines the soil climate rating. The Soil Climate Subrule for the Cotton Submodel, shown in figure 21, also considers the effect of mean annual air temperature on cotton yields. The 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.



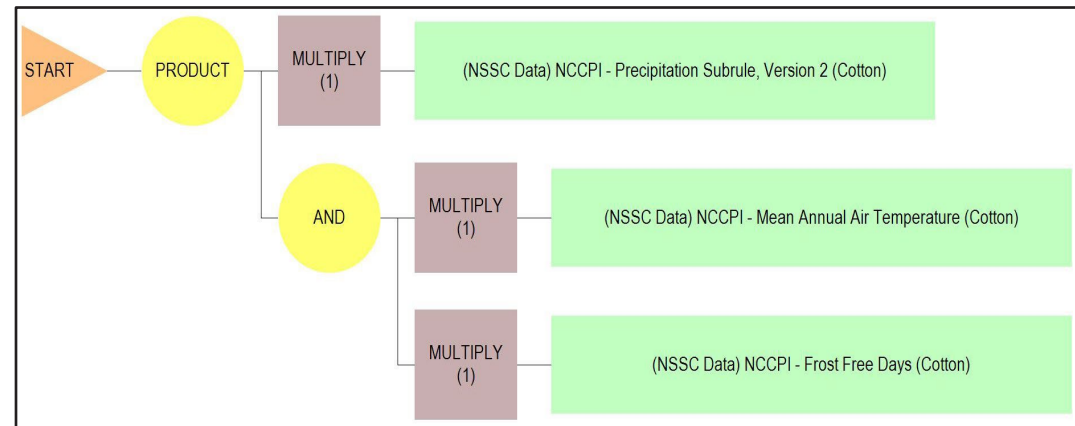
**Figure 18.—The Soil Climate Subrule (Corn and Soybeans).**



**Figure 19.—The Soil Climate Subrule (Soybeans).**



**Figure 20.—The Soil Climate Subrule (Small Grains).**

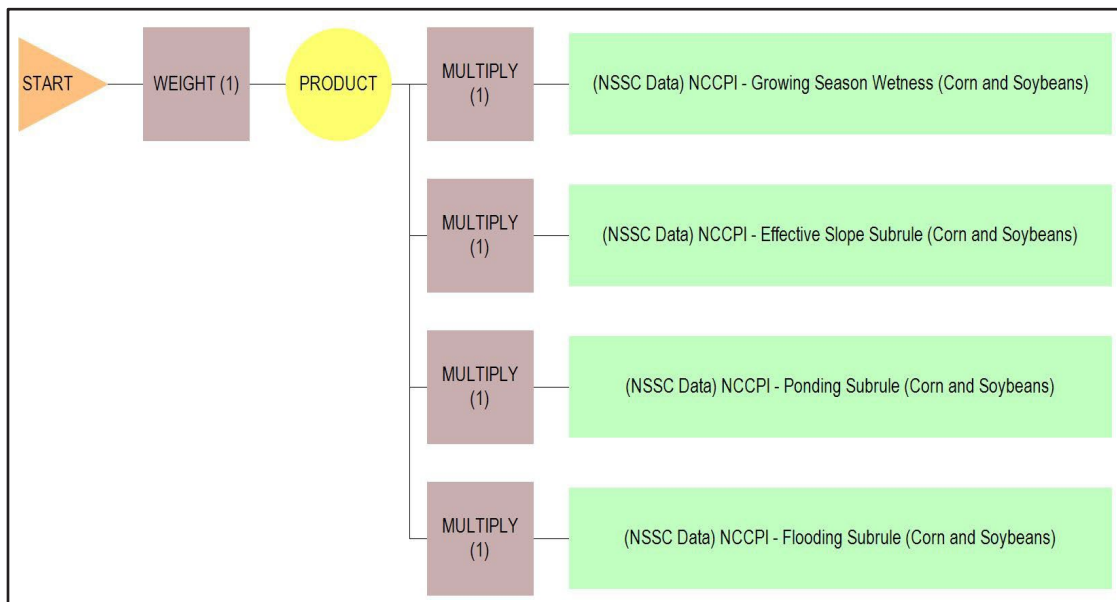


**Figure 21.—The Soil Climate Subrule (Cotton).**

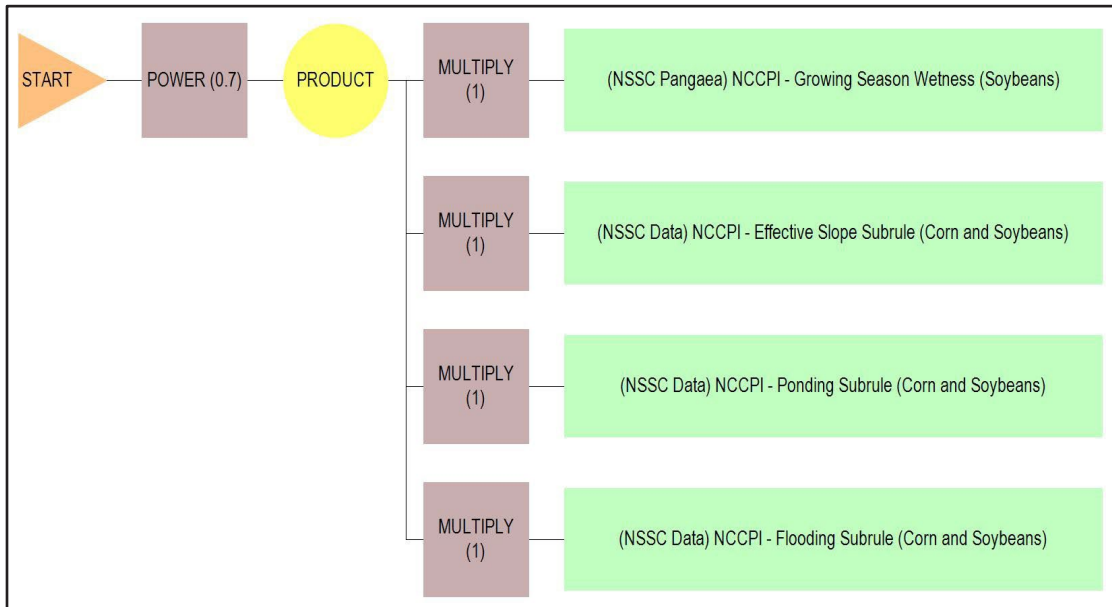
### Soil Landscape Subrule

The Soil Landscape Subrule calculates an index for contributions of the soil landscape to crop productivity. The Corn, Soybeans, and Cotton Submodels (figs. 22, 23, and 25) all use slope gradient, depth to a water table during the growing season (Growing Season Wetness for Corn and Soybeans Submodels), and the occurrence of ponding and flooding during the growing season. 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. In addition, Land Capability Class and Subclass are used as indicators of the presence or absence of artificial drainage. Another difficulty 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.

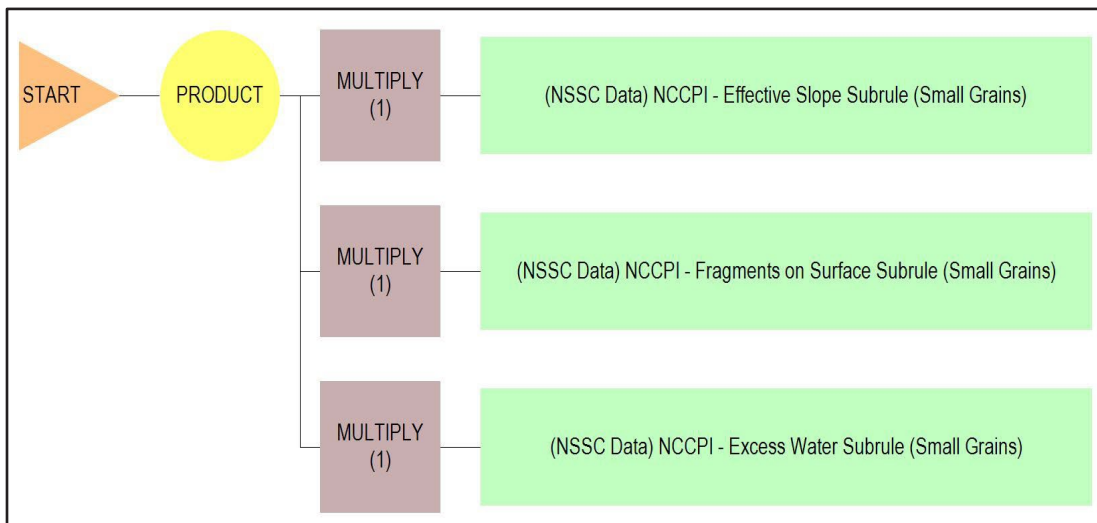
The Soil Landscape Subrule for the Small Grains Submodel is shown in figure 24. The Effective Slope Subrule quantifies the effect of slope gradient. The Excess Water Subrule calculates the combined effects of a water table, ponding, and flooding in the context of a crop that is often seeded in the fall and begins to grow very early in the growing season. This result is multiplied by the results of the Fragments on Surface and Effective Slope Subrules to obtain the score for landscape factors.



**Figure 22.—The Soil Landscape Subrule (Corn and Soybeans).**

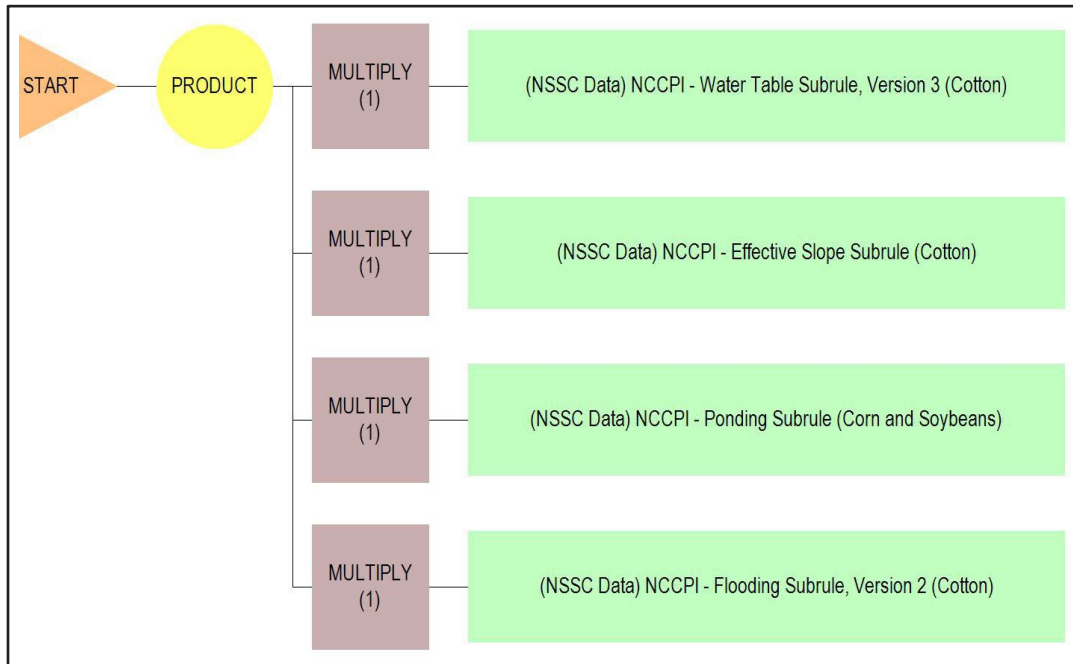


**Figure 23.—The Soil Landscape Subrule (Soybeans).**



**Figure 24.—The Soil Landscape Subrule (Small Grains).**



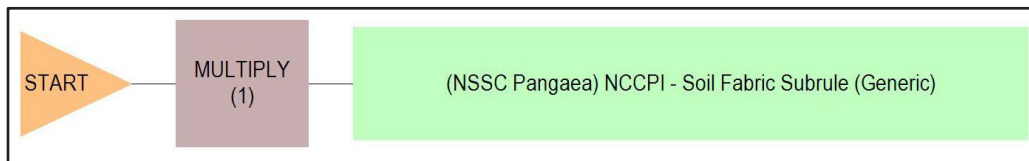


**Figure 25.—The Soil Landscape Subrule (Cotton).**

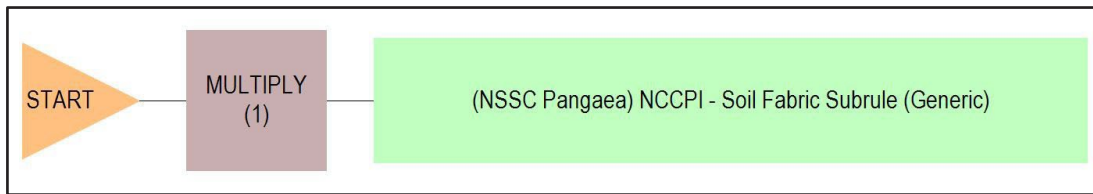
## Crisp Attributes Subrules

### Crisp Positive Attributes

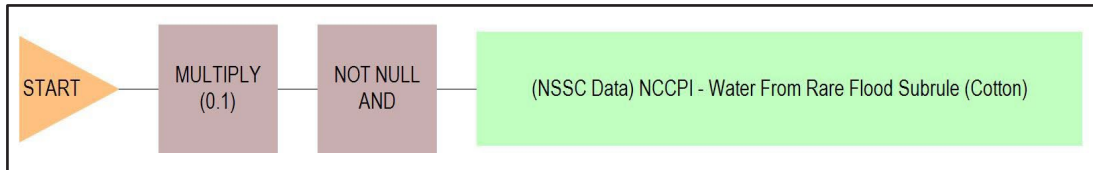
The Crisp Positive Attributes Subrule quantifies soil attributes that foster high productivity but cannot, at present, be reasonably represented by fuzzy set methods. Currently, the Corn and Soybeans Submodels (figs. 26 and 27) recognize the benefits of loess as a parent material, which is observed for at least Wisconsinan-age loess material. This relationship may or may not hold true for older loess deposits. There are no crisp positive soil attributes in the Small Grains Submodel. The Crisp Positive Attributes Subrule for the Cotton Submodel (fig. 28) quantifies the beneficial effect of the landscape position where rare flooding is expected. The result of the crisp positive attributes score is added to the fuzzy score.



**Figure 26.—The Crisp Positive Attributes Subrule (Corn and Soybeans).**



**Figure 27.—The Crisp Positive Attributes Subrule (Soybeans).**



**Figure 28.—The Crisp Positive Attributes Subrule (Cotton).**

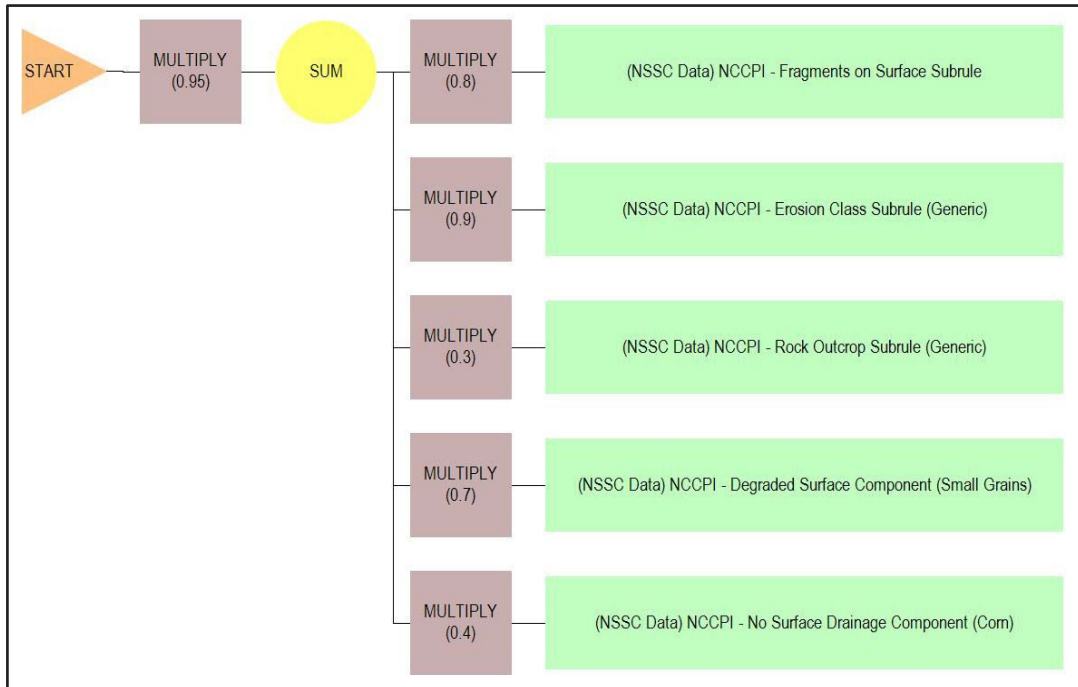
### **Crisp Negative Attributes**

The Crisp Negative Attributes Subrule 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 class of the component or map unit, rock outcrop present in the map unit, surface degradation, and lack of a surface outlet are the current crisp negative attributes considered for the Corn, Soybeans, and Cotton Submodels (figs. 29, 30 and 32).

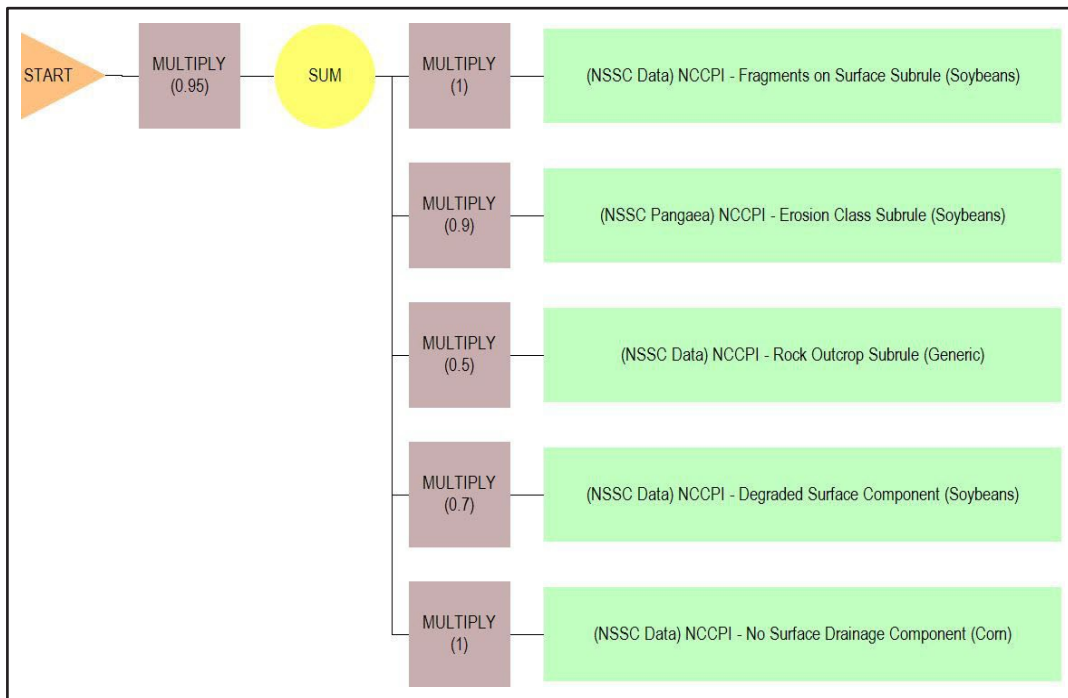
The Crisp Negative Attributes Subrule for the Small Grains Submodel is shown in figure 31. The most intriguing feature of this subrule is the Not Xeric Climate Subrule. A Mediterranean climate (wet winters and dry summers) has been shown to be highly conducive to winter and spring wheat growth. When 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 also 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 the difference is multiplied by the fuzzy soil properties score.

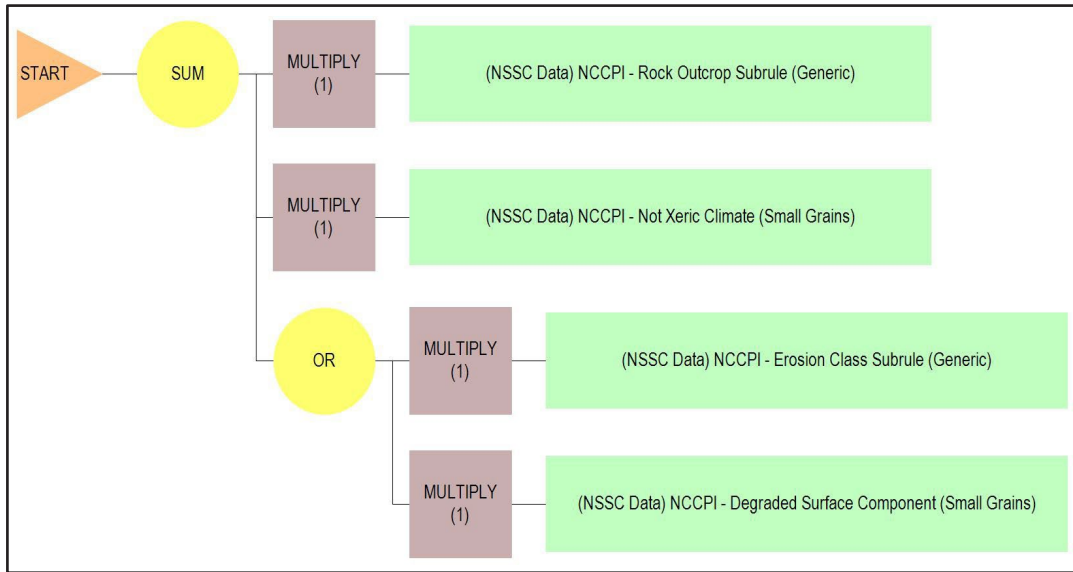
Negative attributes are summed, and the summed total is subtracted from 1.0 (the “NOT” square at the bottom of figures 2 through 5 indicates subtraction). The difference is used to proportionately decrease the sum of the fuzzy and crisp positive features.



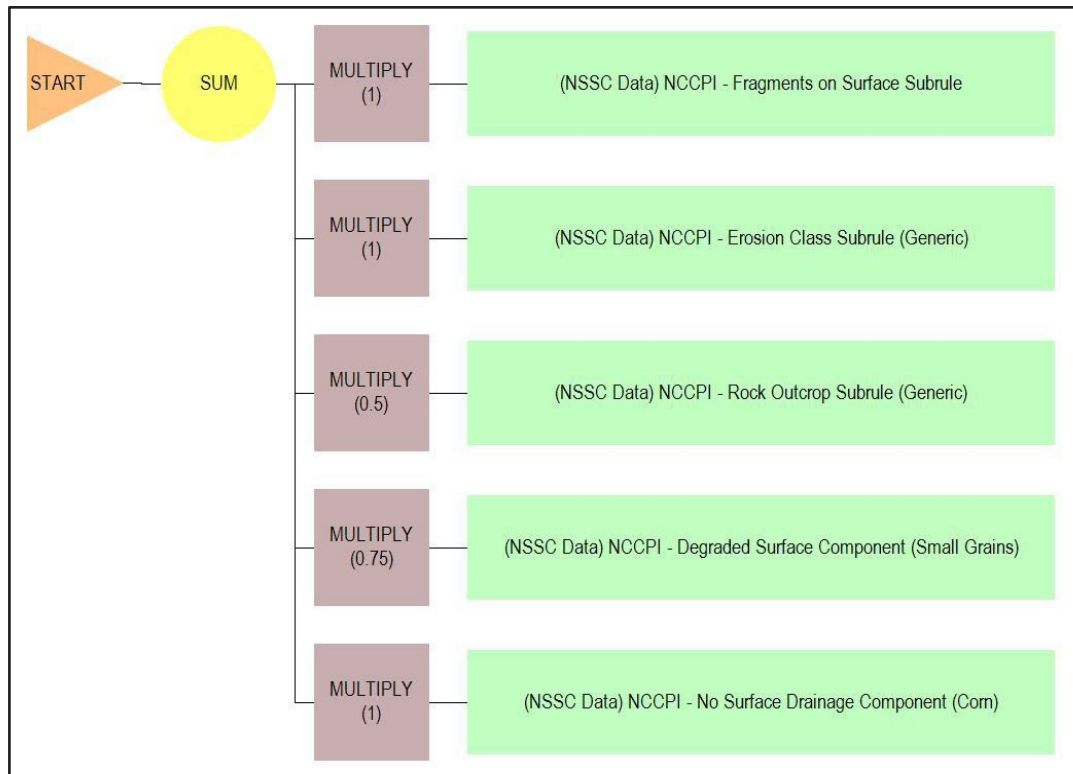
**Figure 29.—The Crisp Negative Attributes Subrule (Corn and Soybeans).**



**Figure 30.—The Crisp Negative Attributes Subrule (Soybeans).**



**Figure 31.—The Crisp Negative Attributes Subrule (Small Grains).**



**Figure 32.—The Crisp Negative 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 four

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 3.0 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 more than 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 Wisconsinan-age 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 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

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## **Appendix 1.—What Is Different?**

Version 3.0 of the NCCPI differs from version 2.0 in several respects.

### **Soybeans Model**

1. A separate model was developed for soybeans. The original corn and soybeans model was based on data from the mid-latitude States of Iowa and Illinois where productivity does not differ greatly between the two crops.

### **Corn Model**

1. Based on comments from users in several States, the deleterious effects of moderate erosion on deep and very deep soils have been decreased.
2. Based on comments from users, some poorly drained, flood-plain soils were rating too high. This was traced to the mechanisms used to tell whether or not it is likely a soil has been drained. One of the clues was whether or not the soil occurred in a glaciated MLRA (major land resource area). However, because some soil map units transcend MLRA boundaries, an additional discriminator is now employed, namely, location on flood plains, depressions, or drainageways, which are generally thought to be undrainable.
3. In the Crisp Negative Attributes Subrule, the stoniness hedge was changed from 1 to 0.8 and the rock outcrop hedge was changed from 0.5 to 0.3. The changes will lessen the deleterious impacts of these two features. Also reduced is the no surface drain hedge, from 1 to 0.4.
4. The frost-free days evaluation was changed to decrease the negative impact of growing seasons exceeding 195 days on the corn index.
5. The evaluation in the Soil Depth Subrule was changed because soils that are less than very deep were being rated too low.
6. The Bulk Density Subrule was removed from the Physical Properties Subrule because it never worked as expected.

### **Small Grains Model**

1. The hedge on the Soil Chemical Properties Subrule was changed from “multiply(1)” to “somewhat.” The somewhat hedge applies a square root to the fuzzy number. This has the effect of contracting the range of the fuzzy numbers. The effect on values close to 1 is slight, but values much smaller than 1, such as 0.01, are noticeably higher.



2. The pH evaluations were adjusted to allow pH around 5 and pH over 7 to return higher fuzzy numbers. They now better reflect the physiology of the crop.
3. The dense layer criteria were removed from the Soil Depth Subrule. Some components had very high bulk density populated at the surface such that these soils were being considered as having a limiting layer at the surface.
4. The Bulk Density Subrule was removed.
5. The membership function of the Frost-Free Days Subrule was adjusted to lessen the impact of shorter growing seasons.
6. The stones on the surface curve was adjusted to lessen the impact of stones on the surface.
7. Syntax was added to the water table property scripts to try to distinguish drained versus undrained components.
8. The subrules for crisp negative attributes were rearranged because erosion effects were being considered twice.

#### **Cotton Model**

1. The water table membership function was adjusted to decrease the rating for soils that have near-surface wetness more than 2 months during the cotton growing season.
2. The Bulk Density Subrule was removed from the Soil Physical Properties Rule.

## Appendix 2.—Reports and Data

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

The data elements currently used in the NCCPI are listed below. Specific elements may vary depending on the crop model. They are listed here in aggregate.

### Impacted Soil Subrule

*Local phase*      Component, Local Phase

### Not Subaqueous Subrule

*Drainage class*      Component, Component Name, Drainage Class

### Soil Chemical Properties Subrule

*pH*                      Component, Component Name, Component Restriction, Horizon, Horizon Bottom Depth rv, Horizon Texture, Horizon Top Depth rv, In Lieu of Texture, MAP rv, pH .01M CaCl<sub>2</sub> low-rv-high, pH 1:1 water low-rv-high, Restriction Kind, Restriction Top Depth low-rv-high, Taxonomic Order, Texture, Texture Group

*CEC*                      Bulk Density 0.33 bar H<sub>2</sub>O rv, CEC-7 rv, Clay % rv, Component, Component Restriction, ECEC rv, Electrical Conductivity rv, Fragment Volume rv, Horizon, Horizon Bottom Depth low-rv- high, Horizon Designation, Horizon Fragments, Horizon Top Depth low-rv-high, MAP rv, Master Horizon Designation, Month, Organic Matter % rv, pH 1:1 water rv, Restriction Top Depth low- rv-high, Sand % rv, Silt % rv, Soil Moisture, Taxonomic Order, Taxonomic Subgroup, Texture Group

*OM*                      Component, Component Name, Component Restriction, Horizon, Horizon Bottom Depth rv, Horizon Texture, Horizon Top Depth rv, In Lieu of Texture, Organic Matter % low-rv-high, Restriction Kind, Restriction Top Depth low-rv-high, Taxonomic Order, Texture, Texture Group

*Adverse Chemistry – SAR, EC, gypsum*  
Component, Electrical Conductivity low-rv-high,

Gypsum % low- rv-high, Horizon, Horizon Bottom Depth rv, Horizon Top Depth rv, Sodium Adsorption Ratio rv

### **Water Subrule**

*RZ AWC* AWC rv, Component, Horizon, Horizon Bottom Depth rv, Horizon Top Depth rv, MAP rv

#### *Water Table Recharge*

Component, Local Phase, Month, SIR Phase, Soil Moisture, Soil Moisture Status, Soil Moisture Top Depth low-rv-high

#### *Mean Annual Air Temperature (MAAT) – Corn and Soybeans Submodels only*

Component, MAAT low-rv-high, Taxonomic Temp Regime

#### *Precipitation Recharge*

Bulk Density 0.1 bar H2O rv, Bulk Density 0.33 bar H2O rv, Component, Component Restriction, Fragment Volume low-rv- high, Horizon, Horizon Bottom Depth rv, Horizon Designation, Horizon Fragments, Horizon Texture, Horizon Top Depth rv, In Lieu of Texture, Ksat low-rv-high, LEP low-rv-high, MAAT low- rv-high, MAP low-rv-high, Organic Matter % rv, Restriction Top Depth low-rv-high, Taxonomic Order, Taxonomic Subgroup, Taxonomic Suborder, Taxonomic Temp Regime, Texture, Texture Group

#### *Water-Gathering Surface – Corn, Soybeans, and Small Grains Submodels*

Component, Geomorphic Description, Slope Shape, Slope Shape Across, Slope Shape Up/Down, Taxonomic Moisture Class, Taxonomic Order

### **Physical Properties Subrule**

*K<sub>sat</sub>* Bulk Density 0.33 bar H2O rv, Clay % rv, Component, Component Restriction, Electrical Conductivity rv, Horizon, Horizon Bottom Depth rv, Horizon Designation, Horizon Texture, Horizon Top Depth low-rv-high, In Lieu of Texture, K<sub>sat</sub> low-rv- high, LEP low-rv-high, MAP rv, Master Horizon Designation, Organic Matter % rv, pH 1:1 water rv, Restriction Top Depth low- rv-high, Sand % rv, Silt % rv, Taxonomic Order, Texture, Texture Group

*LEP* Component, Component Name, Component Restriction, Horizon, Horizon Bottom Depth rv, Horizon Texture, Horizon Top Depth rv, In Lieu of Texture, LEP low-rv-high, MAP rv, Restriction Kind, Restriction Top Depth low-rv-high, Taxonomic Order, Texture, Texture Group

*Rock Fragments* Component, Component Restriction, Fragment Volume rv, Horizon, Horizon Bottom Depth low-rv-high, Horizon Designation, Horizon Fragments, Horizon Top Depth rv, Master Horizon Designation, Restriction Top Depth low-rv-high, Taxonomic Order, Taxonomic Subgroup

*Soil Depth* Component, Component Restriction, Electrical Conductivity rv, Horizon, Horizon Bottom Depth low-rv-high, Horizon Texture, Horizon Top Depth low-rv-high, In Lieu of Texture, Master Horizon Designation, pH 1:1 water rv, Restriction Kind, Restriction Top Depth low-rv-high, Taxonomic Order, Taxonomic Subgroup, Texture, Texture Group

### **Soil Climate Subrule**

*Frost-Free Days* Component, Frost Free Days low-rv-high

*Daylength – Soybeans Submodel only*  
Area Symbol, Component

*Precipitation* Component, MAP low-rv-high, MAAT rv

*Mean Annual Air Temperature (MAAT) – Cotton Submodel only*  
Component, MAAT low-rv-high, Taxonomic Temp Regime

### **Soil Landscape Subrule**

*Growing Season Wetness – Corn and Soybeans Submodels only*  
Area Symbol (MLRA), Component, Drainage Class, Frost Free Days low-rv-high, Geomorphic Description, Geomorphic Feature, Geomorphic Feature Name, Geomorphic Feature Type, Legend Area Overlap, Local Phase, Map unit Area Overlap, Month, Non-Irrigated LCC, Non-Irrigated LCC Subclass, Parent Material, Parent Material Group, Parent Material Kind, SIR Phase, Soil Moisture, Soil Moisture Status, Soil Moisture Top Depth rv, Taxonomic Family Temp

Class, Taxonomic Temp Regime

*Effective Slope* Component, Slope % low-rv-high, Taxonomic Subgroup, Taxonomic Suborder

*Ponding – Not considered for Small Grains Submodel*

Area Symbol (SSA), Component, Drainage Class, Local Phase, Map unit Name, Month, Non-Irrigated LCC, Non-Irrigated LCC Subclass, Ponding Duration, Ponding Frequency, SIR Phase, Taxonomic Temp Regime

*Flooding – Not considered for Small Grains Submodel*

Area Symbol (SSA), Component, Component Name, Flooding Duration, Flooding Frequency, Map unit Name, Frost Free Days rv, Month, Taxonomic Temp Regime

*Fragments on Surface – Small Grains Submodel only*

% Cover Surface Fragments low-rv-high, Component, Fragment Volume rv, Fragment Size rv, Horizon, Horizon Fragments, Horizon Top Depth rv, Surface Fragment Size, Surface Fragments

*Excess Water – Small Grains Submodel only*

Area Symbol (MLRA), Component, Drainage Class, Flooding Duration, Flooding Frequency, Frost Free Days low-rv-high, Geomorphic Description, Geomorphic Feature, Geomorphic Feature Name, Geomorphic Feature Type, Legend Area Overlap, Local Phase, Map unit Area Overlap, Frost Free Days rv, Month, Non-Irrigated LCC, Non-Irrigated LCC Subclass, Ponding Duration, Ponding Frequency, SIR Phase, Soil Moisture, Soil Moisture Status, Soil Moisture Top Depth rv, Taxonomic Family Temp Class, Taxonomic Temp Regime

*Water Table – Cotton Submodel only*

Component, Local Phase, Month, SIR Phase, Soil Moisture, Soil Moisture Status, Soil Moisture Top Depth rv, Taxonomic Family Temp Class, Taxonomic Temp Regime

### **Crisp Positive Attributes Subrule**

*Soil Fabric – Corn and Soybeans Submodels only*

Component, Parent Material Kind

*Water From Rare Flood – Cotton Submodel only*  
Component, Drainage Class, Flooding Frequency,  
Month

**Crisp Negative Attributes Subrule**

*Fragments on Surface – Not used for Small Grains Submodel*  
% Cover Surface Fragments low-rv-high, Component,  
Surface Fragment Size, Surface Fragments

*Erosion Class – Not Used for Soybeans Submodel*  
Component, Component Restriction, Erosion Class,  
Local Phase, Map unit Name, Restriction Kind,  
Restriction Top Depth low-rv-high, SIR Phase

*Not Xeric – Small Grains Submodel only*  
Area Symbol (MLRA), Component, Taxonomic  
Subgroup, Taxonomic Suborder

*Rock Outcrop*      Map unit Name

*Degraded Surface*  
Component, Component Name, Local Phase, Map  
unit Name

*No Surface Outlet – Not used for Small Grains Submodel*  
Component, Drainage Class, Map unit Name, Non-  
Irrigated LCC, Non-Irrigated LCC Subclass

### Appendix 3.—Evaluations

This appendix shows the evaluations used in the calculation of the NCCPI. The evaluations indicate the range of property data used to produce the fuzzy numbers. The functions rarely go to zero. Using 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.

This appendix does not contain an all-inclusive 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.

#### Soil Chemical Properties Subrules

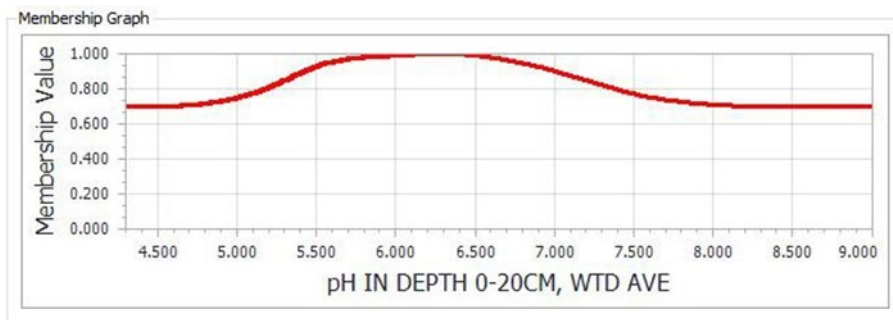
##### 1. RZ pH Evaluation Curves

###### a. Corn Submodel

###### (i) 0-20 cm depth

Arbitrary curve, control points:

X Value	4.3	5.2	5.5	6	6.18	7	7.5	8.2
Y Value	0.7	0.81	0.93	0.99	1	0.9	0.77	0.7

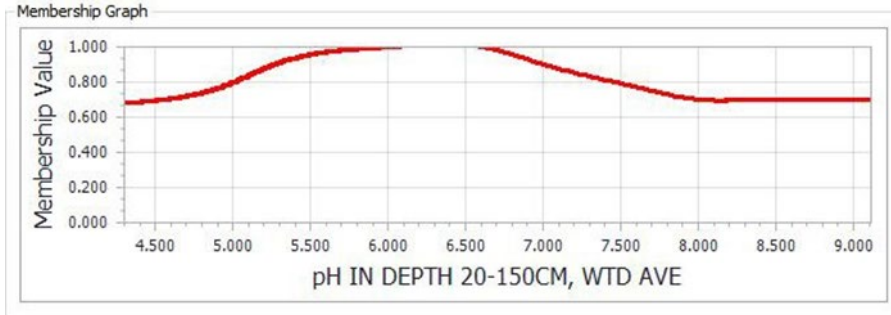


Units are pH units.

(ii) 20-150 cm depth

Arbitrary curve, control points:

X Value	4.3	5	5.2	6	6.6	7	7.6	8	8.3
Y Value	0.63	0.8	0.88	1	1	0.9	0.77	0.7	0.7



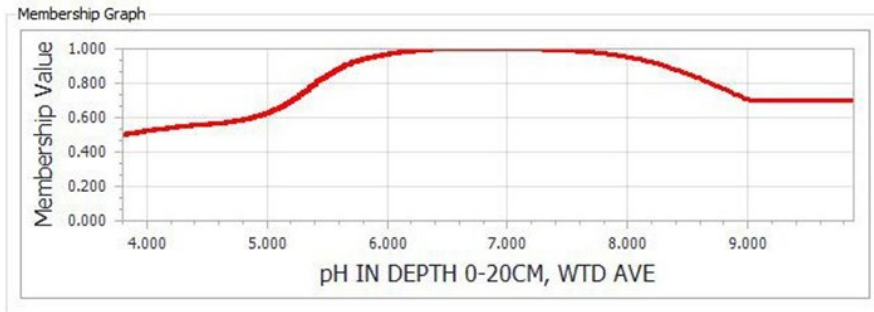
Units are pH units.

b. Soybeans Submodel

(i) 0-20 cm depth

Arbitrary curve, control points:

X Value	3.8	4.3	5.2	5.5	6	6.5	7	7.5	8.2	9
Y Value	0.5	0.55	0.7	0.85	0.97	1	1	0.99	0.92	0.7

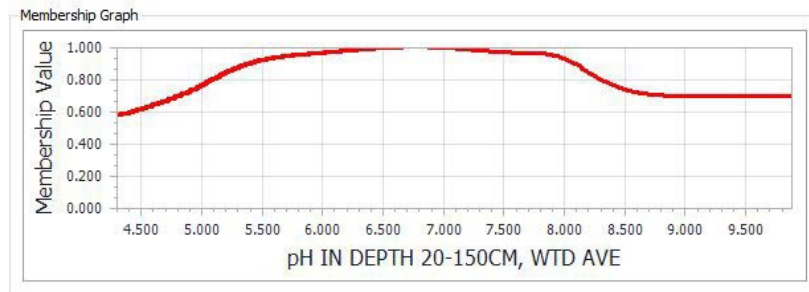


Units are pH units.

(ii) 20-150 cm depth

Arbitrary curve, control points:

X Value	4.3	5	5.2	6	6.5	7	7.6	8	8.3	9
Y Value	0.58	0.77	0.85	0.97	1	1	0.97	0.93	0.8	0.7



Units are pH units.

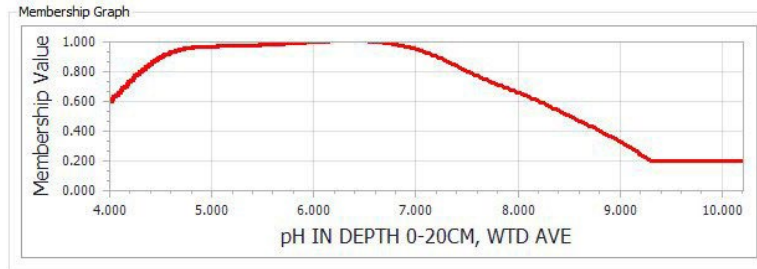


c. Small Grains Submodel

(i) 0-20 cm depth

Arbitrary curve, control points:

X Value	4	4.5	5	5.5	6	6.6	7.2	7.5	8.2	8.5	8.8	9.3
Y Value	0.6	0.9	0.97	0.98	1	1	0.9	0.8	0.6	0.5	0.4	0.2

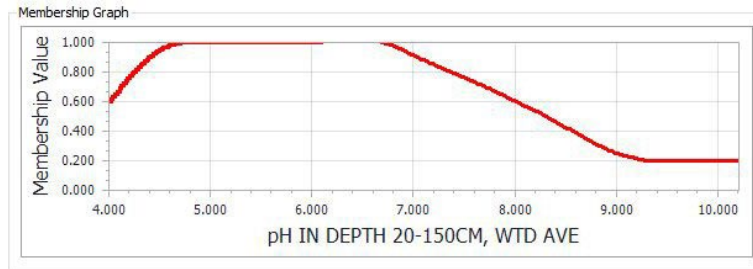


Units are pH units.

(ii) 20-150 cm depth

Arbitrary curve, control points:

X Value	4	4.5	5	5.8	6	6.7	7	7.7	8	8.3	9	9.3
Y Value	0.6	0.95	1	1	1	1	0.91	0.7	0.6	0.5	0.25	0.2



Units are pH units.

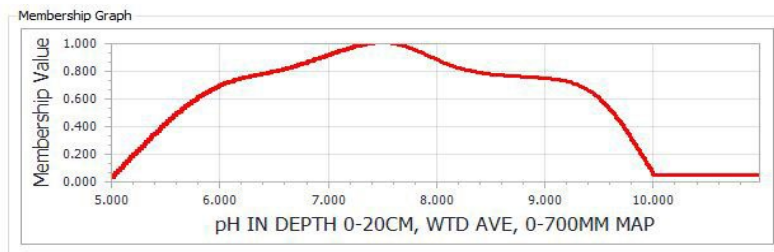
d. Cotton Submodel – pH evaluation is dependent on mean annual precipitation (MAP).

(i) MAP <700 mm

(1) 0-20 cm depth

Arbitrary curve, control points:

X Value	5	6	6.5	7	7.6	8.1	9	9.5	10
Y Value	0.03	0.7	0.8	0.92	1	0.85	0.75	0.6	0.05

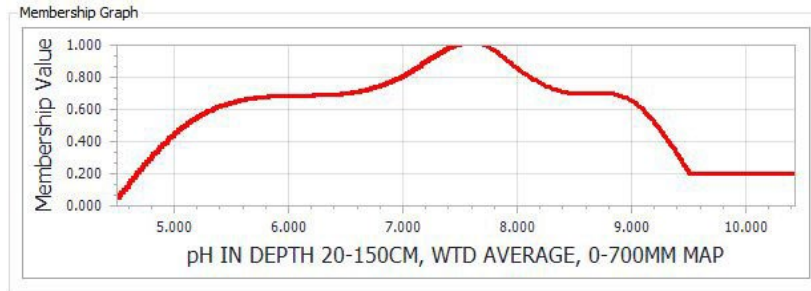


Units are pH units.

(2) 20-150 cm depth

Arbitrary curve, control points:

X Value	4.5	5	6.5	7	7.7	8	8.3	8.5	9	9.5
Y Value	0.05	0.45	0.7	0.81	1	0.85	0.73	0.7	0.65	0.2



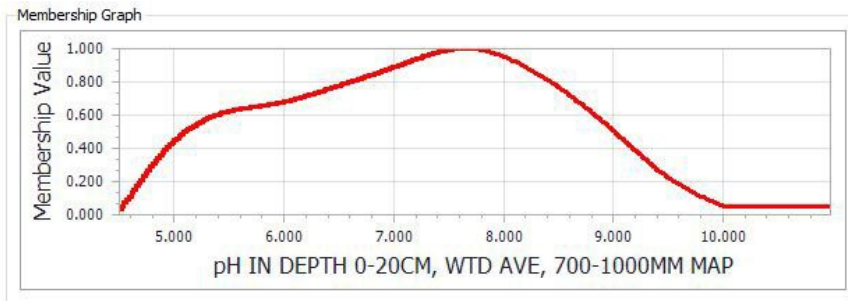
Units are pH units.

(ii) MAP 700-1000 mm

(1) 0-20 cm depth

Arbitrary curve, control points:

X Value	4.5	5	6	6.5	7	7.7	8.1	9	9.5	10
Y Value	0.03	0.7	0.8	0.92	1	0.85	0.75	0.6	0.05	0.05

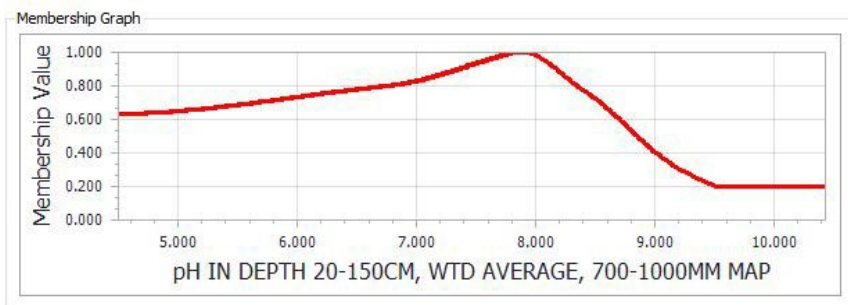


Units are pH units.

(2) 20-150 cm depth

Arbitrary curve, control points:

X Value	4.5	5	6.5	7	7.7	7.9	8	8.3	8.5	9	9.5
Y Value	0.63	0.65	0.78	0.83	0.98	1	0.98	0.82	0.72	0.4	0.2



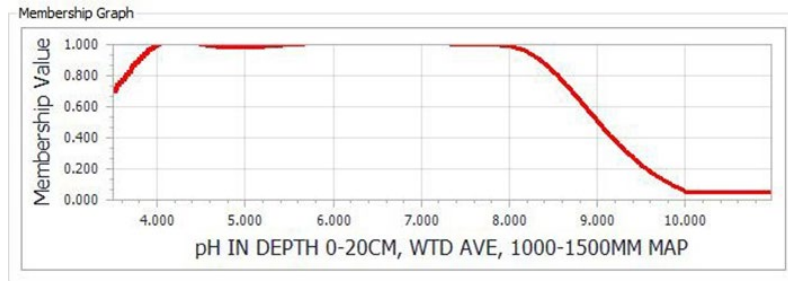
Units are pH units.

(iii) MAP 1000-1500 mm

(1) 0-20 cm depth

Arbitrary curve, control points:

X Value	3.5	4	4.5	5.5	7.7	8.2	9	9.5	10
Y Value	0.7	1	1	1	1	0.95	0.5	0.22	0.05

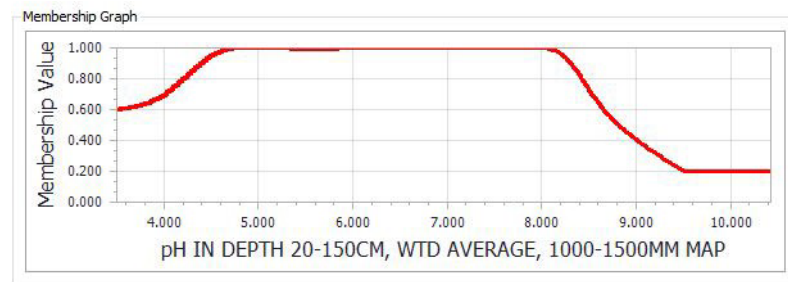


Units are pH units.

(2) 20-150 cm depth

Arbitrary curve, control points:

X Value	3.55	4	4.5	5	6.5	7	7.9	8	8.3	8.5	9	9.5
Y Value	0.6	0.7	0.95	1	1	1	1	1	0.9	0.72	0.4	0.2



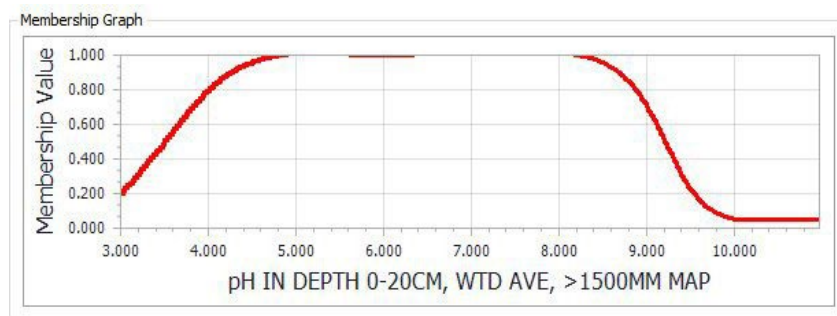
Units are pH units.

(iv) MAP >1500 mm

(1) 0-20 cm depth

Arbitrary curve, control points:

X Value	3.5	4	4.5	5.8	3	8.2	9	9.5	10
Y Value	0.5	0.8	0.96	1	0.2	1	0.7	0.22	0.05

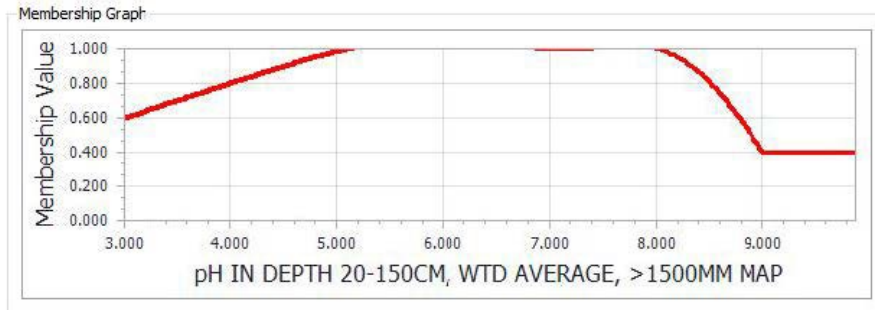


Units are pH units.

(2) 20-150 cm depth

Arbitrary curve, control points:

X Value	3	4.5	5.1	7	7.3	8	8.5	9
Y Value	0.6	0.9	1	1	1	1	0.8	0.4



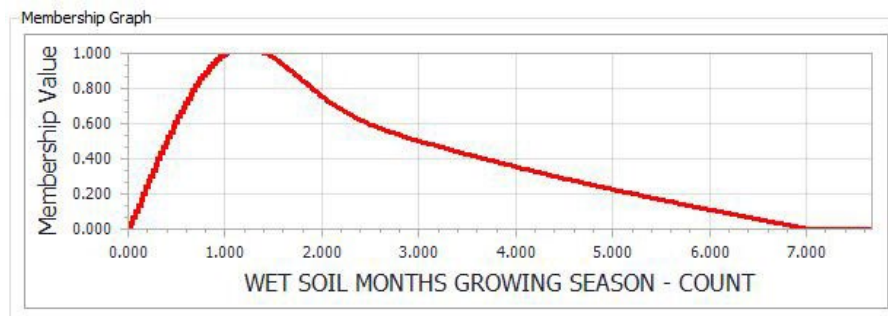
Units are pH units.

## 2. RZ CEC Evaluation Curves

- a. All four models include a slight contribution to CEC for soils having a water table:

Arbitrary curve, control points:

X Value	0	1	2	3	7
Y Value	0	1	0.75	0.5	0

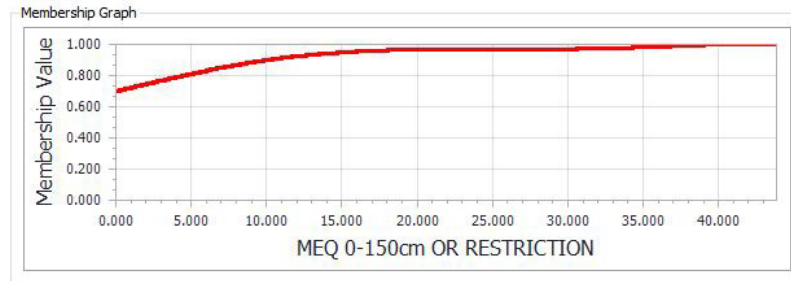


Units are a count of the months a water table is present in the soil.

b. Corn Submodel

Arbitrary curve, control points:

X Value	0	10	30	40
Y Value	0.7	0.9	0.97	1

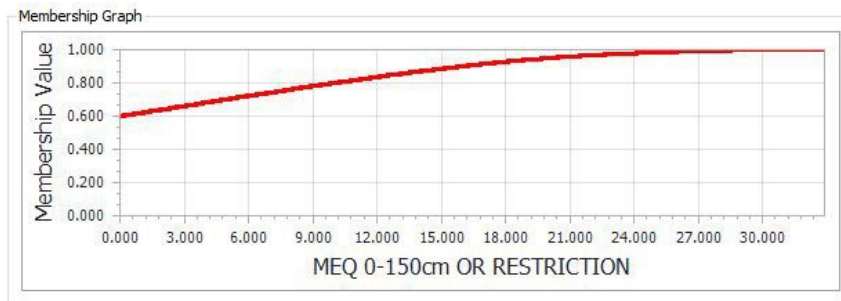


Units are meq/cm<sup>2</sup>. Restriction based on Component restrictive layer, pH<=3.5, EC>=8.01 or Bulk Density too high.

c. Soybeans Submodel

Arbitrary curve, control points:

X Value	0	10	20	30
Y Value	0.6	0.8	0.95	1

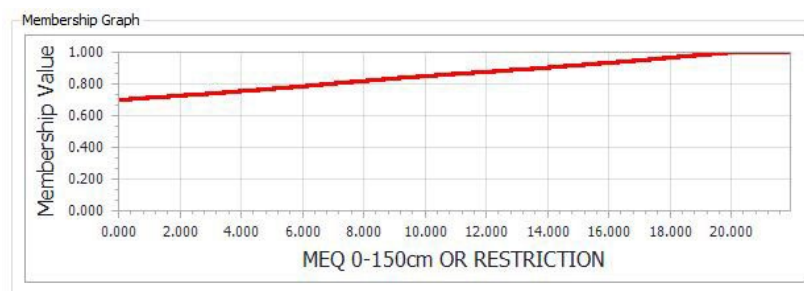


Units are meq/cm<sup>2</sup>. Restriction based on Component restrictive layer, pH<=3.5, EC>=8.01 or Bulk Density too high.

d. Small Grains Submodel

Arbitrary curve, control points:

X Value	0	5	10	13	20
Y Value	0.7	0.77	0.85	0.89	1



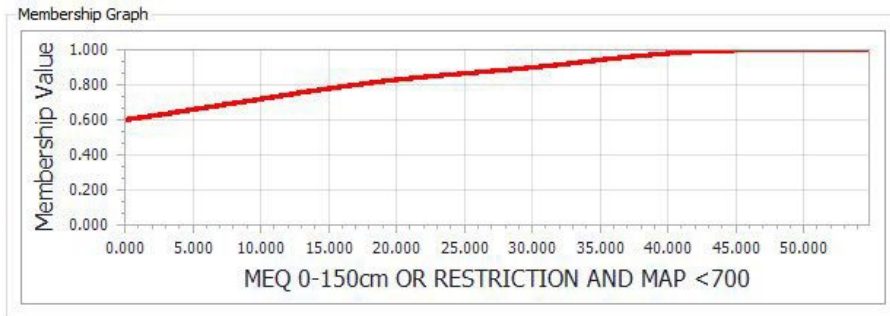
Units are meq/cm<sup>2</sup>. Restriction based on Component restrictive layer, pH<=3.5, EC>=16.01 or Bulk Density too high.

e. Cotton Submodel – Four arbitrary curves based on mean annual precipitation (MAP).

(i) MAP <700 mm

Arbitrary curve, control points:

X Value	0	10	20	30	40	50
Y Value	0.6	0.72	0.83	0.9	0.98	1

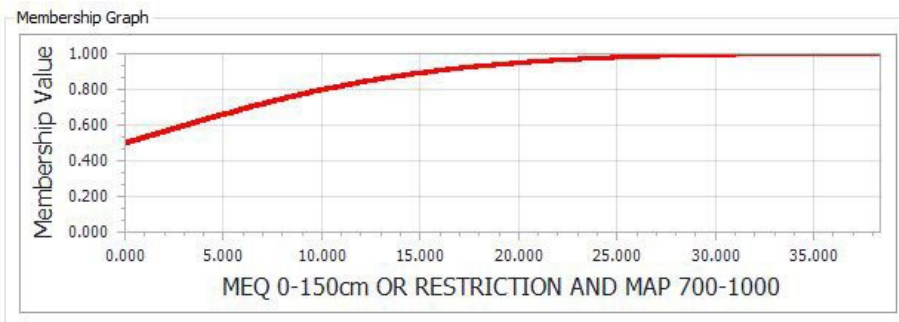


Units are meq/cm<sup>2</sup>. Restriction based on Component restrictive layer.

(ii) MAP 700-1000 mm

Arbitrary curve, control points:

X Value	0	10	20	35
Y Value	0.5	0.8	0.95	1

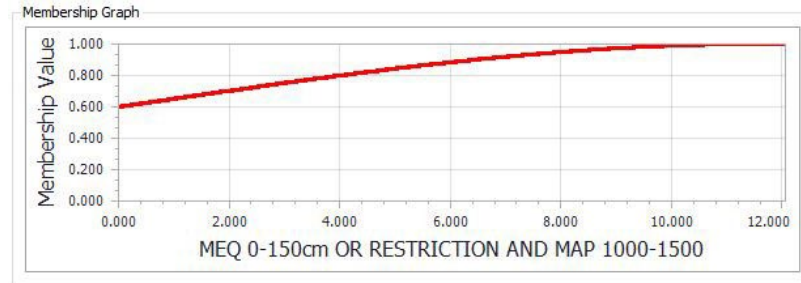


Units are meq/cm<sup>2</sup>. Restriction based on Component restrictive layer.

(iii) MAP 1000-1500 mm

Arbitrary curve, control points:

X Value	0	10	11
Y Value	0.6	0.99	1

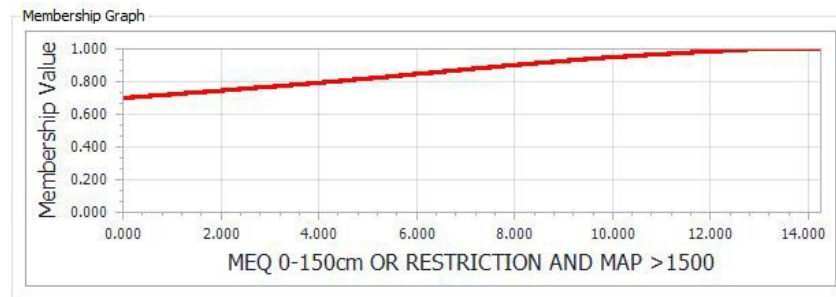


Units are meq/cm<sup>2</sup>. Restriction based on Component restrictive layer.

(iv) MAP >1500 mm

Arbitrary curve, control points:

X Value	0	2	10	13
Y Value	0.7	0.82	0.95	1



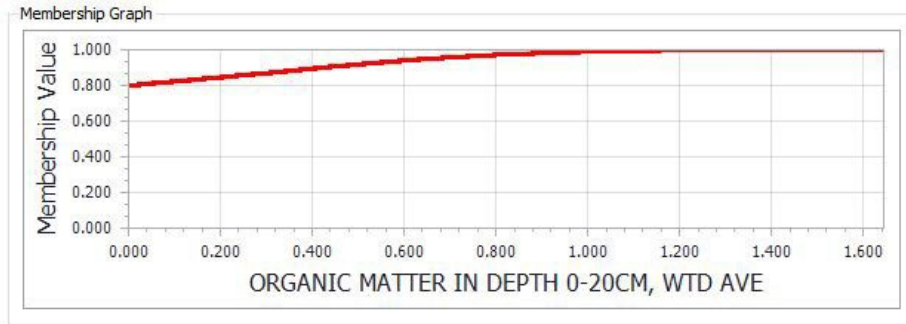
Units are meq/cm<sup>2</sup>. Restriction based on Component restrictive layer.

3. RZ OM Evaluation Curves – Corn, Soybeans, and Small Grains Submodels. Cotton Submodel does not consider organic matter.
  - a. Corn and Small Grains use the same generic evaluations:

- (i) 0-20 cm depth

Arbitrary curve, control points:

X Value	0	0.3	0.6	1.5
Y Value	0.8	0.87	0.94	1

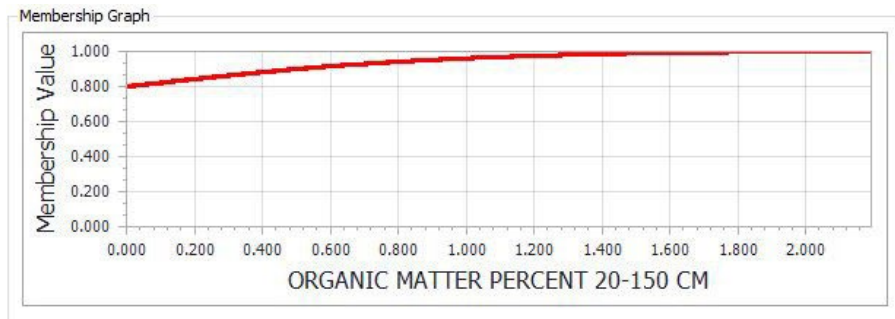


Units are percent by weight.

- (ii) 20-150 cm depth

Arbitrary curve, control points:

X Value	0	0.5	2
Y Value	0.8	0.9	1



Units are percent by weight.

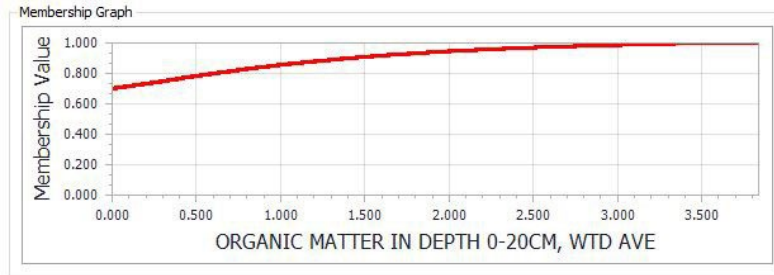


b. Soybeans Submodel evaluations:

(i) 0-20 cm depth

Arbitrary curve, control points:

X Value	0	0.3	0.6	3.5
Y Value	0.7	0.75	0.8	1

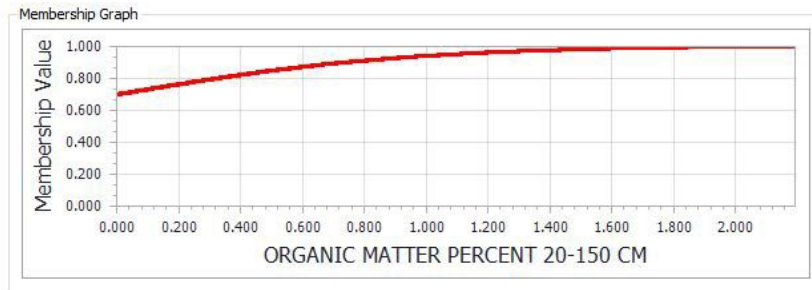


Units are percent by weight.

(ii) 20-150 cm depth

Arbitrary curve, control points:

X Value	0	0.5	2
Y Value	0.7	0.85	1



Units are percent by weight.

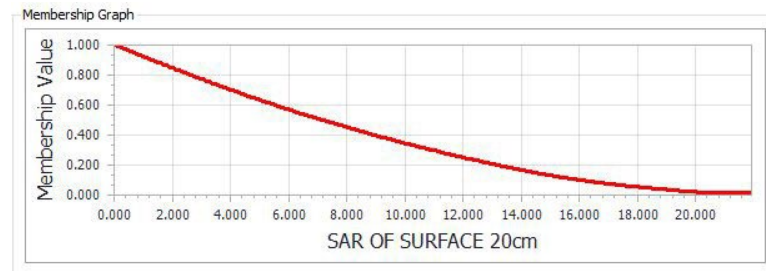
4. Adverse RZ SAR Evaluation Curves

a. Corn Submodel

(i) 0-20 cm depth

Arbitrary curve, control points:

X Value	0	4	8	12	16	20
Y Value	1	0.7	0.45	0.25	0.1	0.02

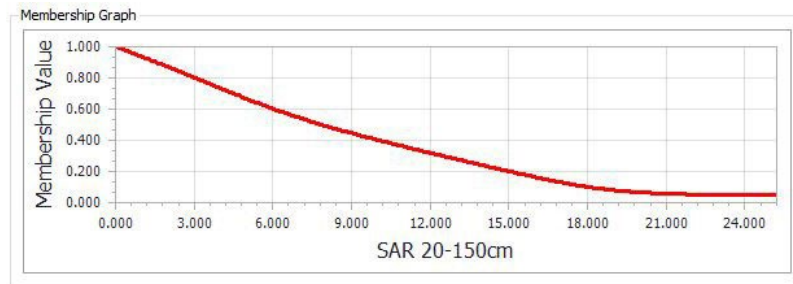


SAR is a unitless ratio.

(ii) 20-150 cm depth

Arbitrary curve, control points:

X Value	0	3	6	10	15	18	23
Y Value	1	0.8	0.6	0.4	0.2	0.1	0.05



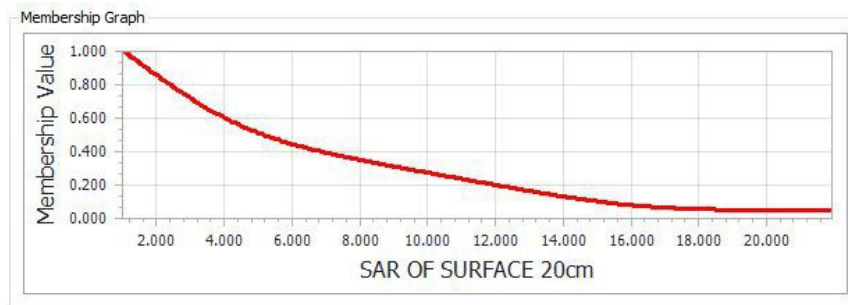
SAR is a unitless ratio.

b. Soybeans Submodel

(i) 0-20 cm depth

Arbitrary curve, control points:

X Value	1	2	8	12	16	20
Y Value	1	0.6	0.35	0.2	0.08	0.05

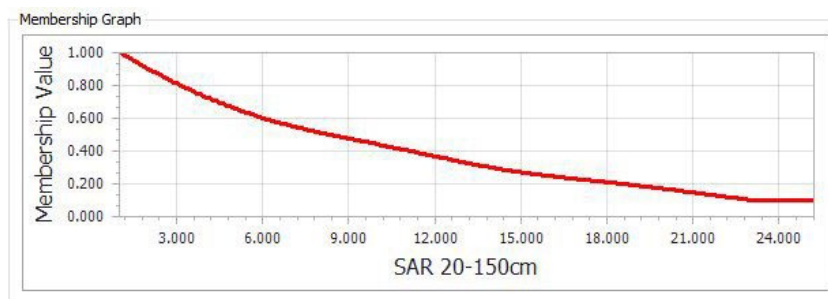


SAR is a unitless ratio.

(ii) 20-150 cm depth

Arbitrary curve, control points:

X Value	1	2	6	10	15	18	23
Y Value	1	0.9	0.6	0.44	0.27	0.21	0.1



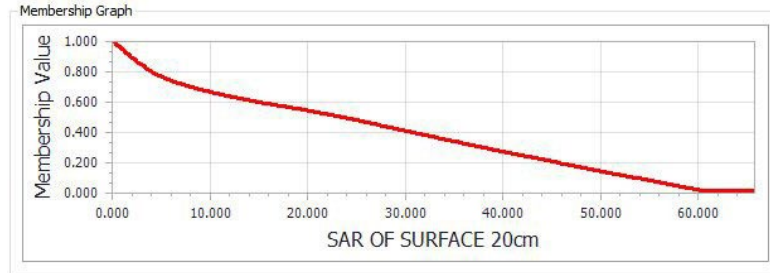
SAR is a unitless ratio.

c. Small Grains Submodel

(i) 0-20 cm depth

Arbitrary curve, control points:

X Value	0	4	8	15	20	30	60
Y Value	1	0.8	0.7	0.6	0.545	0.41	0.02

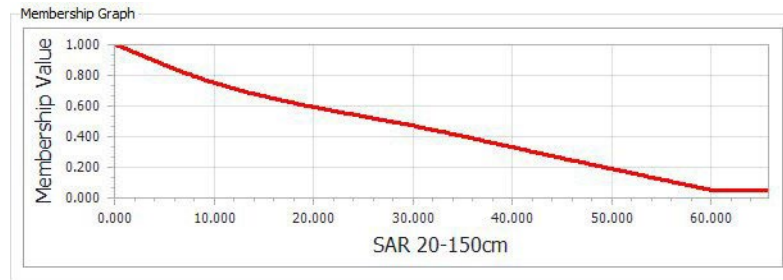


SAR is a unitless ratio.

(ii) 20-150 cm depth

Arbitrary curve, control points:

X Value	0	3	6	10	30	40	60
Y Value	1	0.92	0.84	0.75	0.47	0.33	0.05



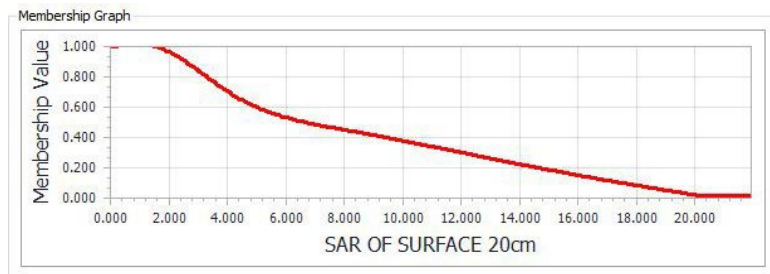
SAR is a unitless ratio.

d. Cotton Submodel

(i) 0-20 cm depth

Arbitrary curve, control points:

X Value	0	4	8	12	16	20	1.5
Y Value	1	0.7	.45	0.3	0.15	0.02	1

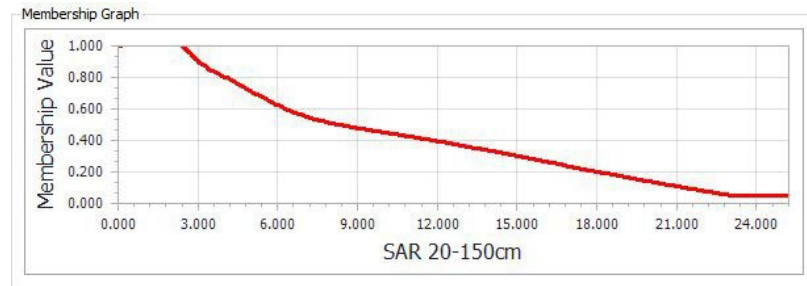


SAR is a unitless ratio.

(ii) 20-150 cm depth

Arbitrary curve, control points:

X Value	0	3	6	10	15	18	23	2.5	4
Y Value	1	0.9	0.62	0.45	0.3	0.2	0.05	0.98	0.8



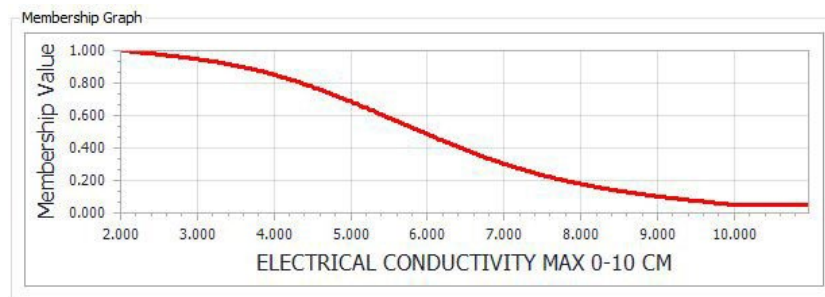
SAR is a unitless ratio.

5. Adverse RZ EC Evaluation Curves

a. Corn Submodel

(i) 0-10 cm depth (germination) Arbitrary curve, control points:

X Value	2	4	10	7
Y Value	1	0.85	0.05	0.3

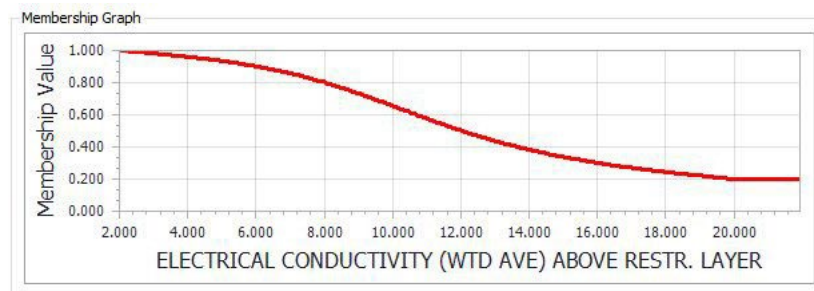


EC units are mmhos/cm.

(ii) 0-150 cm depth

Arbitrary curve, control points:

X Value	2	4	8	12	16	20
Y Value	1	0.96	0.8	0.5	0.3	0.2



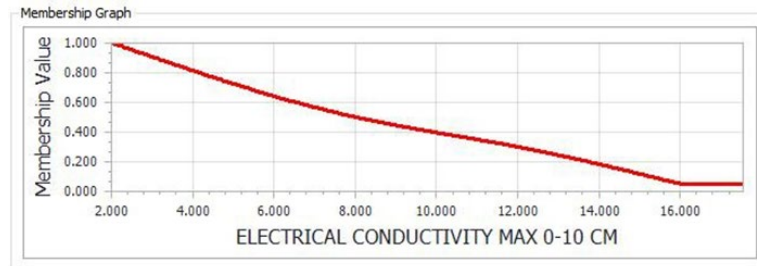
EC units are mmhos/cm. Restriction based on Component restrictive layer, pH<=3.5, EC >=16, or Bulk Density too high.

b. Soybeans Submodel

(i) 0-10 cm depth (germination)

Arbitrary curve, control points:

X Value	2	8	12	16
Y Value	1	0.5	0.3	0.05

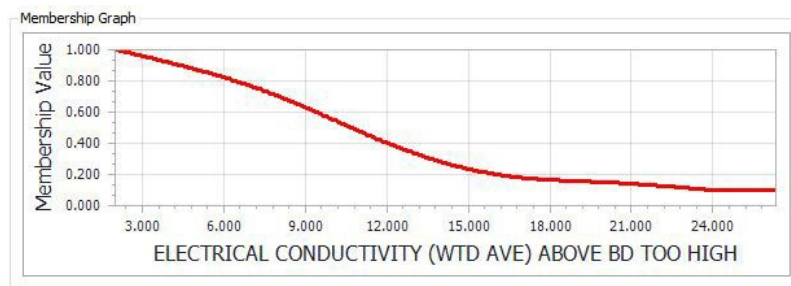


EC units are mmhos/cm.

(ii) 0-150 cm depth

Arbitrary curve, control points:

X Value	2	8		12	16	20	24
Y Value	1	0.7		0.4	0.2	0.15	0.1



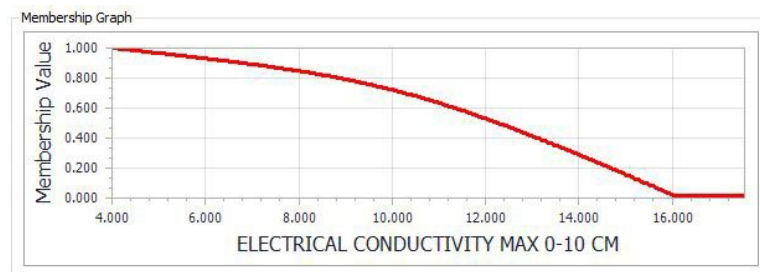
EC units are mmhos/cm. Restriction based on Component restrictive layer, pH<=3.5, EC >=16, or Bulk Density too high.

c. Small Grains Submodel

(i) 0-10 cm depth (germination)

Arbitrary curve, control points:

X Value	4	6	10	16
Y Value	1	0.93	0.72	0.02

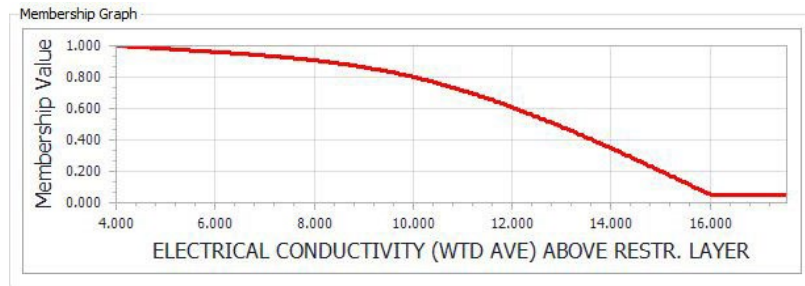


EC units are mmhos/cm.

(ii) 0-150 cm depth

Arbitrary curve, control points:

X Value	4	6	10	16
Y Value	1	0.96	0.8	0.05

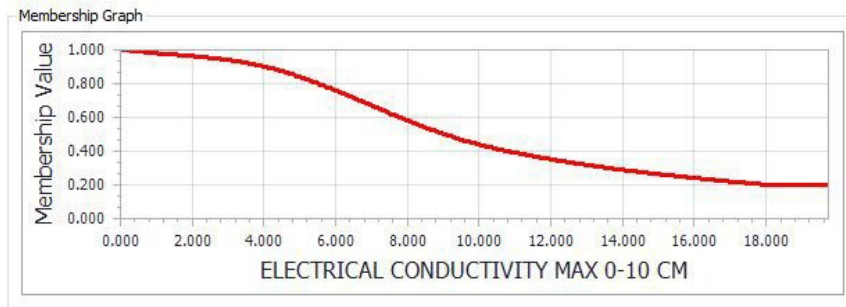


EC units are mmhos/cm. Restriction based on Component restrictive layer, pH<=3.5, EC >=16, or Bulk Density too high.

d. Cotton Submodel

(i) 0-10 cm depth (germination) Arbitrary curve, control points:

X Value	0	1	4	9	12	18
Y Value	1	0.98	0.9	0.5	0.35	0.2

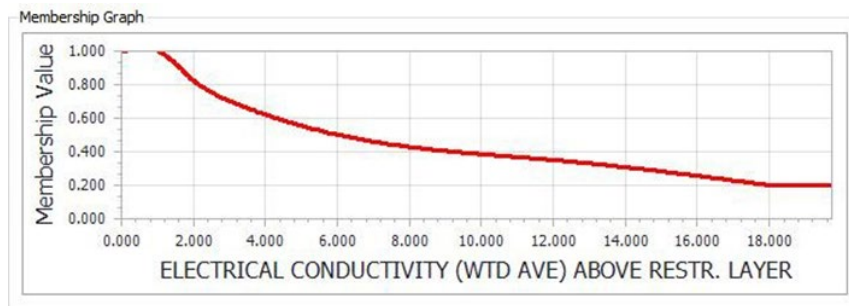


EC units are mmhos/cm.

(ii) 0-150 cm depth

Arbitrary curve, control points:

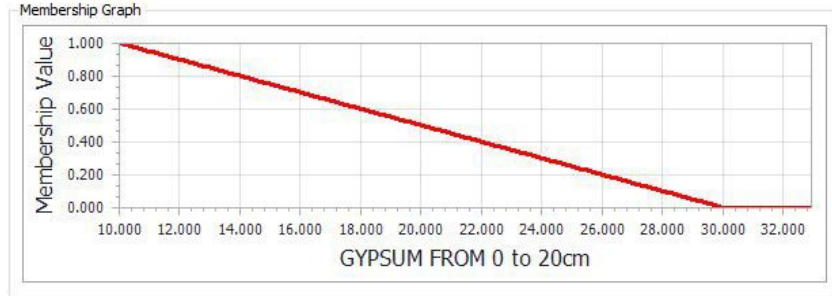
X Value	0	1	2	3	6	12	18
Y Value	1	1	0.82	0.7	0.5	0.35	0.2



EC units are mmhos/cm. Restriction based on Component restrictive layer, pH<=3.5, EC >=16, or Bulk Density too high.

6. Adverse RZ Gypsum – The same generic evaluation is used for all four crop submodels and applied to two depth ranges, 0-20 cm and 20-150 cm.

Linear curve, low value = 10, high value = 30.



Units are percent by weight of material less than 20 mm in size.

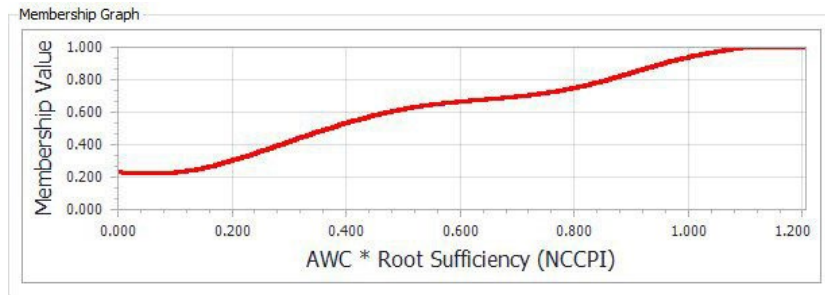
### Water Subrules

7. RZ AWC Sufficiency

- a. Corn Submodel

Arbitrary curve, control points:

X Value	0	0.1	0.3	0.5	0.8	1	1.1
Y Value	0.23	0.23	0.42	0.62	0.75	0.94	1

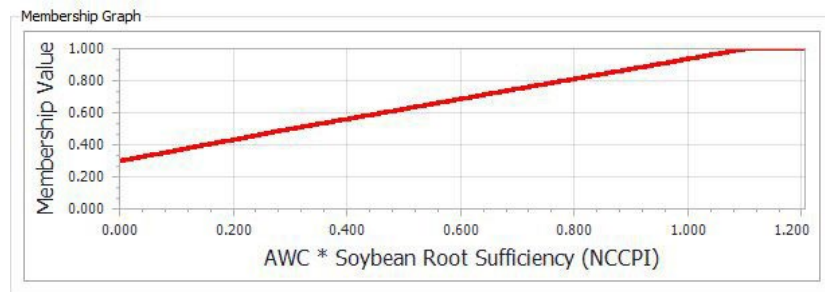


AWC is in cm.

- b. Soybeans Submodel

Arbitrary linear, control points:

X Value	0	0.15	0.3	1.1
Y Value	0.3	0.4	0.5	1

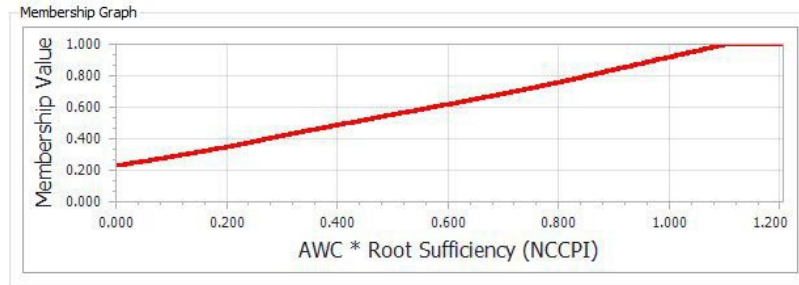


AWC is in cm.

c. Small Grains Submodel

Arbitrary curve, control points:

X Value	0	0.2	0.3	0.6	0.8	0.9	1.1
Y Value	0.23	0.35	0.42	0.62	0.76	0.84	1



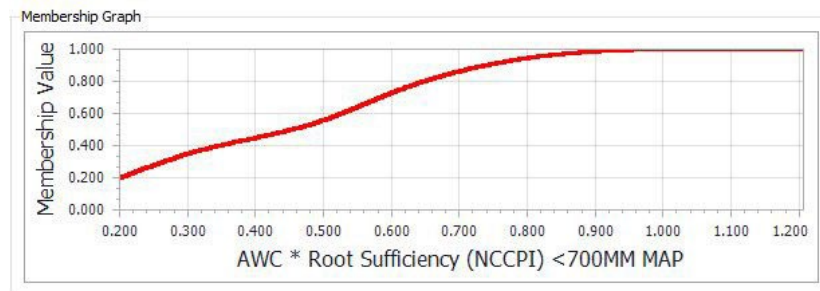
AWC is in cm.

d. Cotton Submodel – Four arbitrary curves based on mean annual precipitation (MAP).

(i) MAP <700 mm

Arbitrary curve, control points:

X Value	0.20	0.3	0.4	0.5	0.6	1	1.1
Y Value	0.2	0.35	0.45	0.56	0.73	1	1

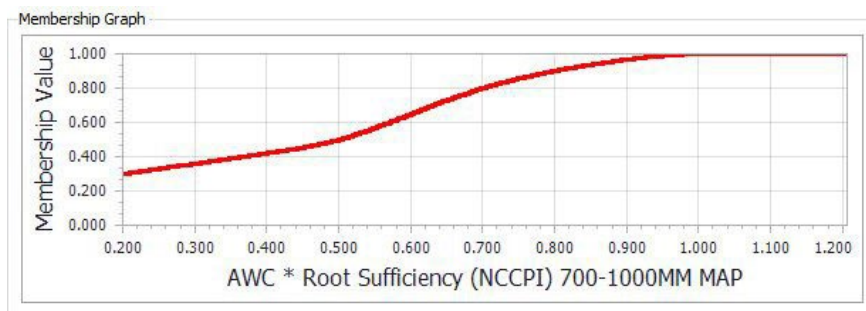


AWC is in cm.

(ii) MAP 700-1000 mm

Arbitrary curve, control points:

X Value	0.2	0.4	0.5	0.6	0.7	0.8	1	1.1
Y Value	0.3	0.42	0.5	0.65	0.8	0.9	1	1



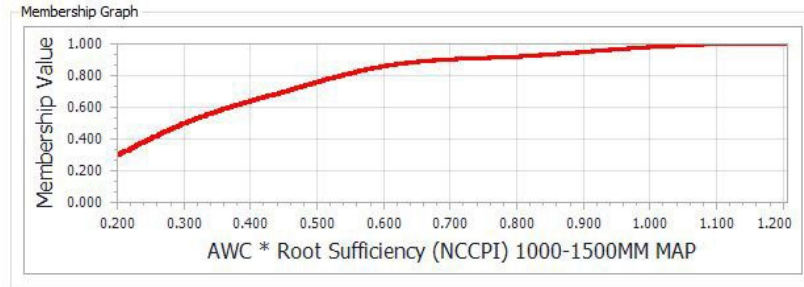
AWC is in cm.



(iii) MAP 1000-1500 mm

Arbitrary curve, control points:

X Value	0.2	0.3	0.45	0.5	0.6	0.8	0.9	1	1.1
Y Value	0.3	0.5	0.7	0.76	0.86	0.92	0.95	0.98	1

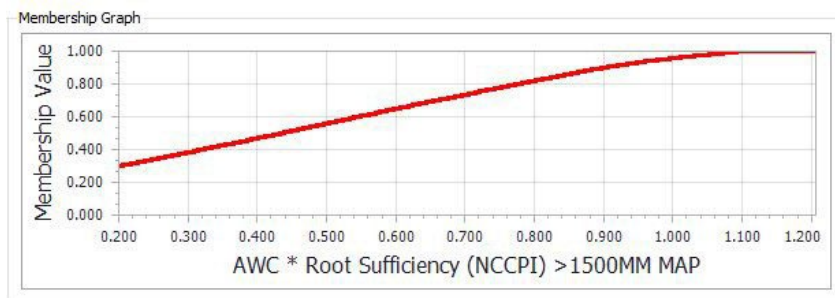


AWC is in cm.

(iv) MAP >1500 mm

Arbitrary curve, control points:

X Value	0.2	0.4	0.6	0.8	0.9	1.1
Y Value	0.3	0.47	0.65	0.82	0.9	1



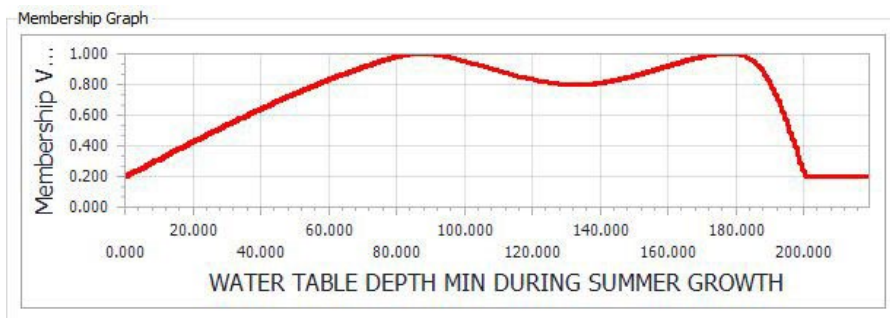
AWC is in cm.

8. Water Table Recharge

a. Corn Submodel

Arbitrary curve, control points:

X Value	0	75	85	100	136	175	190	200
Y Value	0.2	0.95	1	0.95	0.8	1	0.8	0.2

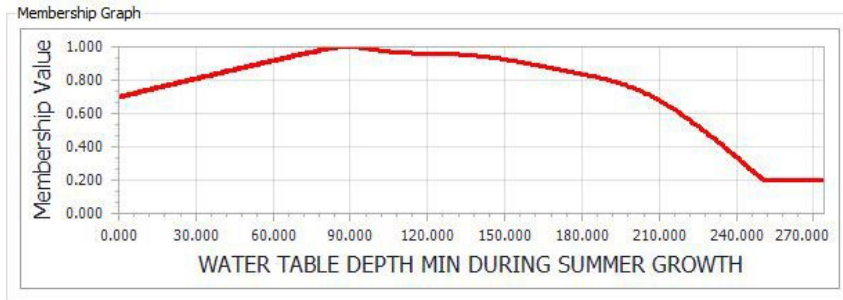


Depth is in cm.

b. Soybeans Submodel

Arbitrary curve, control points:

X Value	0	75	90	100	136	175	190	200	250
Y Value	0.7	0.97	1	0.98	0.95	0.85	0.8	0.75	0.2

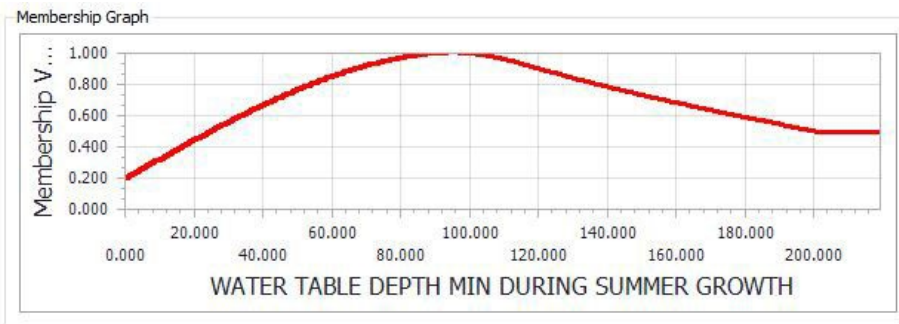


Depth is in cm.

c. Small Grains Submodel

Arbitrary curve, control points:

X Value	0	75	85	100	120	200
Y Value	0.2	0.95	0.99	1	0.9	0.5

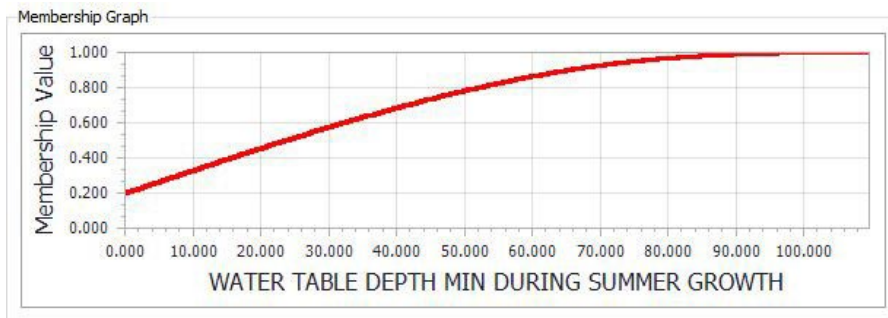


Depth is in cm.

d. Cotton Submodel

Arbitrary curve, control points:

X Value	0	75	85	100
Y Value	0.2	0.95	0.98	1



Depth is in cm.

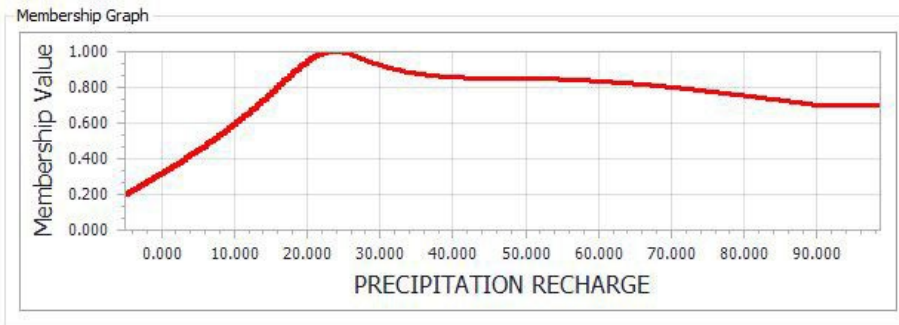
9. Precipitation Recharge – All four crop submodels consider precipitation recharge separately but also take into account the influence of hydraulic conductivity ( $K_{sat}$ ) and organic matter in the soil profile.

a. Precipitation Recharge

(i) Corn Submodel

Arbitrary curve, control points:

X Value	-5	15	23	28	50	70	90
Y Value	0.2	0.77	1	0.95	0.85	0.8	7

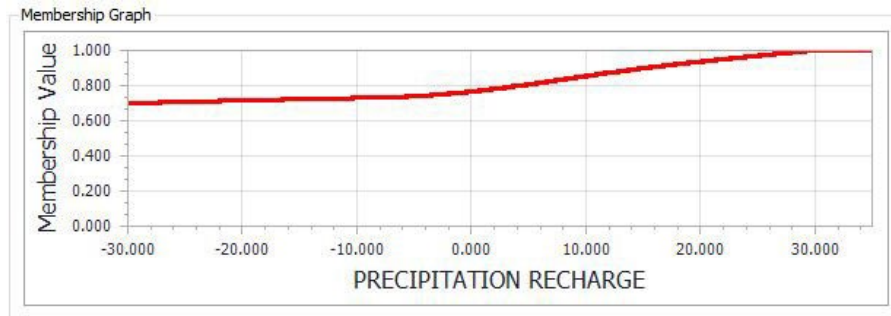


Precipitation is in mm.

(ii) Soybeans Submodel

Arbitrary curve, control points:

X Value	-30	-10	-5	15	28	30	31	32
Y Value	0.7	0.73	0.74	0.9	0.99	1	1	1

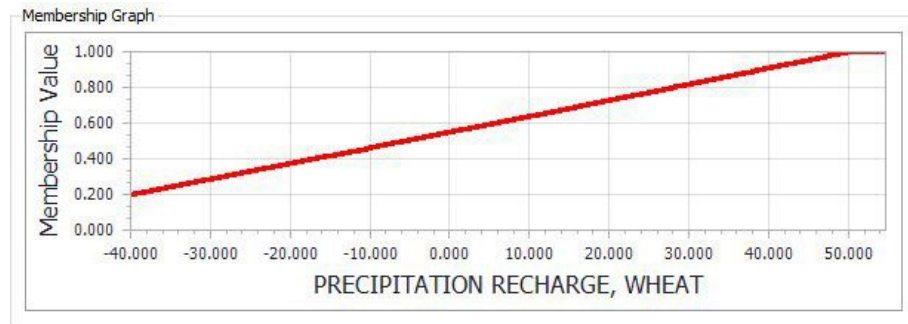


Precipitation is in mm.

(iii) Small Grains Submodel

Arbitrary curve, control points:

X Value	-40	50	0
Y Value	0.2	1	0.55

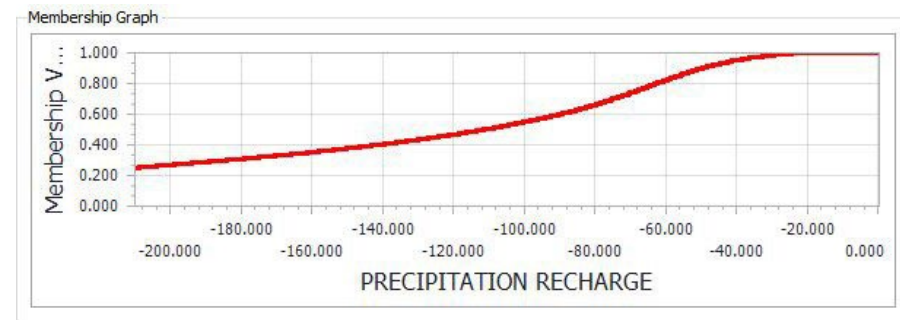


Precipitation is in mm.

(iv) Cotton Submodel

Arbitrary curve, control points:

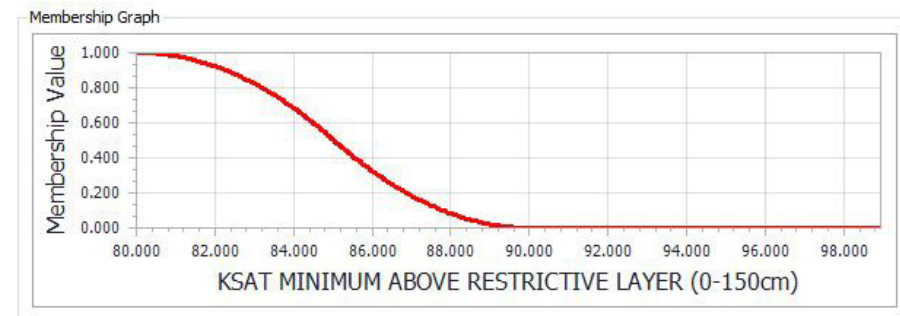
X Value	-210	-170	-100	-90	-75	-20	0	-50
Y Value	0.25	0.33	0.55	0.6	0.7	1	1	0.9



Precipitation is in mm.

b.  $K_{sat}$  Minimum within 150 cm

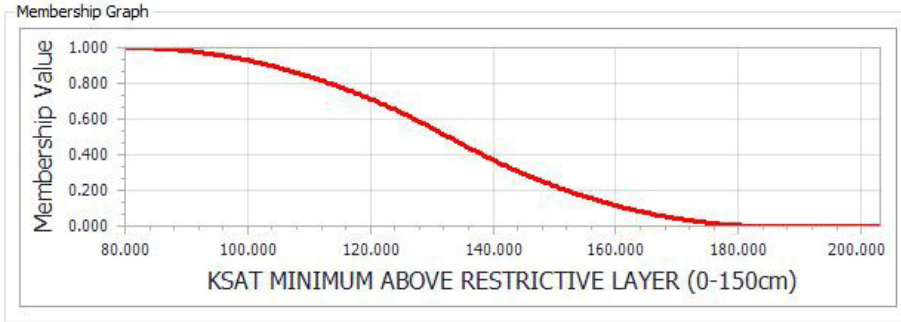
(i) Corn, Small Grains, and Cotton Submodels Sigmoid, low value 80, high value 90:



$K_{sat}$  times LEP. Units are  $\mu\text{m}/\text{sec}$ .

(ii) Soybeans Submodel

Sigmoid, low value 80, high value 185:

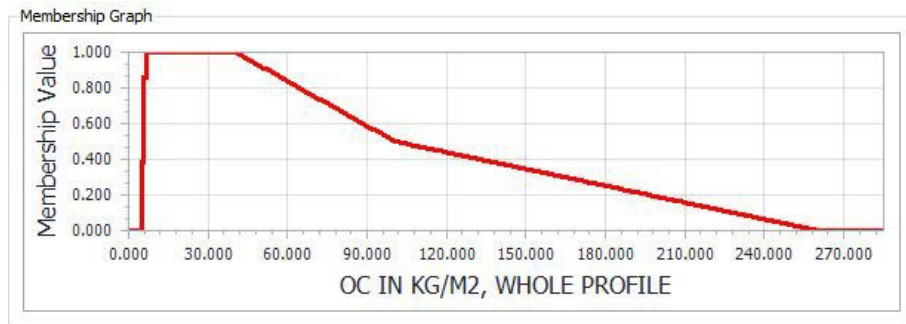


$K_{sat}$  times LEP. Units are  $\mu\text{m}/\text{sec}$ .

c. Organic matter

Arbitrary linear, control points:

X Value	0	4	6	40	100	260
Y Value	0	0	1	1	0.5	0

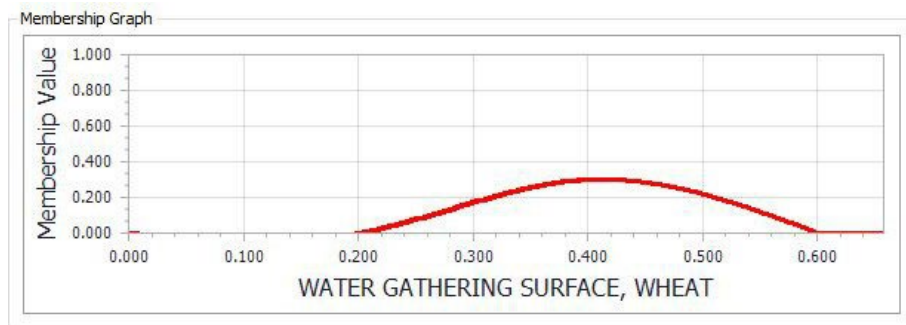


Units are kilograms of OC per square meter of soil.

10. Water-Gathering Surface (not used in the Cotton Submodel)

a. Corn and Soybeans Submodels Arbitrary curve, control points:

X Value	0	0.2	0.4	0.6
Y Value	0	0	0.3	0

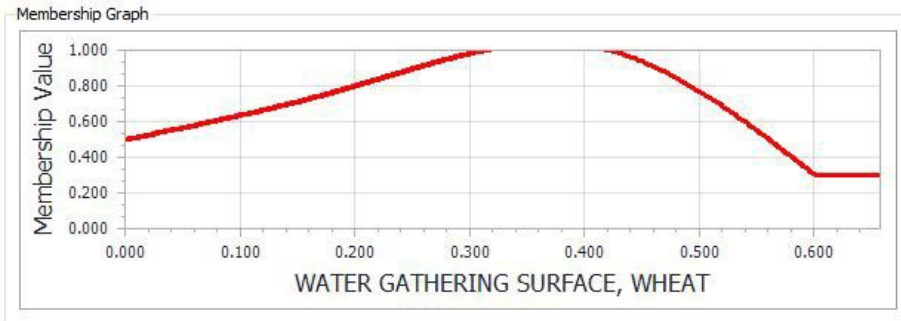


Unitless multiplier to adjust the effect of slope shape for differing rainfall. Property is the same as for wheat, but evaluation is adjusted for corn and soybeans.

b. Small Grains Submodel

Arbitrary curve, control points:

X Value	0	0.2	0.42	0.6
Y Value	0.5	0.8	1	0.3



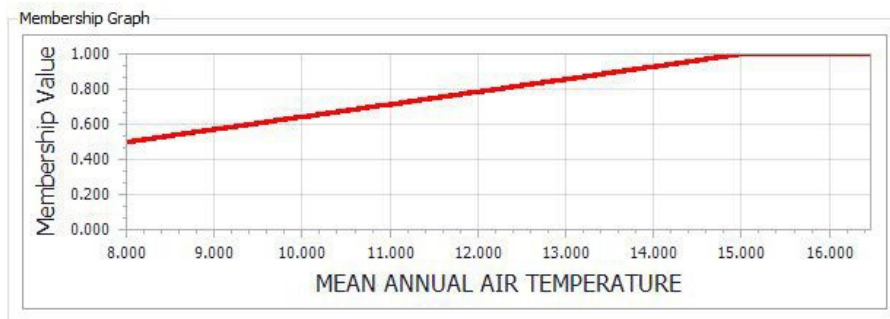
Unitless multiplier to adjust the effect of slope shape for differing rainfall.

11. Mean Annual Air Temperature (MAT) (not used in the Small Grains or Cotton Submodel)

a. Small Grains Submodel

Arbitrary linear, control points:

X Value	8	15
Y Value	0.5	1



Mean annual air temperature in degrees Celsius.

### Soil Physical Properties Subrules

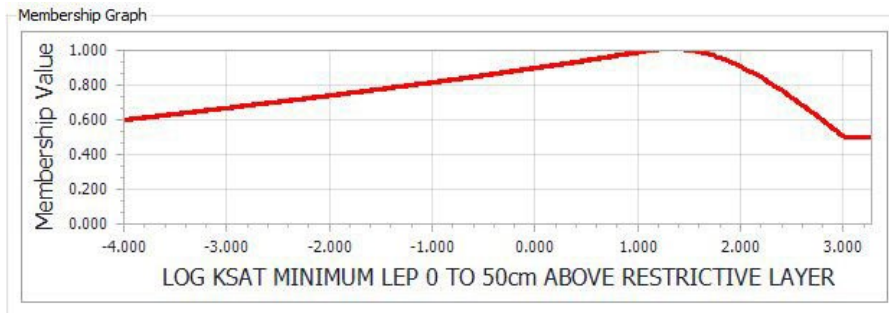
12.  $K_{sat}$  Minimum – Considered for three depth ranges (0-50, 50-100, and 100-150 cm) for each submodel.

a. Corn Submodel

(i) 0-50 cm

Arbitrary curve, control points:

X Value	-4	0.99	1.1	1.6	3
Y Value	0.6	0.99	1	0.99	0.5

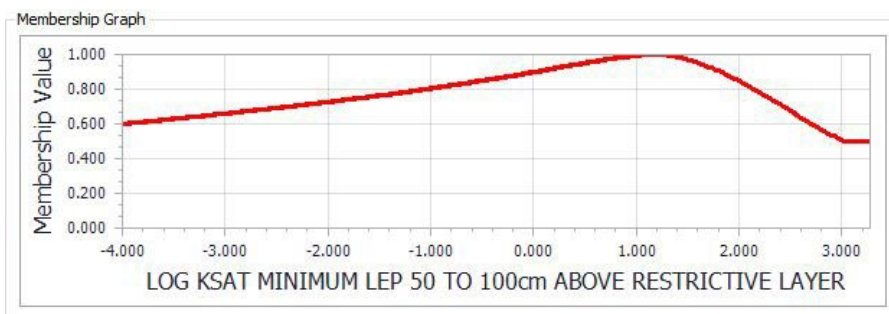


Log ( $K_{sat}$  times LEP) from 0-50 cm evaluation. Units are  $\log(\mu/\text{sec})$ . Restrictive layer is Component Restriction,  $EC \geq 16.01$ , or  $pH \leq 3.5$ .

(ii) 50-100 cm

Arbitrary curve, control points:

X Value	-4	0	1	1.1	1.6	2.7	3
Y Value	0.6	0.9	0.995	1	0.95	0.6	0.5

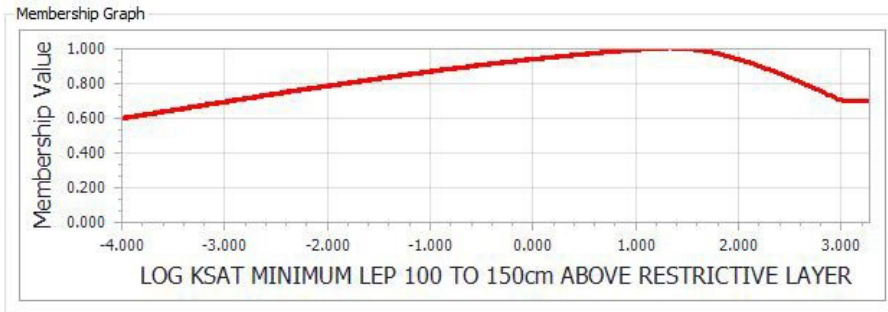


Log ( $K_{sat}$  times LEP) from 50-100 cm evaluation. Units are  $\log(\mu/\text{sec})$ . Restrictive layer is Component Restriction, bulk density too high,  $EC \geq 16.01$ , or  $pH \leq 3.5$ .

(iii) 100-150 cm

Arbitrary curve, control points:

X Value	-4	1	1.5	1.8	3
Y Value	0.6	0.995	1	0.97	0.7



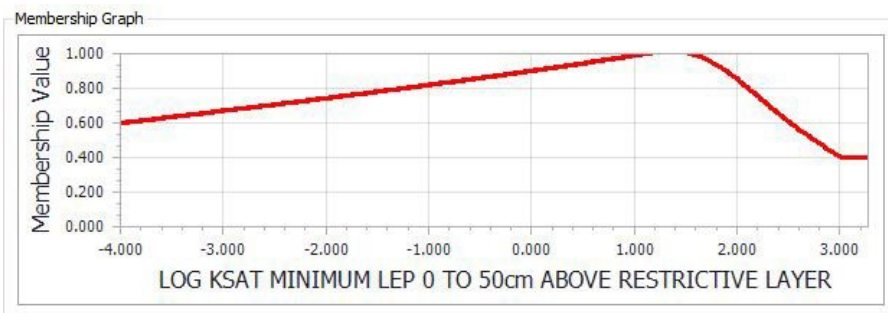
Log ( $K_{sat}$  times LEP) from 100-150 cm evaluation. Units are  $\log(\mu/\text{sec})$ . Restrictive layer is Component Restriction, bulk density too high,  $EC \geq 16.01$ , or  $pH \leq 3.5$ .

b. Soybeans Submodel

(i) 0-50 cm

Arbitrary curve, control points:

X Value	-4	0.99	1.1	1.6	2.4	3
Y Value	0.6	0.99	1	0.99	0.65	0.4



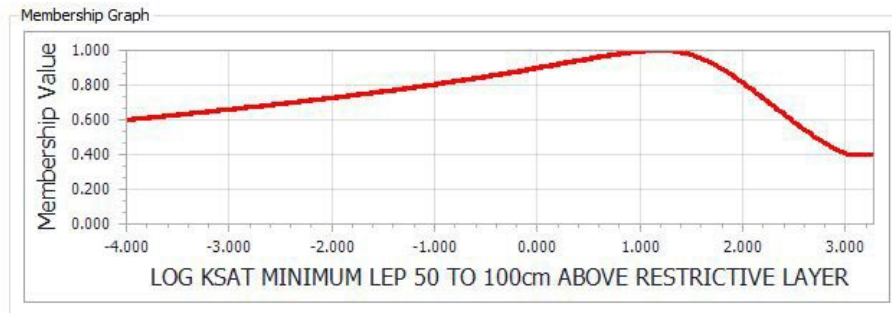
Log ( $K_{sat}$  times LEP) from 0-50 cm evaluation. Units are  $\log(\mu/\text{sec})$ . Restrictive layer is Component Restriction,  $EC \geq 16.01$ , or  $pH \leq 3.5$ .



(ii) 50-100 cm

Arbitrary curve, control points:

X Value	-4	0	1	1.1	1.6	2.7	3
Y Value	0.6	0.9	0.995	1	0.95	0.5	0.4

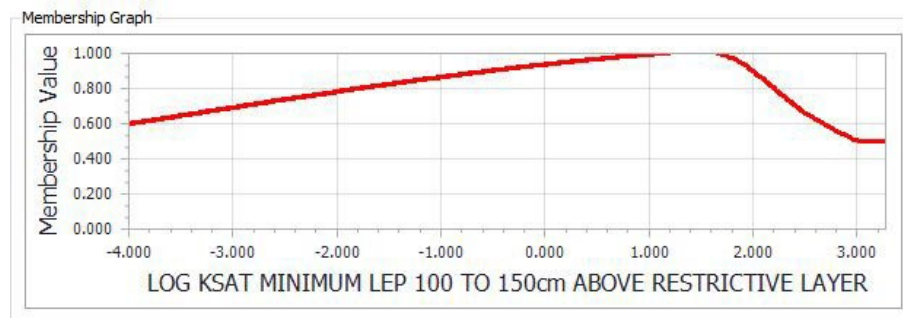


Log ( $K_{sat}$  times LEP) from 50-100 cm evaluation. Units are  $\log(\mu/\text{sec})$ . Restrictive layer is Component Restriction, bulk density too high,  $EC \geq 16.01$ , or  $pH \leq 3.5$ .

(iii) 100-150 cm

Arbitrary curve, control points:

X Value	-4	1	1.1	1.8	2.4	3
Y Value	0.6	0.995	1	0.97	0.7	0.5



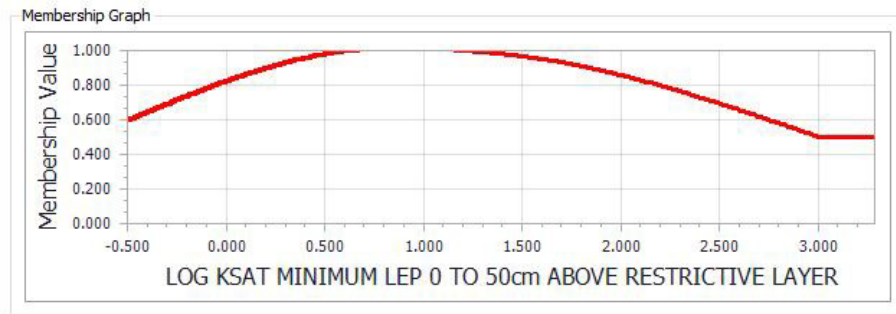
Log ( $K_{sat}$  times LEP) from 50-100 cm evaluation. Units are  $\log(\mu/\text{sec})$ . Restrictive layer is Component Restriction, bulk density too high,  $EC \geq 16.01$ , or  $pH \leq 3.5$ .

c. Small Grains Submodel

(i) 0-50 cm

Arbitrary curve, control points:

X Value	-0.5	0.55	1.2	1.6	3
Y Value	0.6	0.99	1	0.95	0.5



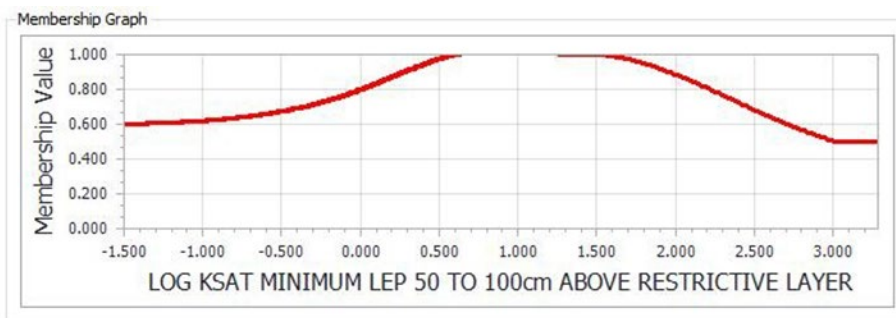
Log ( $K_{sat}$  times LEP) from 0-50 cm evaluation. Units are  $\log(\mu/\text{sec})$ . Restrictive layer is Component Restriction, bulk density too high,  $EC \geq 16.01$ , or  $pH \leq 3.5$ .

(ii) 50-100 cm

(1) Restrictive layer is Component Restriction or  $pH \leq 3.5$ .

Arbitrary curve, control points:

X Value	-1.5	0	0.6	1.4	1.5	1.6	2.7	3
Y Value	0.6	0.8	1	1	1	0.99	0.6	0.5

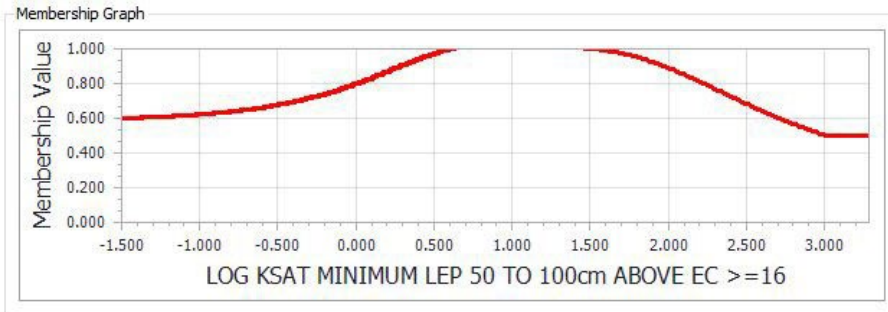


Log ( $K_{sat}$  times LEP) from 50-100 cm evaluation. Units are  $\log(\mu/\text{sec})$ .

(2) Restrictive layer is bulk density too high or EC  $\geq 16.01$ .

Arbitrary curve, control points:

X Value	-1.5	0	0.6	1.5	1.6	2.7	3
Y Value	0.6	0.8	1	1	0.99	0.6	0.5

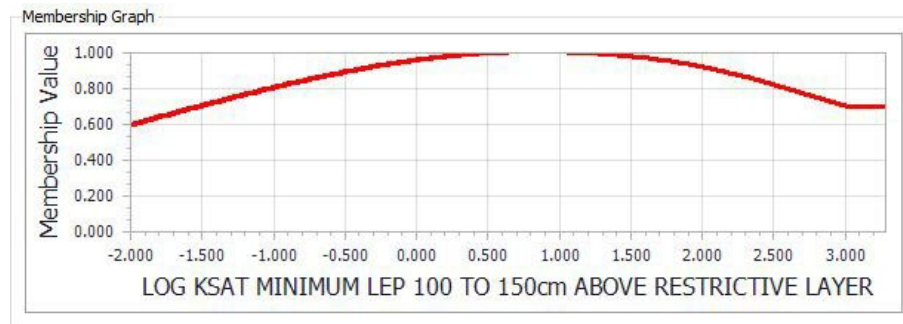


Log ( $K_{sat}$  times LEP) from 50-100 cm evaluation. Units are  $\log(\mu/\text{sec})$ .

(iii) 100-150 cm

Arbitrary curve, control points:

X Value	-2	0.5	1.5	1.8	3
Y Value	0.6	1	0.98	0.95	0.7



Log ( $K_{sat}$  times LEP) from 100-150 cm evaluation. Units are  $\log(\mu/\text{sec})$ . Restrictive layer is Component Restriction, bulk density too high, EC  $\geq 16.01$ , or pH  $\leq 3.5$ .

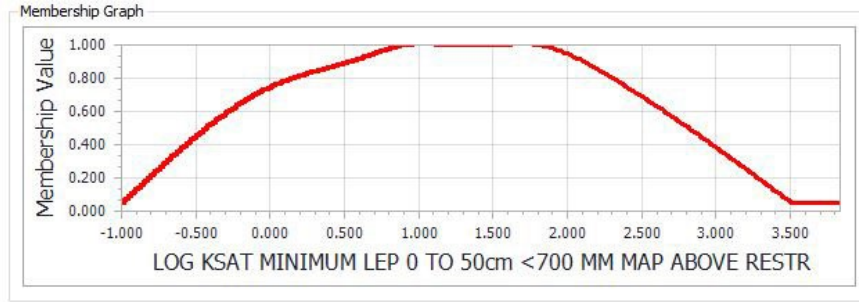
d. Cotton Submodel – Evaluates soils differently based on mean annual precipitation (MAP). Restriction types are Component Restrictions.

(i) MAP <700 mm

(1) 0-50 cm

Arbitrary curve, control points:

X Value	-1	0	0.6	0.9	1.2	1.4	1.5	1.8	2.2	3.5
Y Value	0.05	0.75	0.92	1	1	1	1	1	0.85	0.05

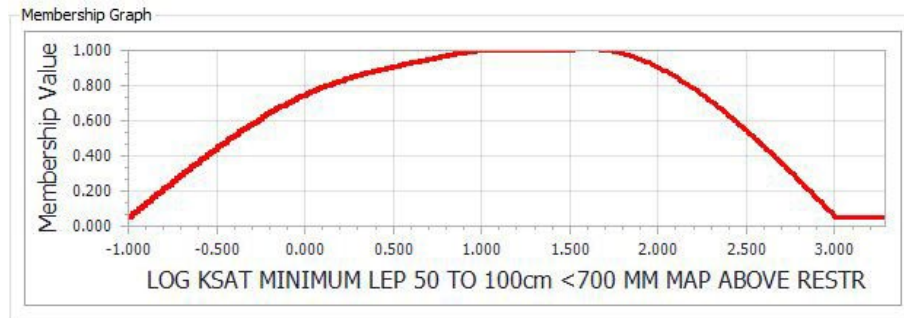


Log ( $K_{sat}$  times LEP) from 0-50 cm evaluation. Units are  $\log(\mu/\text{sec})$ .

(2) 50-100 cm

Arbitrary curve, control points:

X Value	-1	0	0.7	1.7	2	3	1	1.4
Y Value	0.05	0.75	0.95	1	0.9	0.05	1	1

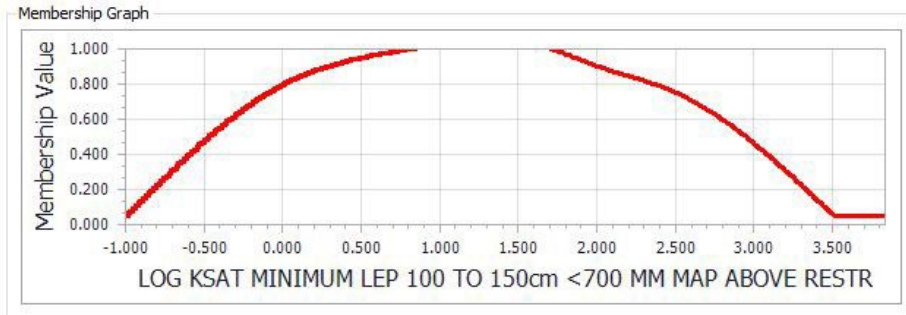


Log ( $K_{sat}$  times LEP) from 50-100 cm evaluation. Units are  $\log(\mu/\text{sec})$ .

(3) 100-150 cm

Arbitrary curve, control points:

X Value	-1	0	0.8	1.7	2	3.5	0.5	2.5
Y Value	0.05	0.8	1	1	0.9	0.05	0.95	0.75



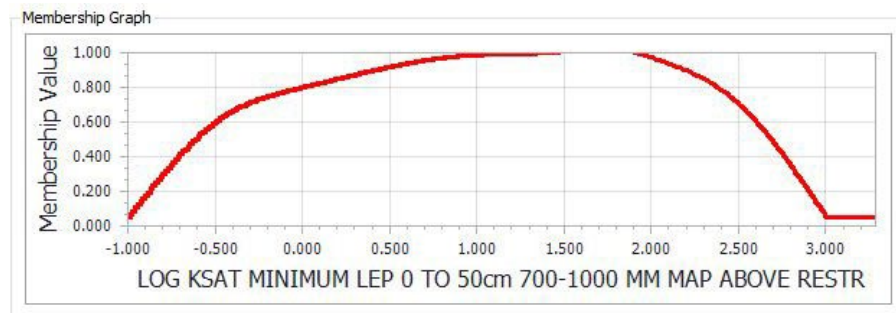
Log ( $K_{sat}$  times LEP) from 100-150 cm evaluation. Units are  $\log(\mu/\text{sec})$ .

(ii) MAP 700-1000 mm

(1) 0-50 cm

Arbitrary curve, control points:

X Value	-1	-0.5	0.9	1.4	1.9	2	2.5	3	0
Y Value	0.05	0.6	0.98	1	1	0.97	0.7	0.05	0.8

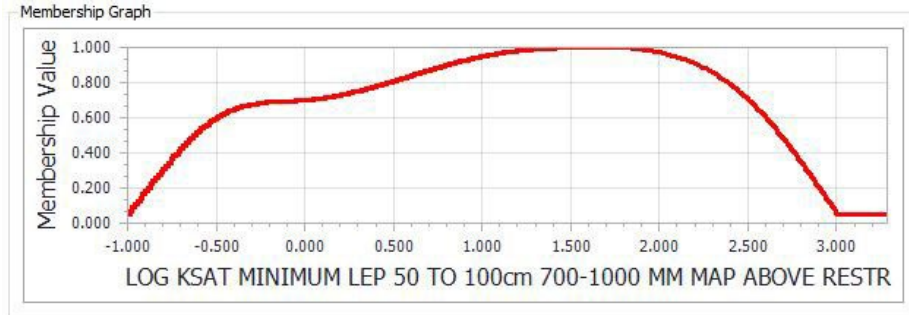


Log ( $K_{sat}$  times LEP) from 0-50 cm evaluation. Units are  $\log(\mu/\text{sec})$ .

(2) 50-100 cm

Arbitrary curve, control points:

X Value	-1	0.5	0.8	1	1.5	2	2.5	3	0
Y Value	0.05	0.6	0.9	0.95	1	0.97	0.7	0.05	0.7

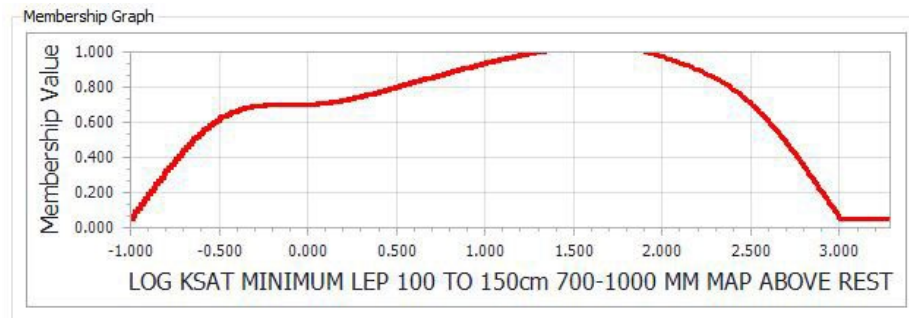


Log ( $K_{sat}$  times LEP) from 50-100 cm evaluation. Units are  $\log(\mu/\text{sec})$ .

(3) 100-150 cm

Arbitrary curve, control points:

X Value	-1	-0.5	0.5	1.3	1.9	2	2.5	3	0
Y Value	0.05	0.62	0.8	1	1	0.97	0.7	0.05	0.7



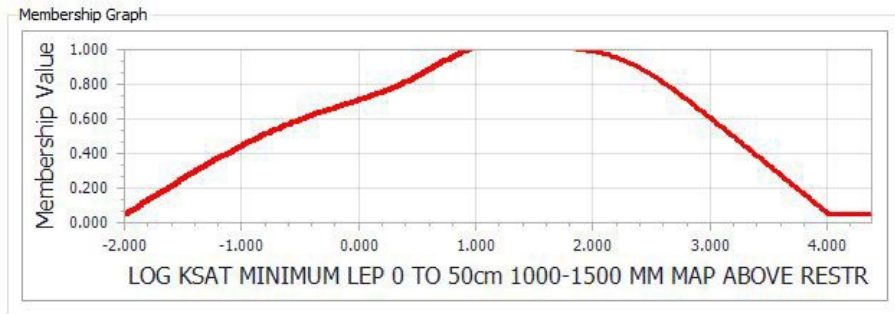
Log ( $K_{sat}$  times LEP) from 100-150 cm evaluation. Units are  $\log(\mu/\text{sec})$ .

(iii) MAP 1000-1500 mm

(1) 0-50 cm

Arbitrary curve, control points:

X Value	-2	-0.5	0.5	0.92	2	2.5	3	4	1.9
Y Value	0.05	0.6	0.85	1	0.99	0.85	0.6	0.05	1

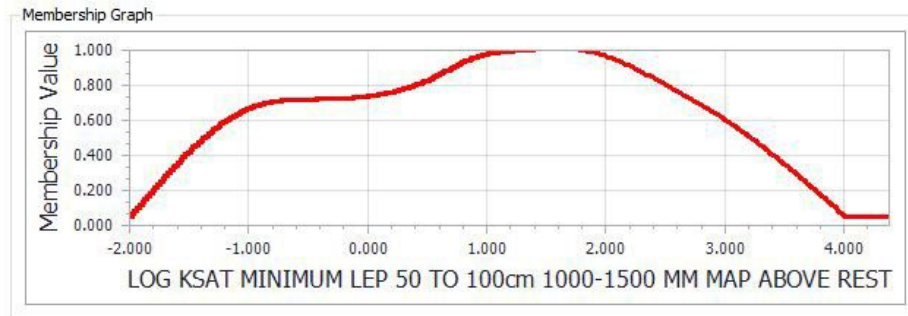


Log ( $K_{sat}$  times LEP) from 0-50 cm evaluation. Units are  $\log(\mu/\text{sec})$ .

(2) 50-100 cm

Arbitrary curve, control points:

X Value	-2	-0.5	1.3	0.5	0.9	1.8	2.5	3	4	-1
Y Value	0.05	0.72	1	0.83	0.96	1	0.8	0.6	0.05	0.67

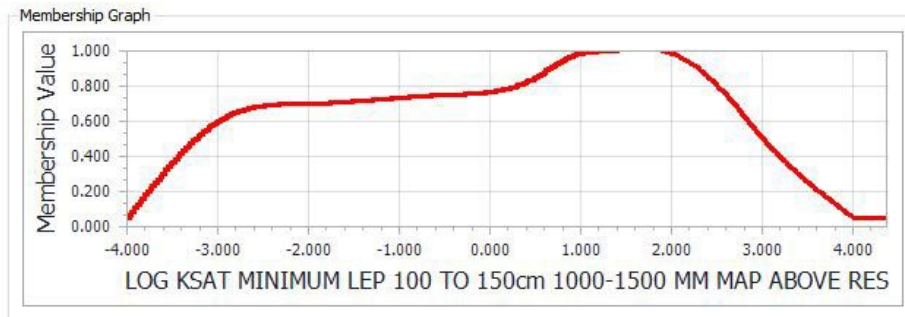


Log ( $K_{sat}$  times LEP) from 50-100 cm evaluation. Units are  $\log(\mu/\text{sec})$ .

(3) 100-150 cm

Arbitrary curve, control points:

X Value	-2	-0.5	1.3	0.5	0.9	1.9	2.5	3	4	-3	-4
Y Value	0.7	0.75	1	0.85	0.97	1	0.8	0.5	0.05	0.6	0.05



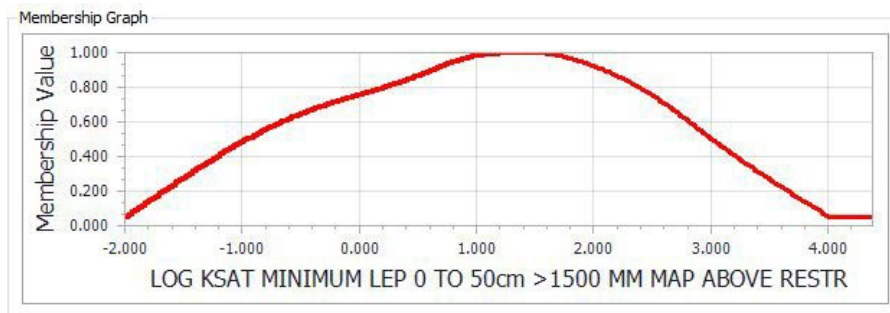
Log ( $K_{sat}$  times LEP) from 100-150 cm evaluation. Units are  $\log(\mu/\text{sec})$ .

(iv) MAP >1500 mm

(1) 0-50 cm

Arbitrary curve, control points:

X Value	-2	-0.5	1.35	0.5	0.9	2	2.5	3	4	1.5
Y Value	0.05	0.65	1	0.87	0.97	0.92	0.75	0.5	0.05	1



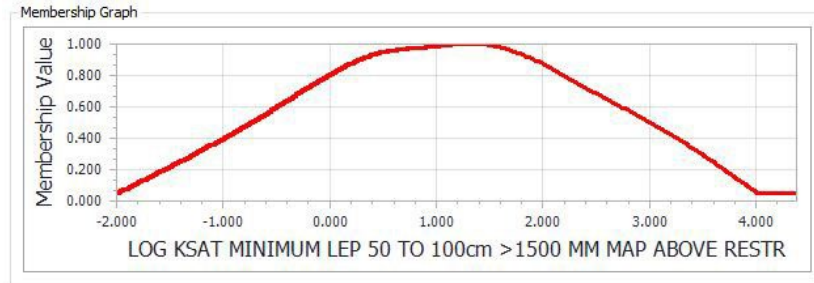
Log ( $K_{sat}$  times LEP) from 0-50 cm evaluation. Units are  $\log(\mu/\text{sec})$ .



(2) 50-100 cm

Arbitrary curve, control points:

X Value	-2	-0.5	1.4	0.5	0.9	2	2.5	3	4
Y Value	0.05	0.6	1	0.95	0.98	0.87	0.68	0.5	0.05

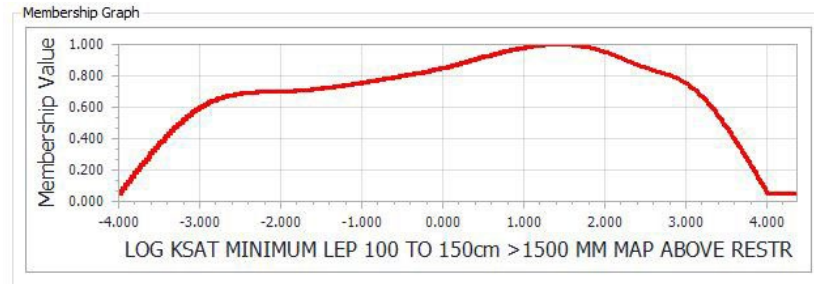


Log ( $K_{sat}$  times LEP) from 50-100 cm evaluation. Units are  $\log(\mu/\text{sec})$ .

(3) 100-150 cm

Arbitrary curve, control points:

X Value	-2	-0.5	1.43	0.5	0.9	2	2.5	3	4	0	-3	-4
Y Value	0.7	0.8	1	0.92	0.97	0.95	0.85	0.75	0.05	0.85	0.6	0.05



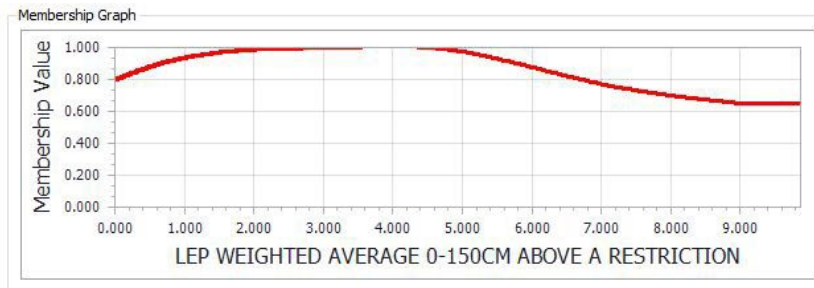
Log ( $K_{sat}$  times LEP) from 100-150 cm evaluation. Units are  $\log(\mu/\text{sec})$ .

13. RZ LEP – Restrictions are Component Restrictions.

a. Corn Submodel

Arbitrary curve, control points:

X Value	0	0.5	1.5	3.2	4.5	7	9
Y Value	0.8	0.88	0.97	1	1	0.77	0.65

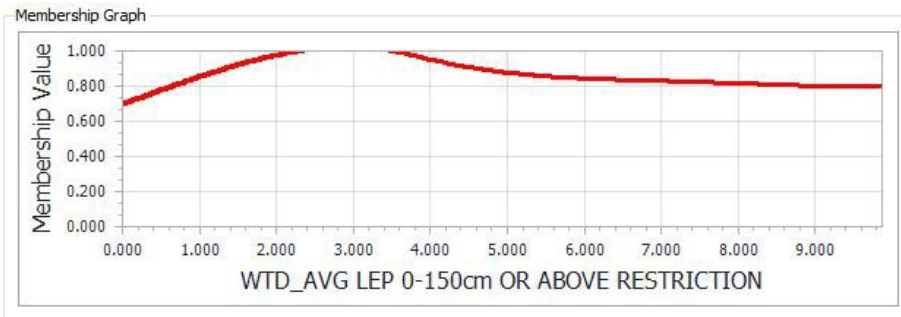


LEP from 0-150 cm evaluation. Units are  $\text{cm}^3/\text{cm}^3$ .

b. Soybeans Submodel

Arbitrary curve, control points:

X Value	0	0.5	1.1	3.5	4	7	9
Y Value	0.7	0.78	0.87	1	0.95	0.83	0.8

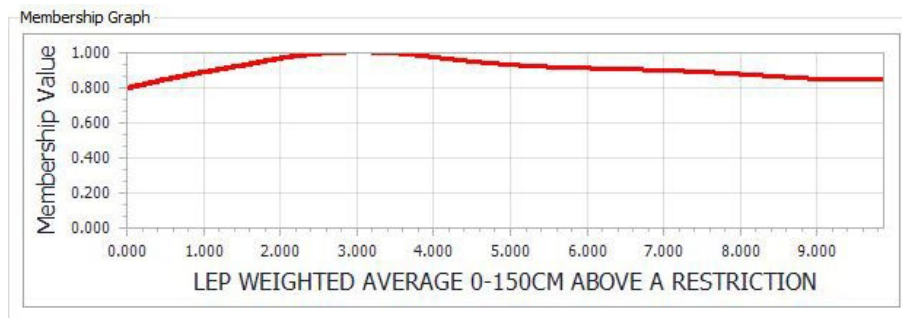


LEP from 0-150 cm evaluation. Units are  $\text{cm}^3/\text{cm}^3$ .

c. Small Grains Submodel

Arbitrary curve, control points:

X Value	0	0.5	1.5	2	3.4	4.5	7	9
Y Value	0.8	0.85	0.93	0.97	1	0.95	0.9	0.85



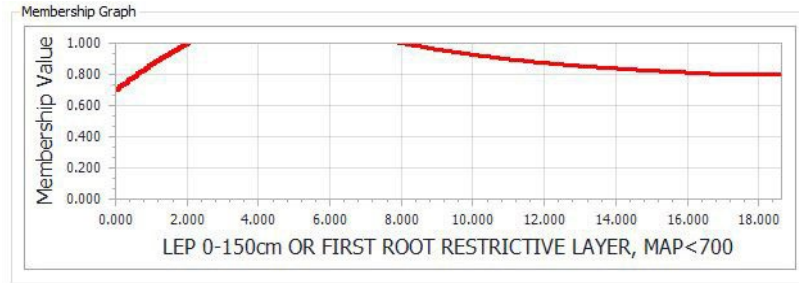
LEP from 0-150 cm evaluation. Units are  $\text{cm}^3/\text{cm}^3$ .

- d. Cotton Submodel - Evaluates soils differently based on mean annual precipitation (MAP). Restriction types are Component Restrictions.

(i) MAP <700 mm

Arbitrary curve, control points:

X Value	0	2	8	17
Y Value	0.7	1	1	0.8

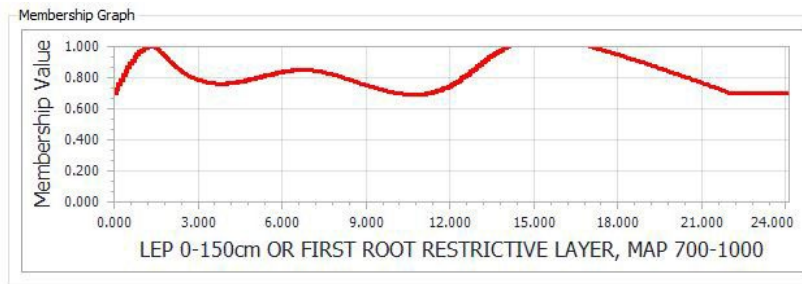


LEP from 0-150 cm evaluation. Units are  $\text{cm}^3/\text{cm}^3$ .

(ii) MAP 700-1000 mm

Arbitrary curve, control points:

X Value	0	1.3	2	6.7	9	12	14	17	22
Y Value	0.7	1	0.9	0.85	0.75	0.75	1	1	0.7

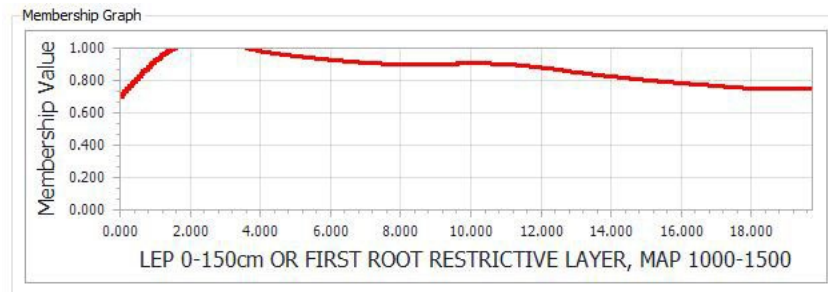


LEP from 0-150 cm evaluation. Units are  $\text{cm}^3/\text{cm}^3$ .

(iii) MAP 1000-1500 mm

Arbitrary curve, control points:

X Value	0	1.5	5	8	11	13	18	4
Y Value	0.7	1	0.95	0.9	0.9	0.85	0.75	0.98

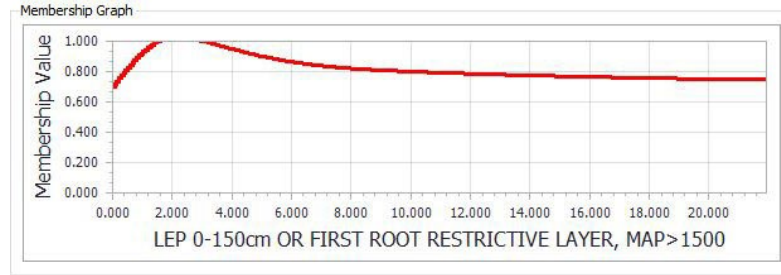


LEP from 0-150 cm evaluation. Units are  $\text{cm}^3/\text{cm}^3$ .

(iv) MAP >1500 mm

Arbitrary curve, control points:

X Value	0	1.5	5	10	20	3
Y Value	0.7	1	0.9	0.8	0.75	1



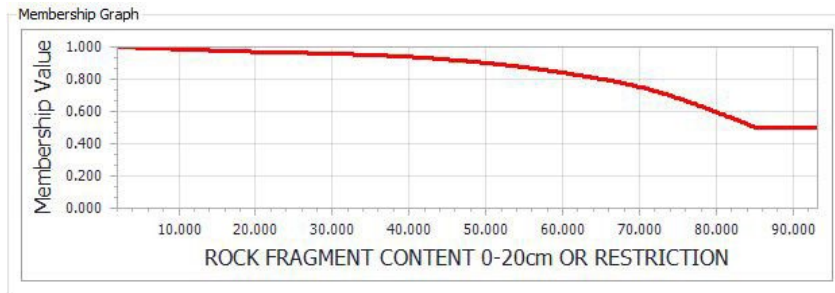
LEP from 0-150 cm evaluation. Units are  $\text{cm}^3/\text{cm}^3$ .

14. RZ Rock Fragment – Same for all four crop submodels.

a. 0-20 cm

Arbitrary curve, control points:

X Value	2	20	35	65	70	85
Y Value	1	0.97	0.95	0.8	0.75	0.5

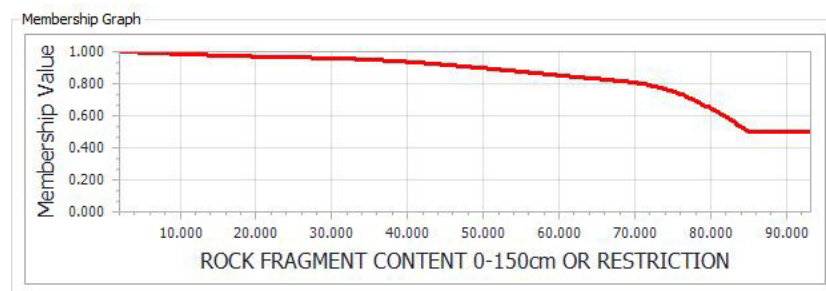


Evaluation of rock fragment volume 0-20 cm. Units are % by volume.

b. 0-150 cm

Arbitrary curve, control points:

X Value	2	20	35	65	75	85
Y Value	1	0.97	0.95	0.83	0.75	0.5

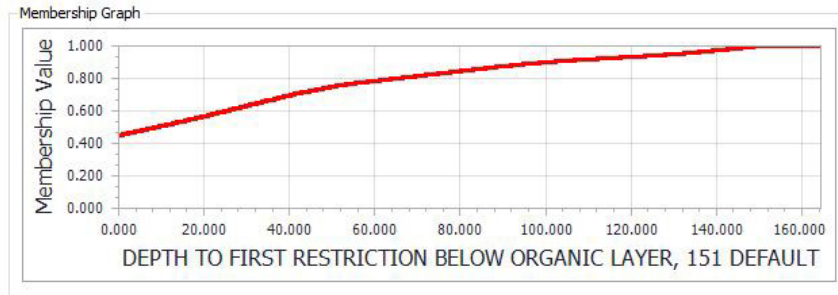


Evaluation of rock fragment volume 0-20 cm. Units are % by volume.

15. RZ Soil Depth – Same for Corn, Soybeans, and Cotton; different for Small Grains.

a. Corn, Soybeans, and Cotton Submodels Arbitrary curve, control points:

X Value	0	25	50	65	100	130	150
Y Value	0.45	0.6	0.75	0.8	0.9	0.95	1

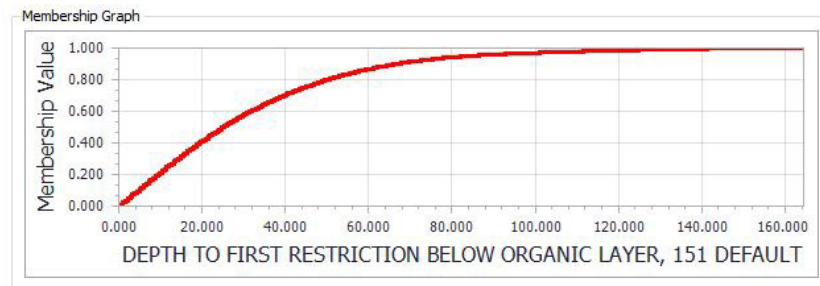


Soil depth evaluation. Units are cm.

b. Small Grains Submodel – Restriction is Component Restriction, pH <3.5, or EC >=16.01.

Arbitrary curve, control points:

X Value	0	25	50	100	150
Y Value	0	0.5	0.8	0.97	1



Soil depth evaluation. Units are cm.

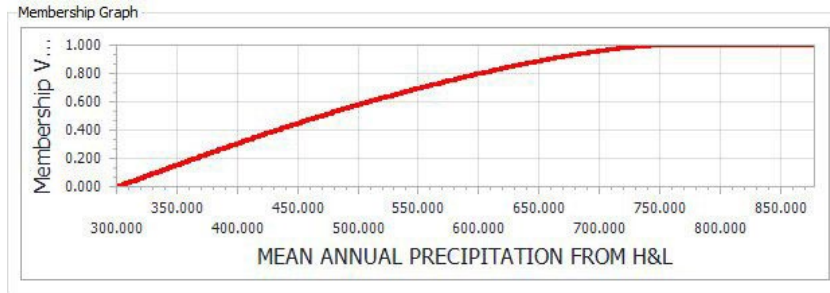
**Soil Climate Subrules**

16. Precipitation

a. Corn

Arbitrary curve, control points:

X Value	300	450	600	700	750	800
Y Value	0	0.45	0.8	0.96	1	1



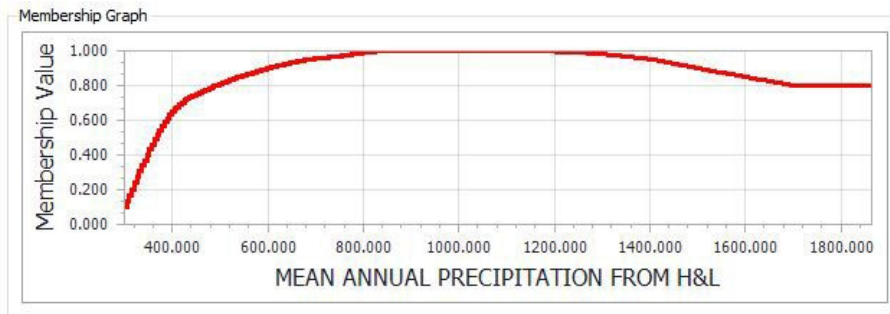
Mean annual precipitation from high and low values. Units are mm.

b. Soybeans

Arbitrary curve, control points:

X Value	300	400	450	600	700	750	800	900	1000
Y Value	0.1	0.65	0.75	0.9	0.955	0.97	0.99	1	1

X Value	1250	1400	1500	1700
Y Value	0.99	0.95	0.9	0.8

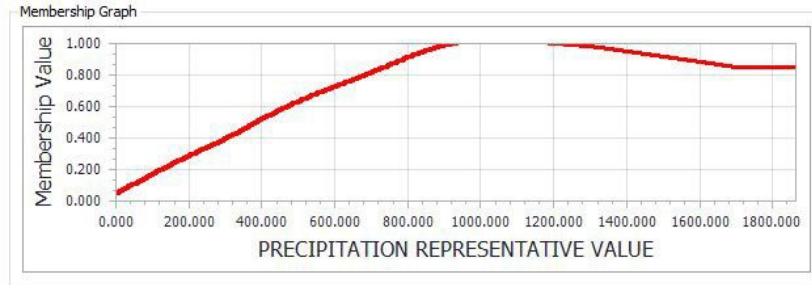


Mean annual precipitation from high and low values. Units are mm.

c. Small Grains

Arbitrary curve, control points:

X Value	0	200	300	430	600	700	900	1200	1300	1400	1700
Y Value	0.1	0.65	0.75	0.9	0.955	0.97	0.99	1	1	0.99	0.95



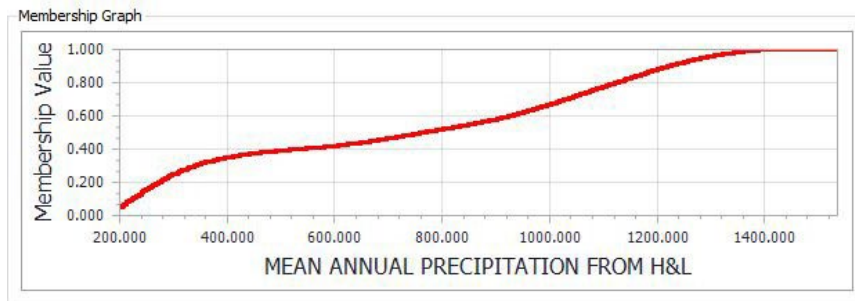
Mean annual precipitation from high and low values. Units are mm.

d. Cotton Submodel – Evaluates precipitation influence overall and depending on mean annual air temperature (MAAT).

(i) Overall

Arbitrary curve, control points:

X Value	200	300	400	600	800	900	1000	1200	1300	1400
Y Value	0.05	0.25	0.35	0.42	0.52	0.58	0.67	0.88	0.96	1

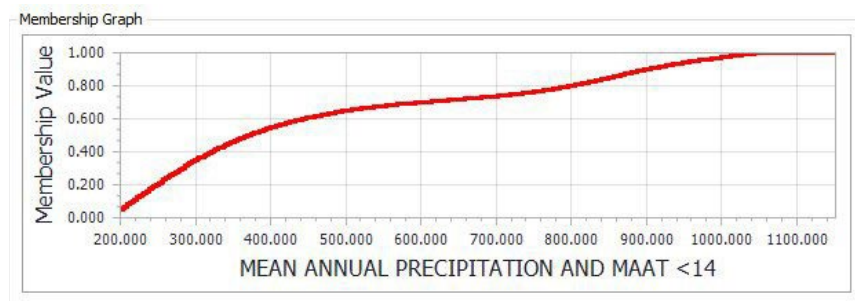


Mean annual precipitation from high and low values. Units are mm.

(ii) MAAT <14

Arbitrary curve, control points:

X Value	200	300	600	800	900	1050
Y Value	0.05	0.35	0.7	0.8	0.9	1

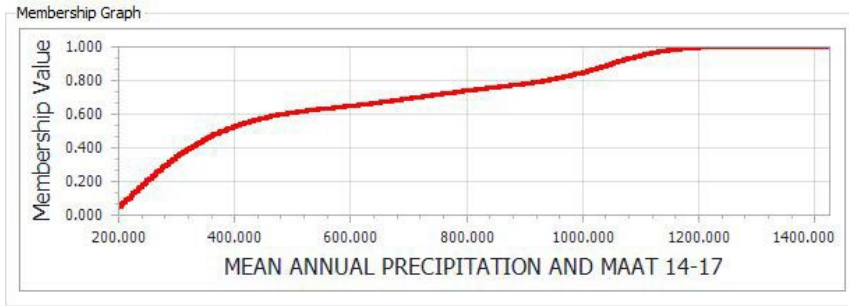


Mean annual precipitation from high and low values. Units are mm.

(iii) MAAT 14-17

Arbitrary curve, control points:

X Value	200	300	600	800	1000	1300	1100
Y Value	0.05	0.35	0.65	0.74	0.85	1	0.95

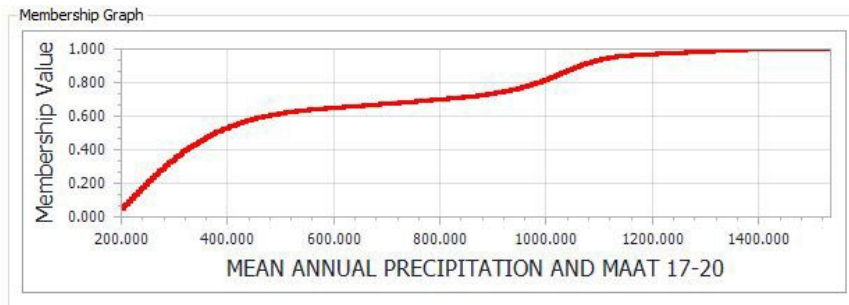


Mean annual precipitation from high and low values. Units are mm.

(iv) MAAT 17-20

Arbitrary curve, control points:

X Value	200	300	600	800	1070	1200	1400	1000
Y Value	0.05	0.35	0.65	0.7	0.91	0.97	1	0.82

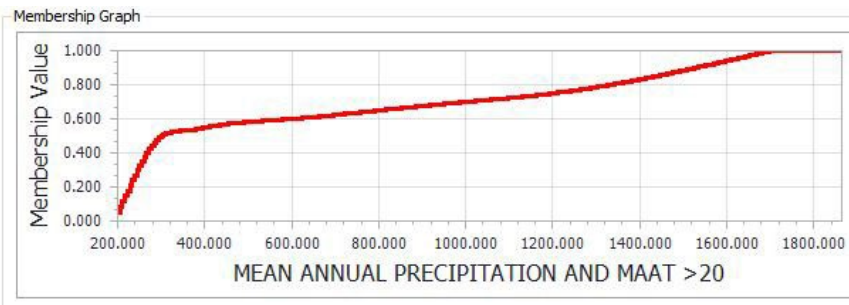


Mean annual precipitation from high and low values. Units are mm.

(v) MAAT >20

Arbitrary curve, control points:

X Value	200	300	600	800	1000	1200	1700	400	350
Y Value	0.05	0.5	0.6	0.65	0.7	0.75	1	0.55	0.53



Mean annual precipitation from high and low values. Units are mm.



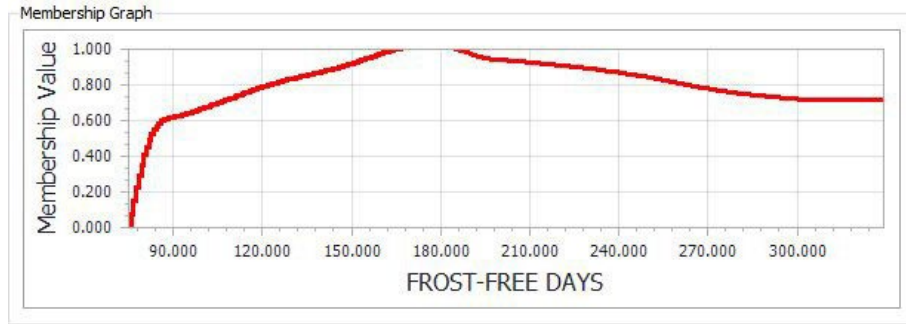
17. Frost-Free Days – Corn and Small Grains consider frost-free days alone, while Soybeans adjusts for daylength and Cotton incorporates mean annual air temperature (MAAT).

a. Corn

Arbitrary curve, control points:

X Value	75	80	90	100	110	120	150	165
Y Value	0	0.4	0.62	0.67	0.73	0.79	0.92	1

X Value	185	195	200	247	265	273	300
Y Value	1	0.95	0.94	0.85	0.8	0.77	0.72



Frost-free days evaluation. Units are frost-free days/year.

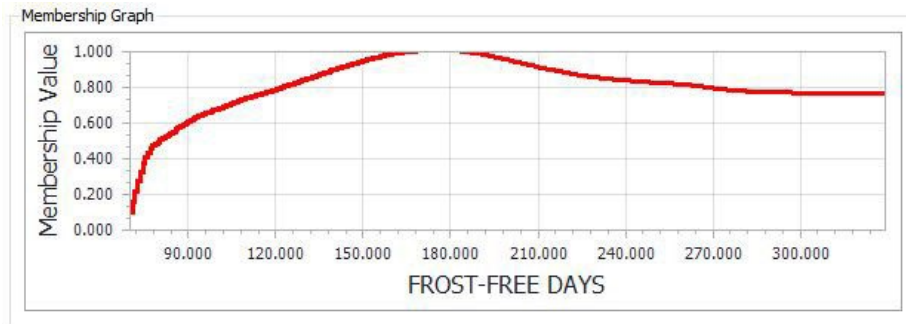
b. Soybeans

(i) Frost-Free Days

Arbitrary curve, control points:

X Value	70	75	80	90	100	110	120	150
Y Value	0.1	0.4	0.5	0.61	0.68	0.74	0.79	0.95

X Value	165	185	195	220	247	263	273	300
Y Value	1	1	0.97	0.88	0.83	0.81	0.79	0.77

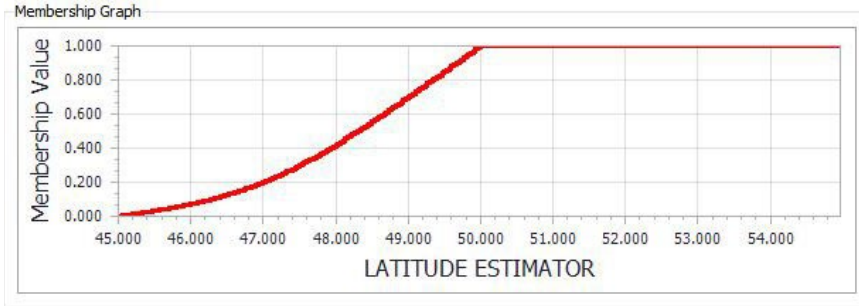


Frost-free days evaluation. Units are frost-free days/year.

(ii) Daylength

Arbitrary curve, control points:

X Value	45	47	49	50
Y Value	0	0.2	0.7	1

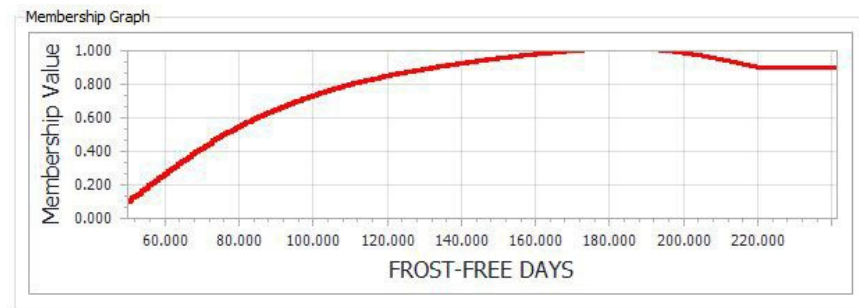


Latitude estimator. Units are degrees north of the equator.

c. Small Grains

Arbitrary curve, control points:

X Value	50	80	90	110	120	160	195	220
Y Value	0.1	0.55	0.65	0.8	0.85	0.98	1	0.9



Frost-free days evaluation. Units are frost-free days/year.

d. Cotton

(i) Frost-Free Days

Arbitrary curve, control points:

X Value	160	170	190	180	250	305	330	350	200	270
Y Value	0	0.3	0.98	0.82	1	0.9	0.6	0.4	0.99	0.99

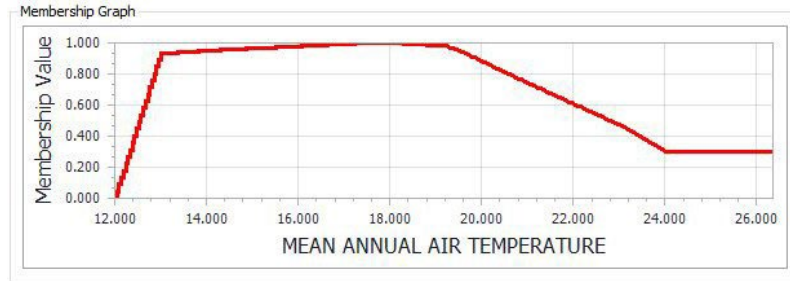


Frost-free days evaluation. Units are frost-free days/year.

(ii) Mean Annual Air Temperature

Arbitrary linear, control points:

X Value	12	13	14	17.5	18	19.2	19.5	20	21	23	24
Y Value	0	0.93	0.95	1	1	0.98	0.95	0.88	0.74	0.47	0.3



Units are degrees Celsius.

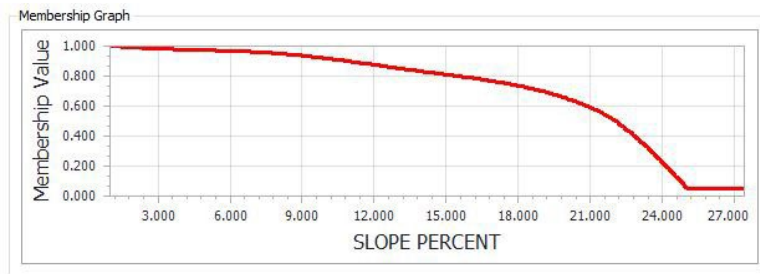
**Soil Landscape Subrules**

18. Effective Slope – Corn, Soybeans, Small Grains, Cotton

a. Corn and Soybeans

Arbitrary curve, control points:

X Value	1	2	8	14	20	22	25
Y Value	1	0.99	0.95	0.83	0.65	0.5	0.05



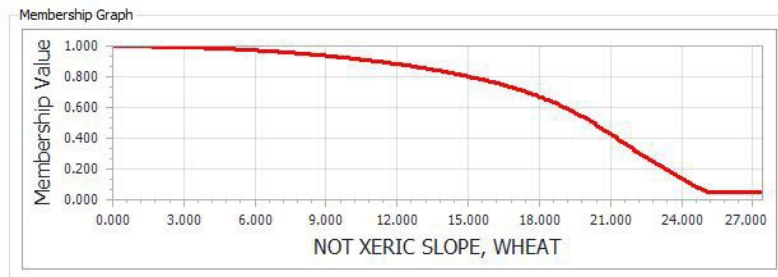
Units are percent slope.

b. Small Grains

(i) Not Xeric

Arbitrary curve, control points:

X Value	0	5	10	15	20	22	25
Y Value	1	0.98	0.92	0.8	0.52	0.32	0.05

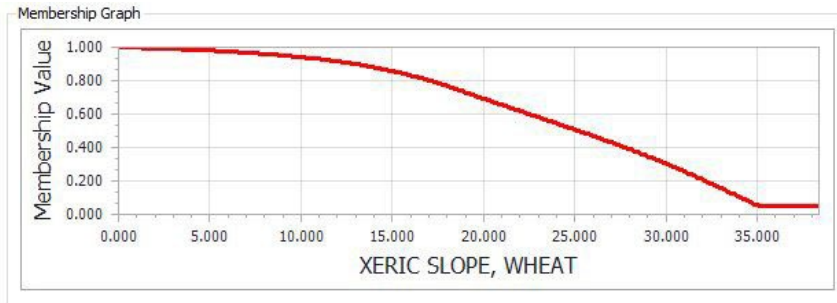


Units are percent slope.

(ii) Xeric

Arbitrary curve, control points:

X Value	0	5	10	17	20	30	35
Y Value	1	0.98	0.94	0.8	0.69	0.3	0.05

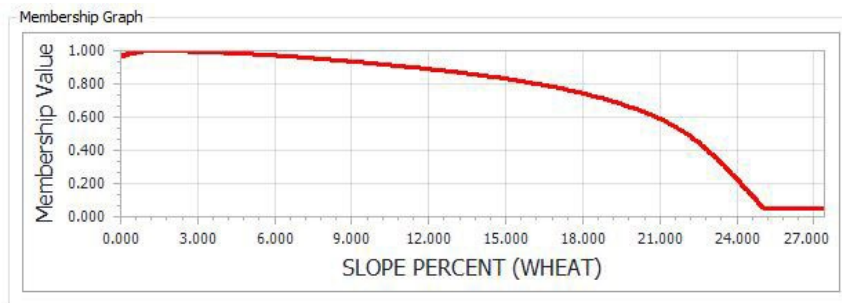


Units are percent slope.

c. Cotton

Arbitrary curve, control points:

X Value	1	5	10	15	20	22	25	0	2
Y Value	1	0.98	0.92	0.83	0.65	0.5	0.05	0.97	1

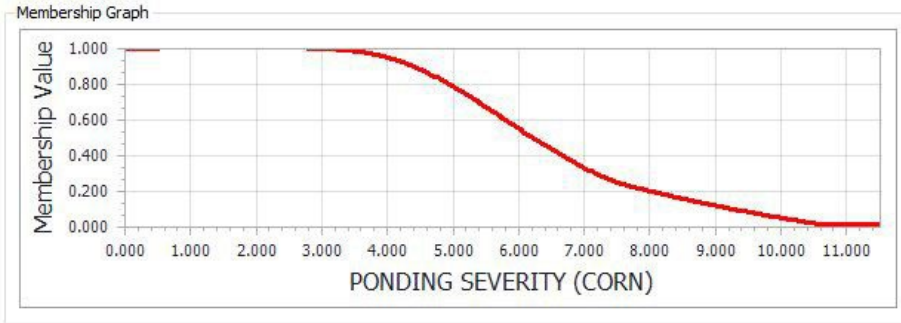


Units are percent slope.

19. Ponding – Same for Corn, Soybeans, and Cotton Submodels.  
Not considered for Small Grains Submodel.

Arbitrary curve, control points:

X Value	0	3	4	7.5	8	10	10.5
Y Value	1	1	0.95	0.25	0.2	0.05	0.02

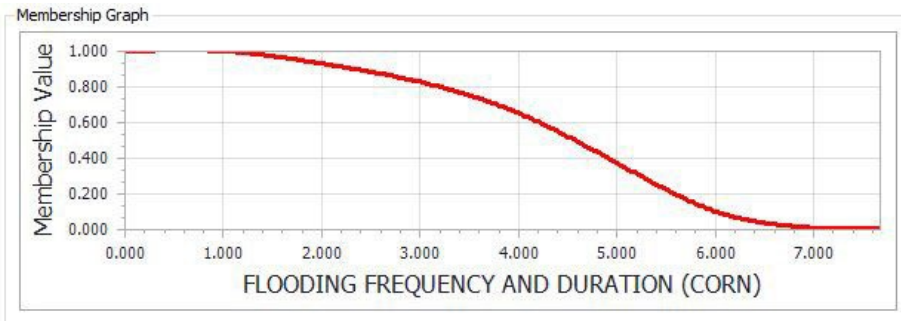


Evaluation of ponding during the growing season. Units are (days)\*(inundations)\*(months).

20. Flooding – Corn, Soybeans, and Cotton Submodels; not considered for Small Grains Submodel.

a. Corn and Soybeans Submodels Arbitrary curve, control points:

X Value	0	1	2	4	5.4	6	7
Y Value	1	1	0.93	0.65	0.25	0.1	0.01



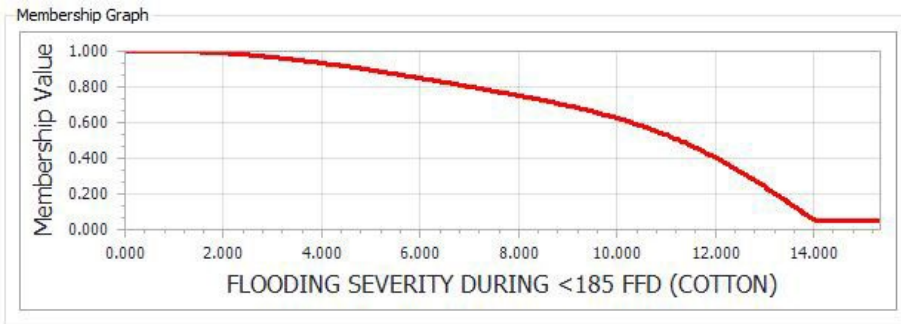
Evaluation of flooding during the growing season. Units are (days)\*(inundations/month)\*(months).

b. Cotton Submodel – Evaluated differently depending on growing season Frost-Free Days (FFD).

(i) <185 FFD

Arbitrary curve, control points:

X Value	0	1	7	8	12	14
Y Value	1	1	0.8	0.75	0.4	0.05

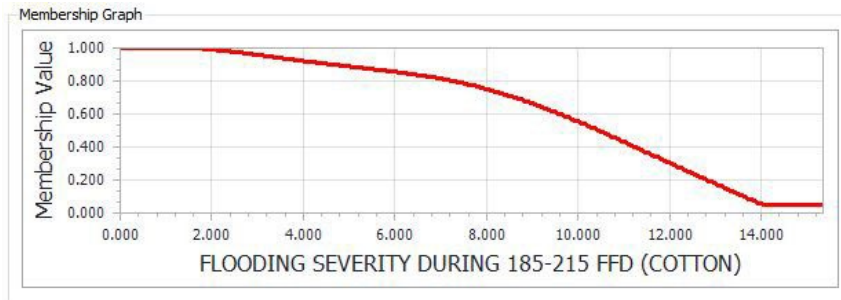


Evaluation of flooding during the growing season. Units are (days)\*(inundations/month)\*(months).

(ii) 185-215 FFD

Arbitrary curve, control points:

X Value	0	1.5	4	8	12	14
Y Value	1	1	0.92	0.75	0.3	0.05

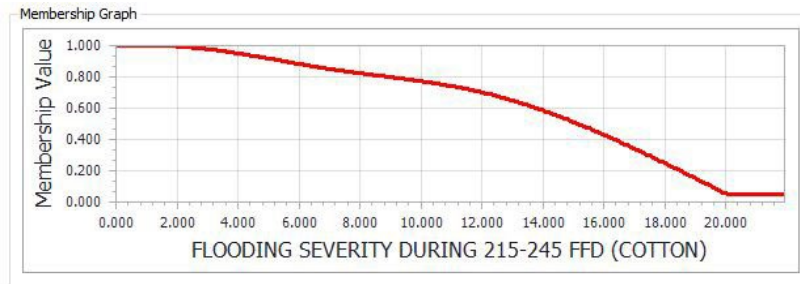


Evaluation of flooding during the growing season. Units are (days)\*(inundations/month)\*(months).

(iii) 215-245 FFD

Arbitrary curve, control points:

X Value	0	1.5	4	7	12	20
Y Value	1	1	0.95	0.85	0.7	0.05

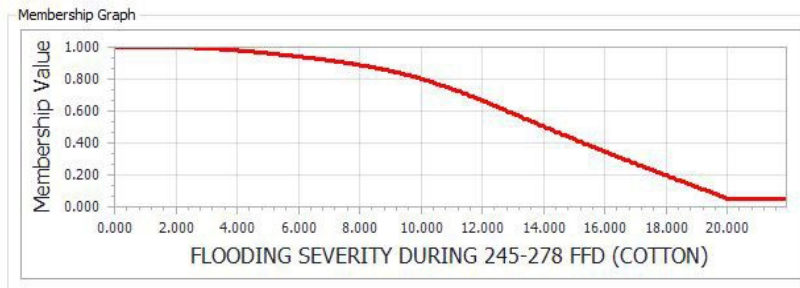


Evaluation of flooding during the growing season. Units are (days)\*(inundations/month)\*(months).

(iv) 245-278 FFD

Arbitrary curve, control points:

X Value	0	2	6	10	14	20
Y Value	1	1	0.94	0.8	0.5	0.05

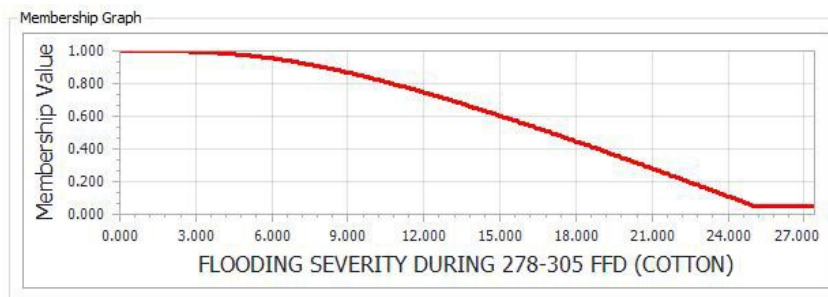


Evaluation of flooding during the growing season. Units are (days)\*(inundations/month)\*(months).

(v) 278-305 FFD

Arbitrary curve, control points:

X Value	0	1.5	7	8	14	25
Y Value	1	1	0.93	0.9	0.65	0.05

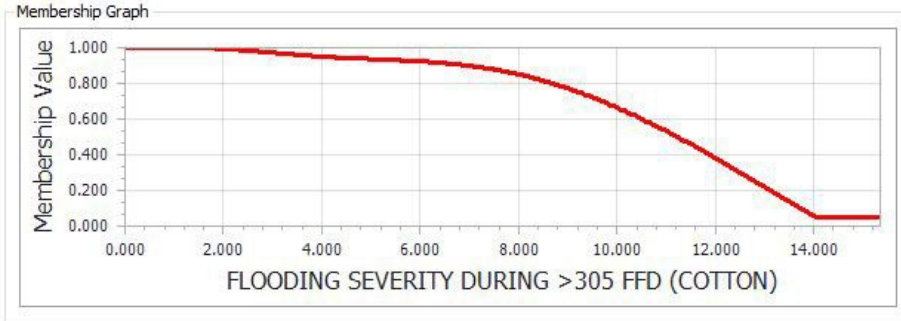


Evaluation of flooding during the growing season. Units are (days)\*(inundations/month)\*(months).

(vi) >305 FFD

Arbitrary curve, control points:

X Value	0	1.5	4	8	14
Y Value	1	1	0.95	0.85	0.05



Evaluation of flooding during the growing season. Units are (days)\*(inundations/month)\*(months).

21. Growing Season Wetness – Corn, Soybeans

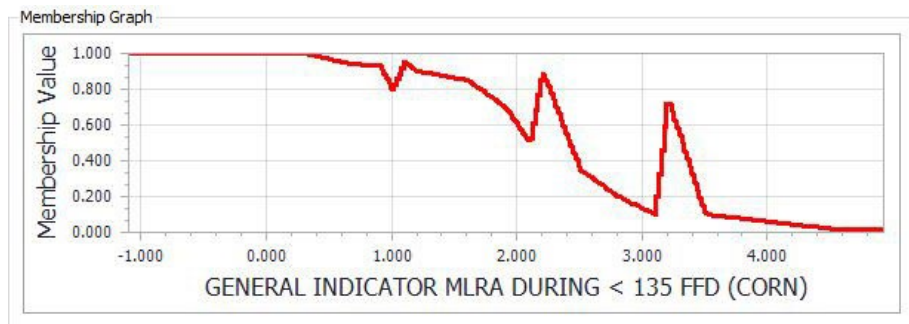
a. Corn

(i) <=135 FFD

Arbitrary linear, control points:

X Value	-1.1	0	0.3	0.6	0.7	0.9	1	1.1	1.2	1.6
Y Value	1	1	1	0.95	0.94	0.93	0.8	0.95	0.9	0.85

X Value	1.9	2.1	2.2	2.5	2.7	2.8	3.1	3.2	3.5	4.5
Y Value	0.7	0.5	0.9	0.35	0.25	0.2	0.1	0.75	0.1	0.02



Water Table Index <=135 Frost-Free Days (unitless).

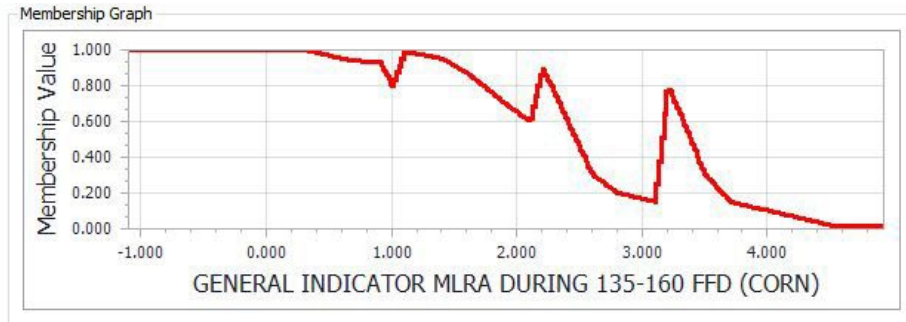


(ii) 135-160 FFD

Arbitrary linear, control points:

X Value	-1.1	0	0.3	0.6	0.7	0.9	1	1.1	1.4	1.6
Y Value	1	1	1	0.95	0.94	0.93	0.8	0.99	0.95	0.87

X Value	1.9	2.1	2.2	2.6	2.8	3.1	3.2	3.5	3.7	4.5
Y Value	0.7	0.6	0.9	0.3	0.2	0.15	0.8	0.3	0.15	0.02



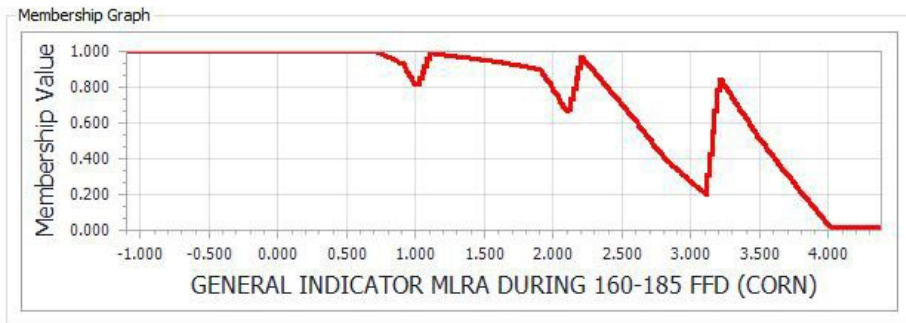
Water Table Index 135-160 Frost-Free Days (unitless).

(iii) 160-185 FFD

Arbitrary linear, control points:

X Value	-1.1	0	0.3	0.6	0.7	0.9	1	1.1	1.2	1.6
Y Value	1	1	1	1	1	0.93	0.8	0.99	0.98	0.94

X Value	1.9	2.1	2.2	2.6	2.8	3.1	3.2	3.5	3.7	4
Y Value	0.9	0.65	0.97	0.6	0.4	0.2	0.85	0.5	0.3	0.02



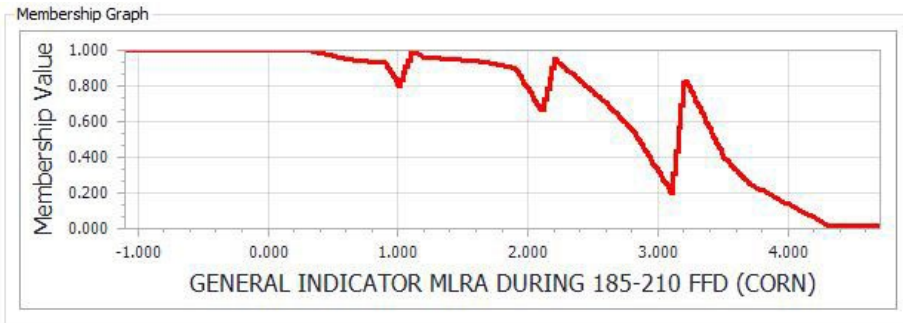
Water Table Index 160-185 Frost-Free Days (unitless).

(iv) 185-210 FFD

Arbitrary linear, control points:

X Value	-1.1	0	0.3	0.6	0.7	0.9	1	1.1	1.2	1.6
Y Value	1	1	1	0.95	0.94	0.93	0.8	0.99	0.96	0.94

X Value	1.9	2.1	2.2	2.6	2.8	3.1	3.2	3.5	3.7	4.3
Y Value	0.9	0.65	0.95	0.7	0.55	0.2	0.85	0.4	0.25	0.02



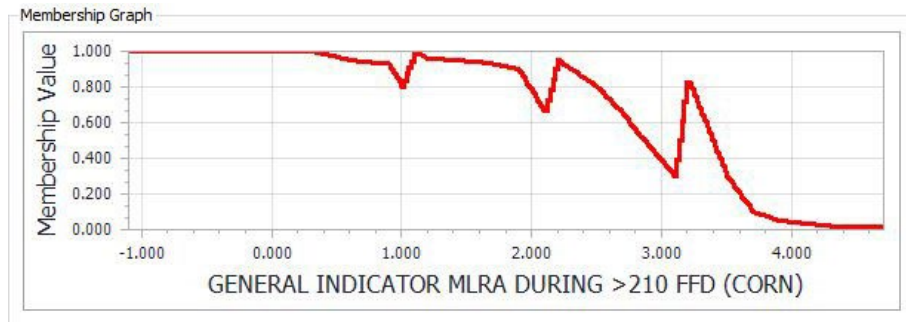
Water Table Index 185-210 Frost-Free Days (unitless).

(v) >210 FFD

Arbitrary linear, control points:

X Value	-1.1	0	0.3	0.6	0.7	0.9	1	1.1	1.2	1.6	1.9
Y Value	1	1	1	0.95	0.94	0.93	0.8	0.99	0.96	0.94	0.9

X Value	2.1	2.2	2.5	2.7	2.8	3.1	3.2	3.5	3.7	3.9	4.3
Y Value	0.65	0.95	0.8	0.65	0.55	0.3	0.85	0.3	0.1	0.05	0.02



Water Table Index 185-210 Frost-Free Days (unitless).

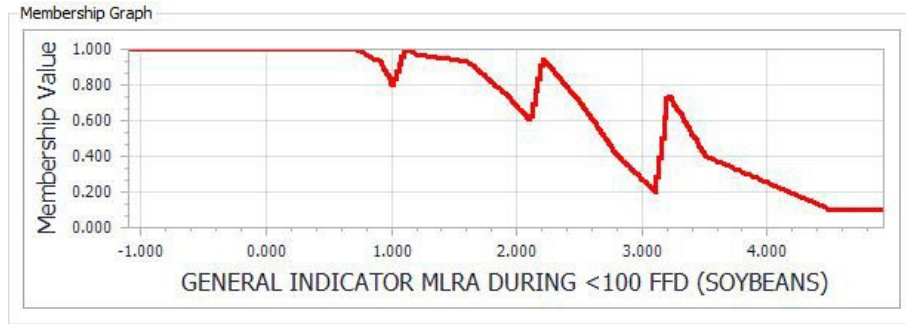
b. Soybeans

(i) <100 FFD

Arbitrary linear, control points:

X Value	-1.1	0	0.3	0.6	0.7	0.9	1	1.1	1.2	1.6
Y Value	1	1	1	1	1	0.93	0.8	1	0.97	0.93

X Value	1.9	2.1	2.2	2.5	2.7	2.8	3.1	3.2	3.5	4.5
Y Value	0.75	0.6	0.95	0.7	0.5	0.4	0.2	0.75	0.4	0.1



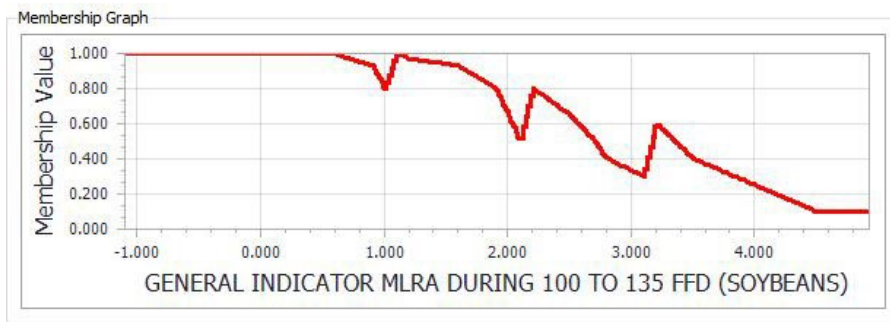
Water Table Index <100 Frost-Free Days (unitless).

(ii) 100-135 FFD

Arbitrary linear, control points:

X Value	-1.1	0	0.3	0.6	0.7	0.9	1	1.1	1.2	1.6
Y Value	1	1	1	1	0.97	0.93	0.8	1	0.97	0.93

X Value	1.9	2.1	2.2	2.5	2.7	2.8	3.1	3.2	3.5	4.5
Y Value	0.8	0.5	0.8	0.65	0.5	0.4	0.3	0.6	0.4	0.1



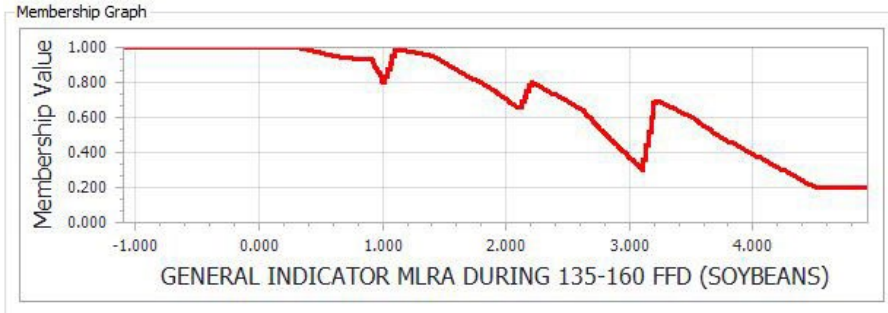
Water Table Index 100-135 Frost-Free Days (unitless).

(iii) 135-160 FFD

Arbitrary linear, control points:

X Value	-1.1	0	0.3	0.6	0.7	0.9	1	1.1	1.4	1.6
Y Value	1	1	1	0.95	0.94	0.93	0.8	0.99	0.95	0.87

X Value	1.9	2.1	2.2	2.6	2.8	3.1	3.2	3.5	3.7	4.5
Y Value	0.75	0.65	0.8	0.65	0.5	0.3	0.7	0.6	0.5	0.2



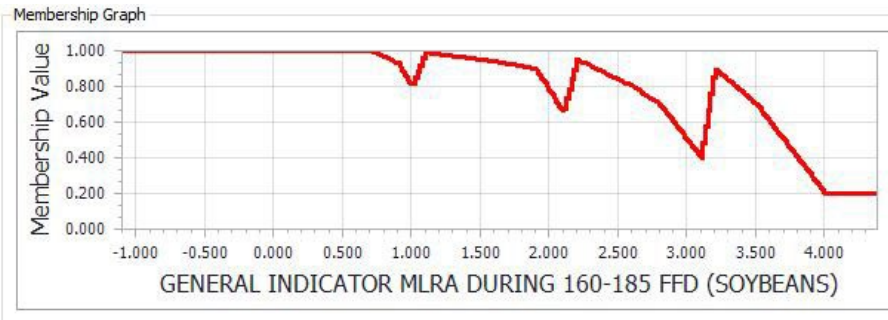
Water Table Index 135-160 Frost-Free Days (unitless).

(iv) 160-185 FFD

Arbitrary linear, control points:

X Value	-1.1	0	0.3	0.6	0.7	0.9	1	1.1	1.2	1.6
Y Value	1	1	1	1	1	0.93	0.8	0.99	0.95	0.94

X Value	1.9	2.1	2.2	2.6	2.8	3.1	3.2	3.5	3.7	4
Y Value	0.9	0.65	0.95	0.8	0.7	0.4	0.9	0.7	0.5	0.2



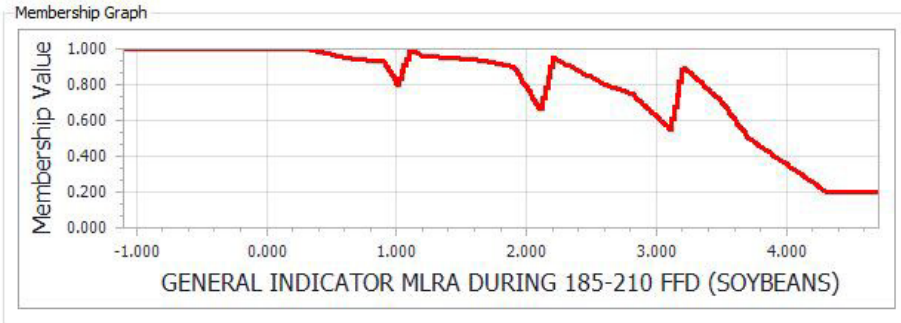
Water Table Index 160-185 Frost-Free Days (unitless).

(v) 185-210 FFD

Arbitrary linear, control points:

X Value	-1.1	0	0.3	0.6	0.7	0.9	1	1.1	1.2	1.6
Y Value	1	1	1	0.95	0.94	0.93	0.8	0.99	0.96	0.94

X Value	1.9	2.1	2.2	2.6	2.8	3.1	3.2	3.5	3.7	4.3
Y Value	0.9	0.65	0.95	0.8	0.75	0.55	0.9	0.7	0.5	0.2



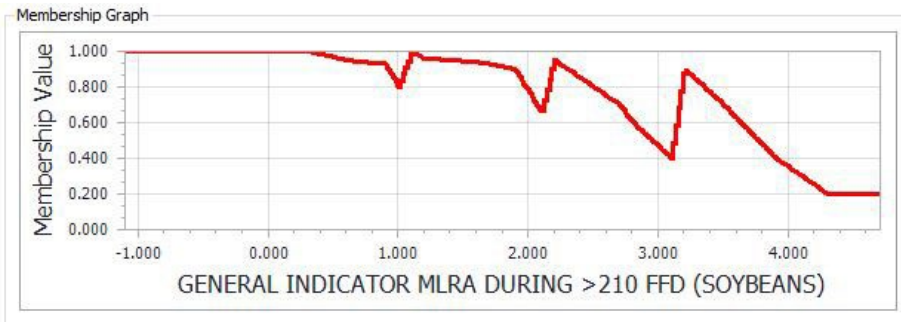
Water Table Index 185-210 Frost-Free Days (unitless).

(vi) >210 FFD

Arbitrary linear, control points:

X Value	-1.1	0	0.3	0.6	0.7	0.9	1	1.1	1.2	1.6	1.9
Y Value	1	1	1	0.95	0.94	0.93	0.8	0.99	0.94	0.9	0.65

X Value	2.1	2.2	2.5	2.7	2.8	3.1	3.2	3.5	3.7	3.9	4.3
Y Value	0.65	0.95	0.8	0.7	0.6	0.4	0.9	0.7	0.55	0.4	0.2



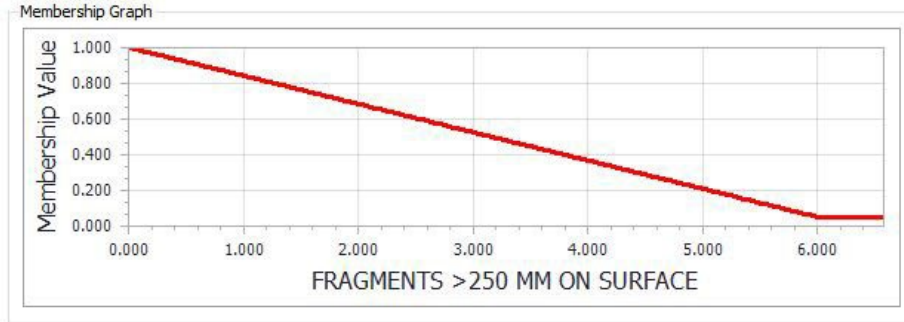
Water Table Index >210 Frost-Free Days (unitless).

22. Fragments on Surface – Small Grains

a. Fragments >250 mm on Surface

Arbitrary linear, control points:

X Value	0	6
Y Value	1	0.05

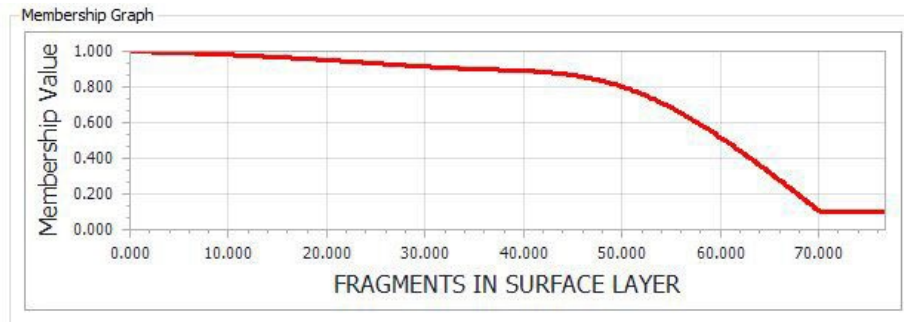


Fragments on soil surface greater than 250 mm in diameter. Units are percent of ground surface area.

b. Fragments in Surface

Arbitrary curve, control points:

X Value	0	10	20	35	50	70
Y Value	1	0.98	0.95	0.9	0.8	0.1



Fragments in soil surface layer greater than 4 mm in diameter. Units are percent of whole soil layer by volume.

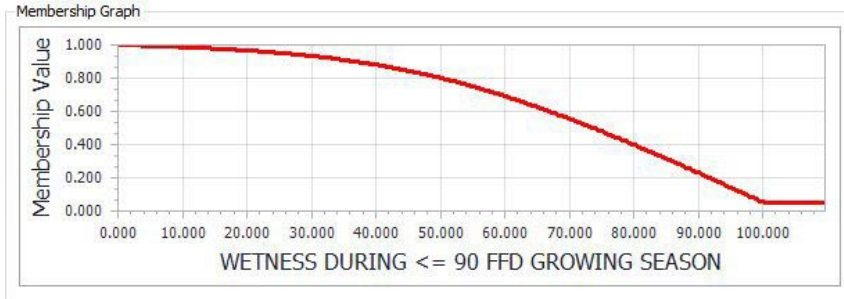
23. Excess Water – Small Grains

a. Water Table

(i)  $\leq 90$  FFD

Arbitrary curve, control points:

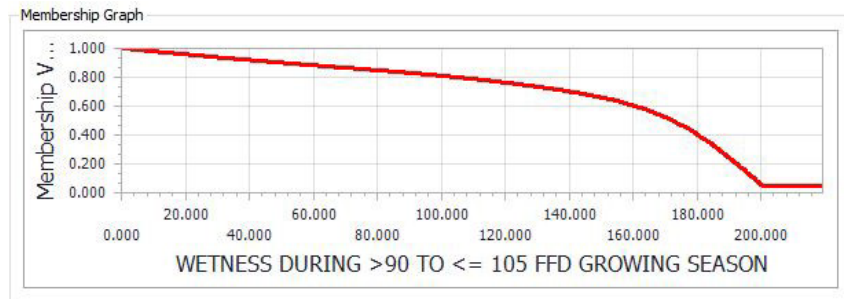
X Value	0	50	100
Y Value	1	0.8	0.05



Evaluation of Wetness During FFD  $\leq 90$  (Wheat). Units are cm. 90-105 FFD.

Arbitrary curve, control points:

X Value	0	50	140	180	200
Y Value	1	0.9	0.7	0.4	0.05

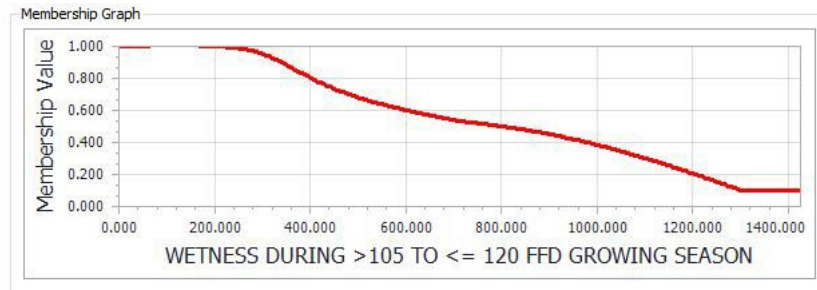


Evaluation of Wetness During FFD 90-105 (Wheat). Units are cm.

(ii) 105-120 FFD

Arbitrary curve, control points:

X Value	0	200	300	400	600	700	800	900	1100	1300
Y Value	1	1	0.95	0.8	0.6	0.54	0.5	0.45	0.3	0.1

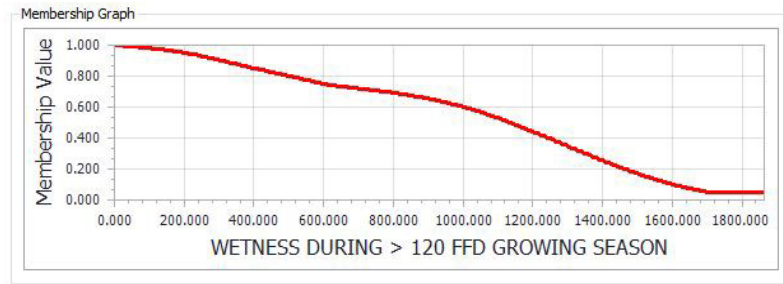


Evaluation of Wetness During FFD 105-120 (Wheat). Units are cm.

(iii) >120 FFD

Arbitrary curve, control points:

X Value	0	201	400	500	600	700	1000	1500	1700
Y Value	1	0.95	0.85	0.8	0.75	0.72	0.6	0.1	0.05



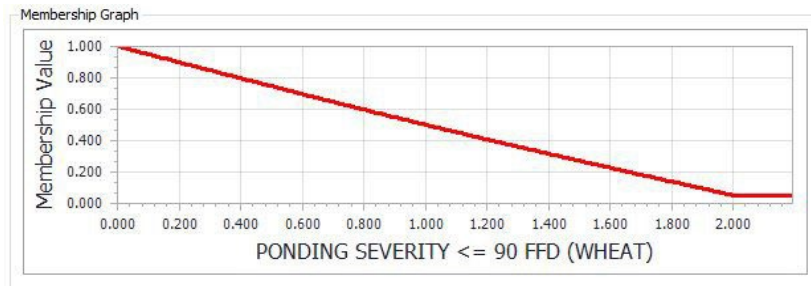
Evaluation of Wetness During FFD >120 (Wheat). Units are cm.

b. Ponding

(i) <90 FFD

Arbitrary curve, control points:

X Value	0	1	2
Y Value	1	0.5	0.05

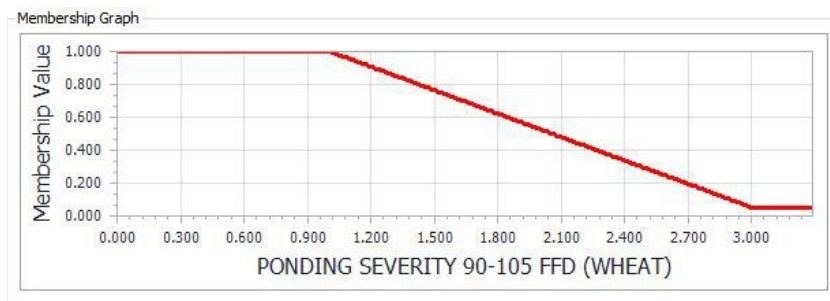


Ponding During Growing Season <90 FFD (Wheat). Units are (days)\*(inundations)\*(months).

(ii) 90-105 FFD

Arbitrary linear, control points:

X Value	0	1	2
Y Value	1	1	0.05



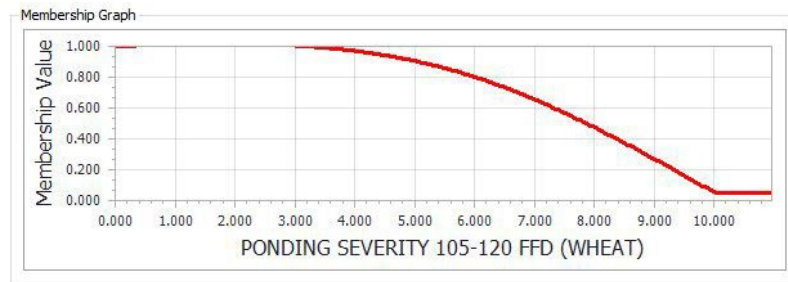
Ponding During Growing Season 90-105 FFD (Wheat). Units are (days)\*(inundations)\*(months).



(iii) 105-120 FFD

Arbitrary curve, control points:

X Value	0	6	10
Y Value	1	0.8	0.05

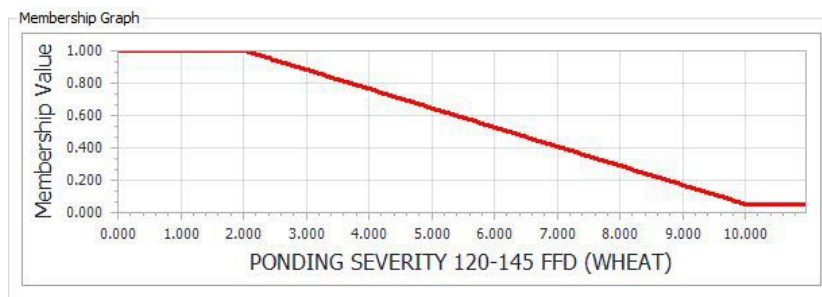


Ponding During Growing Season 105-120 FFD (Wheat). Units are (days)\*(inundations)\*(months).

(iv) 120-145 FFD

Arbitrary linear, control points:

X Value	0	2	10
Y Value	1	1	0.05

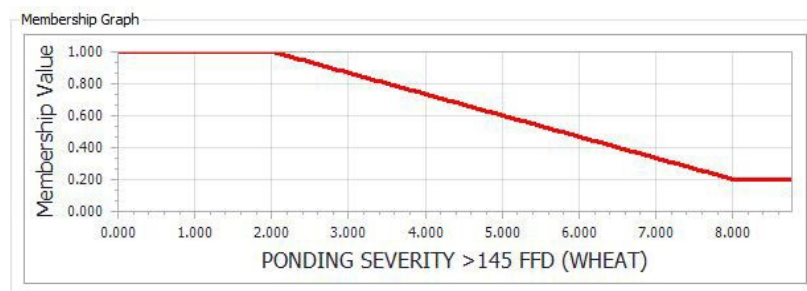


Ponding During Growing Season 120-145 FFD (Wheat). Units are (days)\*(inundations)\*(months).

(v) >145 FFD

Arbitrary linear, control points:

X Value	0	2	8
Y Value	1	1	0.2



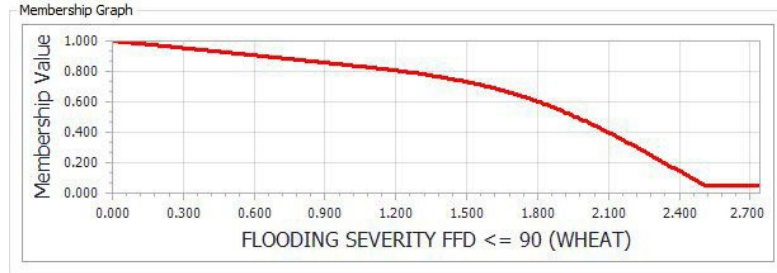
Ponding During Growing Season >145 FFD (Wheat). Units are (days)\*(inundations)\*(months).

c. Flooding

(i) <90 FFD

Arbitrary curve, control points:

X Value	0	1	2.5	1.8
Y Value	1	0.84	0.05	0.6

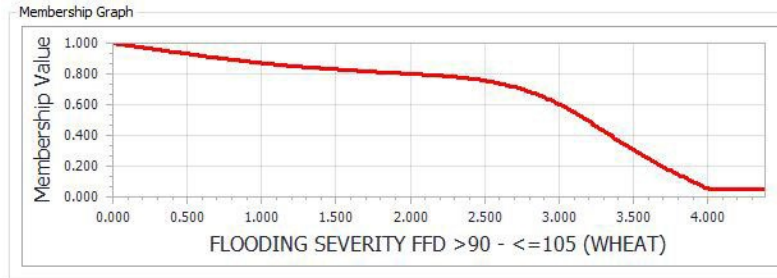


Flooding During Growing Season <90 FFD (Wheat). Units are (days)\*(inundations/month)\*(months).

(ii) 90-105 FFD

Arbitrary curve, control points:

X Value	0	1	2	3	3.5	4
Y Value	1	0.87	0.8	0.6	0.3	0.05

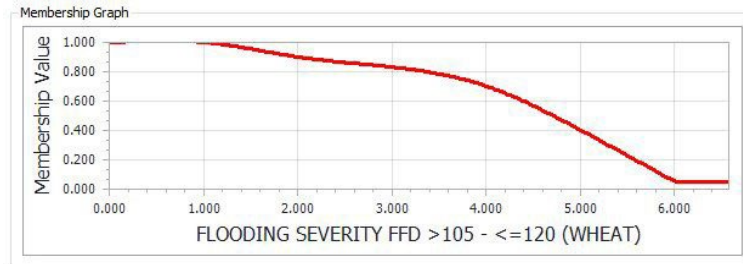


Flooding During Growing Season 90-105 FFD (Wheat). Units are (days)\*(inundations/month)\*(months).

(iii) 105-120 FFD

Arbitrary curve, control points:

X Value	0	1	2	4	5	6
Y Value	1	1	0.9	0.7	0.4	0.05

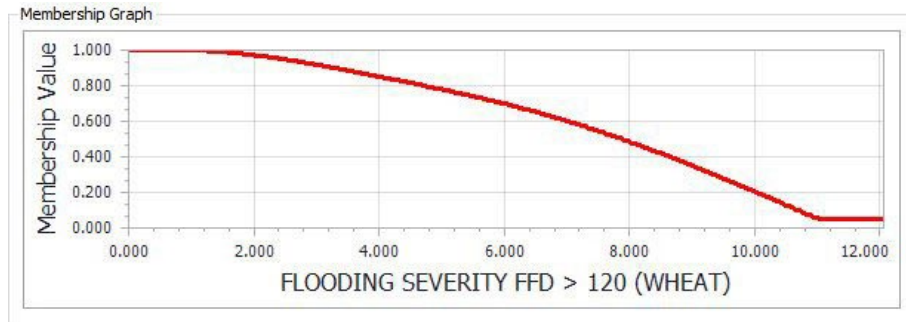


Flooding During Growing Season 105-120 FFD (Wheat). Units are (days)\*(inundations/month)\*(months).

(iv) >120 FFD

Arbitrary curve, control points:

X Value	0	1	4	11	7
Y Value	1	1	0.85	0.05	0.6



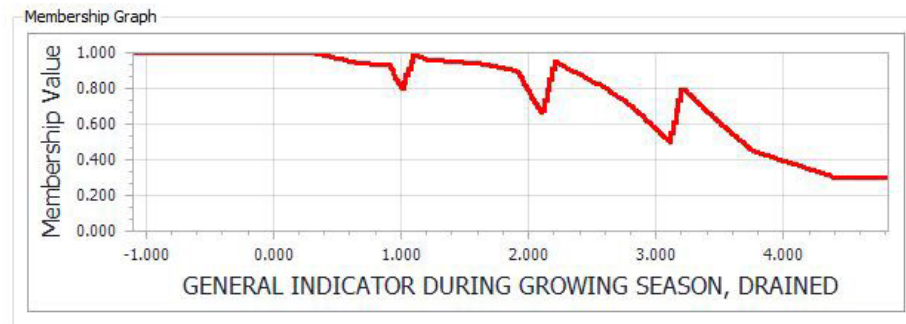
Flooding During Growing Season >120 FFD (Wheat). Units are (days)\*(inundations/month)\*(months).

24. Water Table – Cotton

Arbitrary linear, control points:

X Value	-1.1	0	0.3	0.6	0.7	0.9	1	1.1	1.2	1.6
Y Value	1	1	1	0.95	0.94	0.93	0.8	0.99	0.96	0.94

X Value	1.9	2.1	2.2	2.6	2.8	3.1	3.2	3.5	3.75	4.4
Y Value	0.9	0.65	0.95	0.8	0.7	0.5	0.8	0.6	0.45	0.3



Evaluation of Wetness Index During Growing Season (Cotton); 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

Frost-Free Days  $K_{sat}$

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<sub>2</sub>O or CaCl<sub>2</sub> CEC

Component Kind

Horizon Depth Top and Bottom

## **Appendix 5.—Root-Limiting Layers in the NCCPI**

The depth (and therefore volume) of soil that roots can access contributes significantly to soil productivity. Many calculations of soil capacity factors, such as available water-holding capacity (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.

The 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 by 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. For available water storage, a maximum depth of 150 cm is examined for small grains, cotton, and soybeans. The corn model examines the available water storage of soils to 200 cm to acknowledge the deepest rooting potential in growing seasons long enough for the roots to use the deeply stored water.

## 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 after several possibilities were considered. This section discusses these relationships and considerations.

### Available Water-Holding Capacity

Available water-holding capacity (AWC) is represented in the database as simply cm of available water per centimeter of soil. However, AWC in the surface soil horizons, where more plant roots occur, will contribute more toward crop productivity than AWC at greater depths. The calculation, based on one developed in Missouri, attempts to determine the contribution of AWC sufficiency for each centimeter of soil material to a depth of 200 cm (Kiniry et al., 1983).

```
#ASSIGN awc_r ISNULL(awc_r) ? 0 : awc_r < 0.08 ? 0 : awc_r - 0.08.

# use an upper limit of 0.14 (0.22-0.08) for awc
#ASSIGN awc_r awc_r > 0.14 ? 0.14 : awc_r.

# calculate the sufficiency using an ideal root equation for each cm increment
# each value, if in range, is added to the previous value (200 summations)
DEFINE suff 0.
ASSIGN suff hzdept_r < 1 AND hzdepb_r >= 1 ? suff + (awc_r/0.20 * (-0.0511789 *
logn(1) + 0.270865)/10) : suff.
ASSIGN suff hzdept_r < 2 AND hzdepb_r >= 2 ? suff + (awc_r/0.20 * (-0.0511789 *
logn(2) + 0.270865)/10) : suff.
ASSIGN suff hzdept_r < 3 AND hzdepb_r >= 3 ? suff + (awc_r/0.20 * (-0.0511789 *
logn(3) + 0.270865)/10) : suff.

  [***continue script with a line for each centimeter depth increment, abbreviated here
  for simplicity****]

ASSIGN suff hzdept_r < 198 AND hzdepb_r >= 198 ? suff + (awc_r/0.20 * (-
0.0511789 * logn(198) + 0.270865)/10) : suff.
ASSIGN suff hzdept_r < 199 AND hzdepb_r >= 199 ? suff + (awc_r/0.20 * (-
0.0511789 * logn(199) + 0.270865)/10) : suff.
ASSIGN suff hzdept_r < 200 AND hzdepb_r >= 200 ? suff + (awc_r/0.20 * (-
0.0511789 * logn(200) + 0.270865)/10) : suff.

# return rv value for component as the sum of the horizons
DEFINE rv ARRAYSUM(suff).
```

## Bulk Density

Bulk density is represented in the database as simply grams per cubic centimeter. Bulk density may limit root growth. The calculation uses the difference between the bulk density of a given soil and the “ideal” bulk density for the given sand, silt, and clay content to determine if the given bulk density is root-limiting. Organic soils are currently considered to have an optimum bulk density.

```
# Calculate a theoretical ideal bulk density for that proportion of sand, silt, clay in the horizon.
# Subtract the "ideal" bulk density from the given bulk density.
# If the difference is greater than
((0.002081(sandtotal_r))+0.003912(silttotal_r))+0.04435125), the layer has a root-limiting bulk density.

((dbthirdbar_r-
(((sandtotal_r*1.65)/100)+((silttotal_r*1.30)/100)+((claytotal_r*1.25)/100)))
> ((0.002081*sandtotal_r)+(0.003912*silttotal_r)+(0.0024351*claytotal_r)))
```

## Cation-Exchange Capacity (CEC)

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 considered 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 chiid REGROUP chiid by chiid 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 ( $K_{sat}$ )

Saturated hydraulic conductivity is measured when the soil is saturated by water. In the case of Vertisols, this measurement pushes the  $K_{sat}$  to an unrealistically low level, in terms of what a growing root senses. Vertisols are expansive and allow aeration and water movement primarily through cracks. A better measure of aeration is provided by multiplying the  $K_{sat}$  by the linear extensibility (LEP) rather than using the  $K_{sat}$  by itself. Using the  $\log_{10}$  of the product also helps in graphing a value that crosses several orders of magnitude. When mean annual precipitation (MAP) is important for crop productivity, the product of  $K_{sat}$  and LEP is also doubled, e.g., define `lepksat_r 2*lep_r*ksat_r`.

```
# 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 < 150 and not isnull(depth) ? depth : 150.
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 calculations must consider duration, frequency, and timing. Flooding during the time of year when the crop is in the ground is detrimental. Flooding while the ground is unused 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

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

# Get ponding duration classes

exec sql select pondeurcl
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 pondeurcl max.

#Convert class to a number

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

## 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 1.
```

```
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

```
FLOODING SEVERITY FFD >90 - <=105 (WHEAT)
```

```
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 growseas from rv using "NSSC Data":"FROST-FREE DAYS".  
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 ffd growseas.  
assign ffd if (ffd >90 and ffd<=105) then ffd else 1/0.  
define rv      isnull(ffd) ? ffd : rv1.
```

## Ponding

Like flooding, ponding calculations must consider duration, frequency, and timing. Ponding during the time of year when the crop is in the ground is detrimental. Ponding while the ground is unused 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 1.

```

## 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

```

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**

```
PONDING SEVERITY 90-105 FFD (WHEAT)
```

```
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 growseas from rv using "NSSC Data":"FROST-FREE DAYS".
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".
derive drainmlra from rv using "NSSC Data":"DRAINED MLRA".

define draindur          if drainmlra ==1 then duration/3 else duration.
define rv1                (duration*frequency*months)/10.
define ffd growseas.
assign ffd if (ffd > 90 and ffd <=105) then ffd else 1/0.
define rv                 isnull(ffd) ? ffd : rv1..
```

## Water Tables

```

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).
    
```

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.

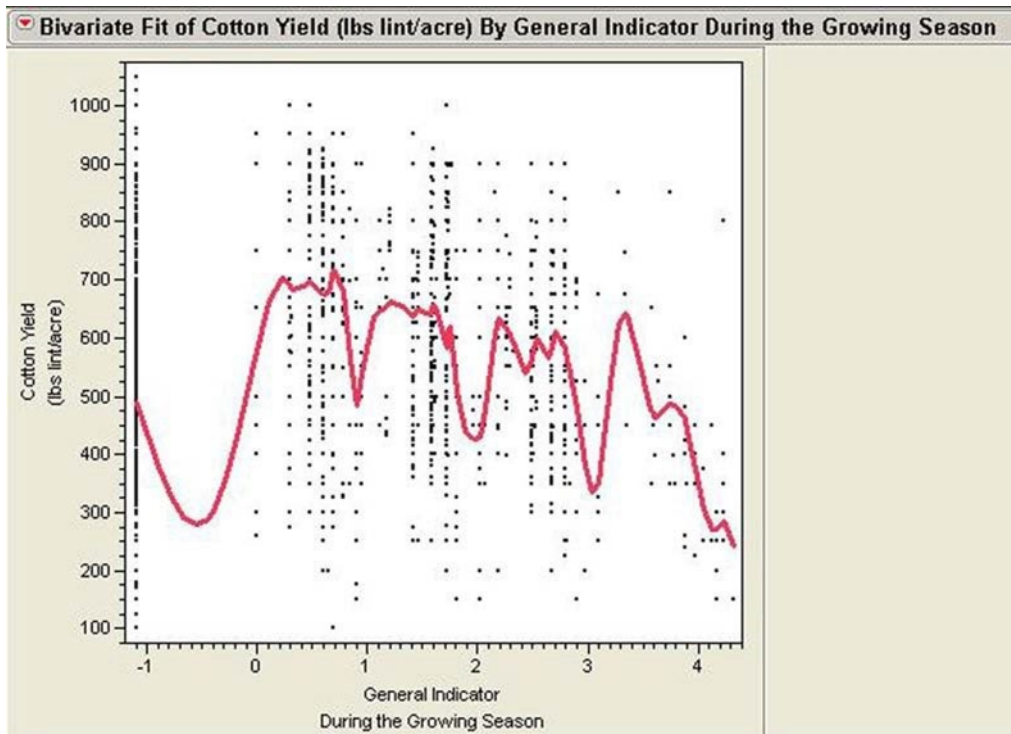
An example of saturation during the growing season at a given depth is given a rating according to this table:

Saturation depth (cm)	Monthly rating
>200	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 a depth of 200 cm during a 6-month growing season would have an index of:

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

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 Evaluation Curve 21a(v) in appendix 3, 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 Evaluation Curve 15b in appendix 3.

## Precipitation Recharge

```

exec sql select map_r, airtempa_r, taxsuborder, taxsubgrp
from component;.

derive precip from rv using "NSSC Pangaea":"PRECIPITATION".
derive temp from rv using "NSSC Pangaea":"MEAN ANNUAL AIR
TEMPERATURE".

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.

define low          isnull(recharge) then recharge else
                    if taxsuborder matches "**xeri*" then 0 else
                    if taxsubgrp matches "**xer*" then 0 else recharge.

define high         isnull(recharge) then recharge else
                    if taxsuborder matches "**xeri*" then 0 else
                    if taxsubgrp matches "**xer*" then 0 else recharge.

```

## Corn, Cotton, and Soybean (Spring Planted)

```

base table component.

exec sql select map_r, airtempa_r, taxsuborder, taxsubgrp
from component;.

DERIVE xericclim from rv using "NSSC Data":"XERIC CLIMATE".
DERIVE precip from rv using "NSSC Pangaea":"PRECIPTIATION".
DERIVE maat from rv using "NSSC Pangaea":"MEAN AIR TEMPERATURE".

#define precip isnull(map_r) ? map_r : map_r.
#define maat   isnull(airtempa_r) ? airtempa_r : airtempa_r.

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

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

define rv           isnull(recharge) then recharge else
                    if xericclim == "Y" then xercharge else recharge.

define low          isnull(recharge) then recharge else
                    if xericclim == "Y" then xercharge else recharge.

define high         isnull(recharge) then recharge else
                    if xericclim == "Y" then xercharge else recharge.

```

### **Fall Planted**

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.



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# Glossary

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**Available water capacity (available moisture capacity).** 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).** Measurement of 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 (33kPa or 10kPa 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.** Fine grained material, dominantly of silt-sized particles, that is transported and deposited by wind.

**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. (See Reaction, 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.

**Reaction, soil.** A measure of acidity or alkalinity of a soil, expressed as pH values. A soil that tests to pH 7.0 is described as precisely neutral in reaction because it is neither acid nor alkaline. The degrees of acidity or alkalinity, expressed as pH values, are:

Ultra acid .....	less than 3.5
Extremely acid .....	3.5 to 4.4
Very strongly acid .....	4.5 to 5.0
Strongly acid.....	5.1 to 5.5
Moderately acid .....	5.6 to 6.0
Slightly acid .....	6.1 to 6.5
Neutral.....	6.6 to 7.3
Slightly alkaline.....	7.4 to 7.8
Moderately alkaline.....	7.9 to 8.4
Strongly alkaline .....	8.5 to 9.0
Very strongly alkaline.....	9.1 and higher

**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 ( $K_{sat}$ ).** The quality of the soil that enables water to move through the profile.  $K_{sat}$  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.

**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.