

Chapter 19: Introducing Interpretations

This chapter is designed to provide an understanding of some of the basic concepts underlying NASIS interpretations: interpretive statements, fuzzy logic (or approximate reasoning), and converting fuzzy logic results to rating classes. These concepts are essential for using NASIS to generate interpretations (Chapter 20) and create interpretive criteria (Chapter 21).

Developing Interpretive Statements

The first step in developing interpretive criteria is to articulate an interpretive statement. An interpretive statement is simple explanation of the land use, the limiting features, and the relationship among the limiting features (the interactions or the lack of interactions among the features). This approach to developing interpretations is a method to prepare for thinking in terms of fuzzy logic.

Consider a simple example of evaluating a site for the construction of a picnic area.

It might be determined that ***“a site has limitations for picnic areas if it is too wet or too steep”*** (limitation). On the contrary, it might be determined that ***“a site has no limitations for picnic areas if it is not too wet or too steep”*** (suitability). The perspective from which the interpretive statement is articulated, either negative (limitation) or positive (suitability), depends on the interpretation preference. Regardless of the perspective chosen, the statement must contain the three elements:

1. land use,
2. limiting features (soil features affecting land use), and
3. relationship between the limiting features (or logical connection).

For this lesson, the following example will assume the negative perspective:

A soil has limitations for picnic areas if it is too wet or too steep.

Exploring the meaning of Limiting Features in the context of a Land Use

After articulating the interpretive statement, the definition of “too steep” and “too wet” in the context of picnic areas must be determined. As an expert, or more preferable, a team of experts, there may be a variety of meanings to consider. Table 19-1 is a template for filling in the meanings that are determined for each limiting feature.

Limitations for Picnic Areas				
Property	Not Limited	Somewhat Limited	Very Limited	restrictive feature
				too steep
				too wet

Table 19-1. Table for Defining the Meaning of Limiting Features

The meaning of “too steep”

What property would be evaluated in determining whether a soil is too steep for a picnic area? *Slope* is the most likely property to evaluate.

The next step is to consider the class limits for slope. Based on requirements for a picnic area, it could contain a wood or a concrete table with a bench and a fire pit. It might be concluded that a slope less than 8 percent would be a Not Limited, Somewhat Limited would be 8-15 percent, and Very Limited would be any slope greater than 15 percent. These values will be entered into Table 19-2.

The meaning of “too wet”

Determining a property for “too steep” was fairly straightforward. However, *wetness* can be measured in a variety ways: depth to wet layer, available water capacity (AWC), texture, or soil moisture in surface layer. Each property might be valid given the land use of picnic areas. Therefore, what is meant by picnic areas and their expected use must be further defined. Will the picnic area be paved or gravel, seeded to turf grasses or in a forest cover? What months of the year will it be used? And so on.

Any of the properties mentioned could be used. For this demonstration, *minimum depth to soil zone of saturation* will be used. Given expert knowledge on the land use and requirements, it is determined that depth to saturation greater than or equal to 100cm is Not Limited; Somewhat Limited is between 20-99 cm; and Very Limited is less than 20 cm to saturation. These values are entered into the template, as shown here in Table 19-2.

Limitations for Picnic Areas				
Property	Not Limited	Somewhat Limited	Very Limited	restrictive feature
Slope(%)	< 8%	8 – 15%	> 15%	too steep
Depth to saturation (cm)	> 100	20 – 99	< 20	too wet

Table 19-2. Table of Limiting Features for Picnic Areas

Table 19-2 is similar to the historical rating guides used for interpreting soils prior to NASIS. The rating classes of Not limited (slight), Somewhat Limited (moderate), and Very Limited (severe) are referred to as “crisp” limits or defined class breaks.

The Limitation of Using “Crisp Limits”

The main limitation in the use of rating classes, or “crisp limits”, is that they do not always indicate a fine enough distinction of gradation. For example, referring to Table 19-2 above, crisp rating classes define both 8% and 15% slope as having “Somewhat Limited” limitations for picnic areas. Consider the 15% slope categorized as Somewhat Limited whereas 16% is considered Very Limited. Therefore, a wide variation of slopes between 8 and 15 percent get the same rating, however slopes that are nearly the same, 15 and 16 percent, get different ratings. Given this limitation of defined classes, the fuzzy logic approach is used to rate affecting features using numerical values instead of rating classes.

Introducing Fuzzy Logic

What if the evaluation of a property was continuous? What if the degree of limitation increased continuously as slope increased or as the soil saturation rose closer to the surface? The use of fuzzy logic makes this possible. The fact that something is true does not exclude the possibility that it is also false. Fuzzy logic is built upon the precept of approximate reasoning. With fuzzy logic, a complete gradation of the truth (or false) of the interpretive statement can be represented.

Fuzzy logic provides a translation of the ranges of properties into a uniform basis. The uniform basis is a value from 0 to 1 where 1 means a statement is absolutely true and 0 means a statement is absolutely not true. For example,

The slope percentage for picnic areas is rated as:

- < 8 Not limited
- 8-15 Somewhat limited
- > 15 Very limited

The minimum depth to water table is rated as:

- > 100 Not limited
- 20-99 Somewhat limited
- < 20 Very limited

With fuzzy logic, a value in the middle or anywhere along a continuum can be identified. The easiest method to see this continuum is to set up a graph. Notice that in Figures 19-1 and 19-2, the values for slope and minimum depth to water table are translated into some measure of truthfulness about the statement of being too wet or too steep. (In this simple example, a sigmoid curve will be used.)

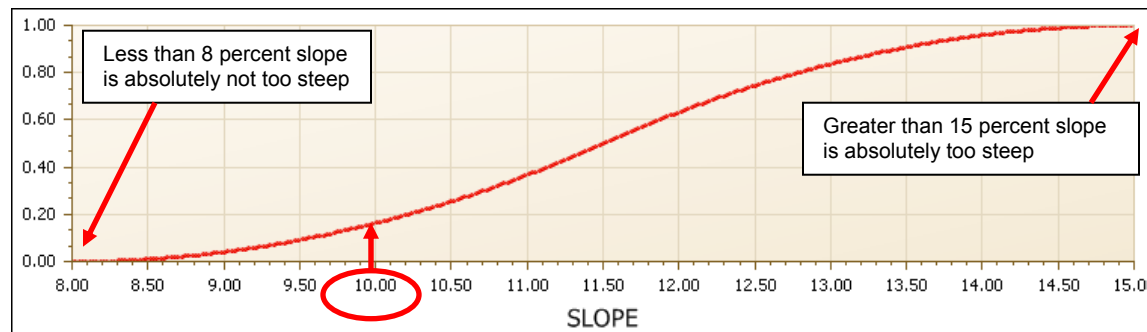


Figure 19-1. Percent Slope Along a Continuum

With fuzzy logic, a value in the middle can be shown. It is partly true that 10% slope is too steep. It's also partly not true.

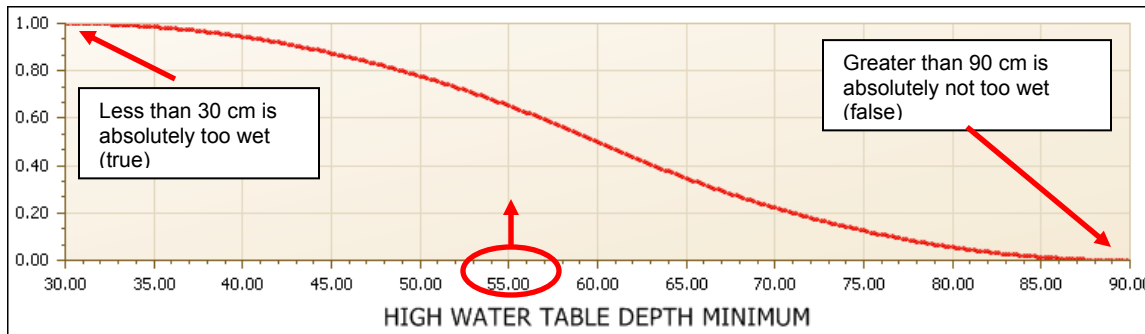


Figure 19-2. Minimum Depth to Water Table Along a Continuum

With fuzzy logic, a value in the middle can be shown. It is partly true that a 55 cm depth is too wet. It’s also partly not true.

Compare the graphs in Figures 19-1 and 19-2 to Table 19-2. The difference is, instead of crisp limits, there are now gradational limits. To understand the improvement in the interpretive criteria, there must be an understanding in fuzzy math concepts.

Although in this demonstration the numerical values for too steep and too wet seem arbitrarily determined, the values would actually be based on know data or opinions of experts creating the interpretation. When the numerical values for “too steep” and “too wet” are determined, the possibilities of dealing with interactions and relative weights become real.

Understanding fuzzy math concepts

Applying fuzzy math allows soil interpretations to handle interactions. For example, interpretations using the interaction of slope and soil saturation, where, as slope increases, water decreases can be evaluated. Fuzzy logic allows the use of relative weights, such as providing slope to have more importance to the interpretation than the depth to saturation.

Consider the conventional method of thinking. As stated previously, the fact that something is true does not exclude the possibility that it is also false, although the conventional bias is to believe that true excludes false. In the conventional way of thinking, a condition of A OR B is TRUE under the first three conditions in Table 19-3 below. The condition of A OR B is FALSE under the last condition:

if A is true	OR	if B is true	THEN	the condition is true
T		T		T
T		F		T
F		T		T
F		F		F

Table 19-3. Conventional Math Concepts

In order to use Fuzzy math, there must be an understanding of the logic that it uses.

Fuzzy Math
 $A \text{ OR } B \approx \text{Max} [A, B]$
 $A \text{ AND } B \approx \text{Min} [A, B]$

Figure 19-3. Fuzzy Math Rules for OR and AND Operators

OR Operator

Table 19-4 shows a truth table for the Boolean **OR** operator. Using fuzzy math, the *true* values are equal to 1 and the *false* values are equal to 0. By inserting the fuzzy values of 0 to 1 and then applying the fuzzy math rule of $A \text{ OR } B \sim \text{Max} [A, B]$, the conditions are expressed for the OR statement.

The table demonstrates with true=1 and false=0 that **OR** is equivalent to **Max**.

if A is true	OR	if B is true	THEN	the condition is true
T (1)		T (1)		T (1)
T (1)		F (0)		T (1)
F (0)		T (1)		T (1)
F (0)		F (0)		F (0)

Table 19-4. Fuzzy Math Using OR Operator

AND Operator

Table 19-5 below shows a truth table for the Boolean **AND** operator. Using fuzzy math, the *true* values are equal to 1 and the *false* values are equal to 0. By inserting the fuzzy values of 0 to 1 and then applying the fuzzy math rule of $A \text{ AND } B \sim \text{Min} [A, B]$, the conditions are expressed for the AND statement.

This table demonstrates with true=1 and false=0 that **AND** is equivalent to **Min**.

if A is true	AND	if B is true	THEN	the condition is true
T (1)		T (1)		T (1)
T (1)		F (0)		F (0)
F (0)		T (1)		F (0)
F (0)		F (0)		F (0)

Table 19-5. Fuzzy Math Using AND Operator

This demonstration of fuzzy math is not meant as a proof but simply as a demonstration of how the math works. Returning to the picnic area example, insert into the equation the fuzzy values shown in the following graphs: Figures 19-4 and 19-5.

A – If slope is 11.85 percent, then the fuzzy value is 0.60

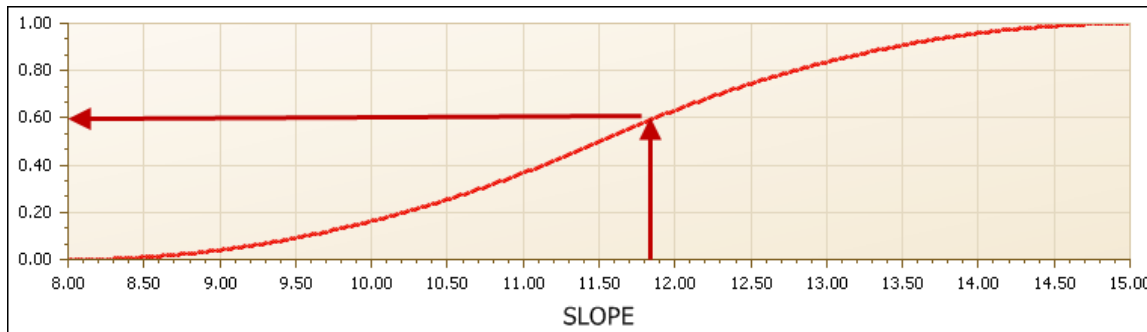


Figure 19-4. Fuzzy Logic Applied to Percent Slope

B – If the soil is saturated at 63 cm, then the fuzzy value is 0.40

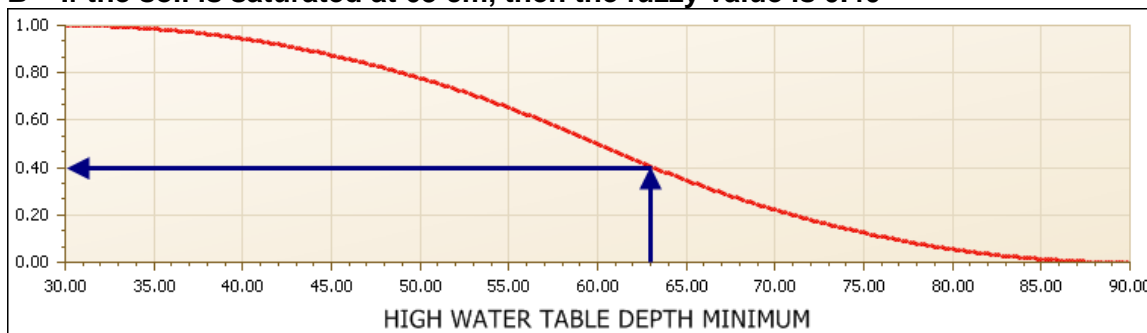


Figure 19-5. Fuzzy Logic Applied to Minimum Depth to Soil Saturation

Remember the interpretive statement and apply the fuzzy values from the graphs above, refer to Figure 19-6 below for a picture of how it fits together.

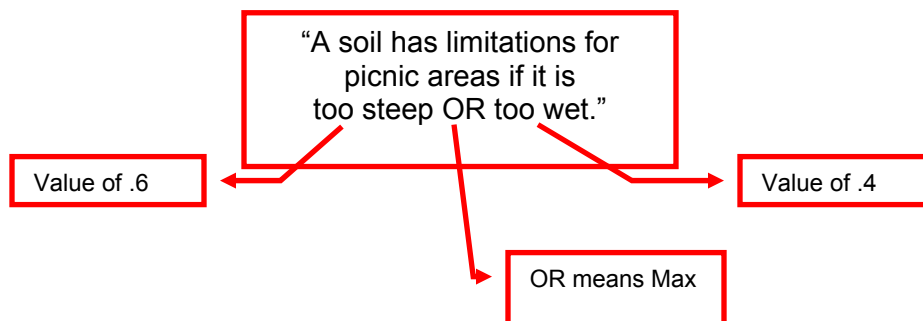


Figure 19-6. Interpretive Statement with Fuzzy Values for Picnic Areas

Finally, compute the interpretive result given the OR operator:

A	OR	B	Then (max)
T.6		T.4	T.6

A site has limitations for picnic areas if the site is 0.6 too steep or the soil is 0.4 too wet. The statement has an OR condition so the fuzzy rule of $A \text{ OR } B \sim \text{Max} [A, B]$ was applied to produce the maximum value of 0.6. With fuzzy logic, there is a 0.6 truthfulness that the site has limitations for picnic areas and that the primary limitation is related to slope.

What is the result if the statement of limitations was constructed: “A site has limitations for picnic areas if it is too wet *AND* too steep?” Using the math for AND statements the result would be a 0.4 truthfulness that the site has limitations for picnic areas.

A	AND	B	Then
T.6		T.4	T.4

Is it good or bad that there is a 0.4 truthfulness that the site has limitations for picnic areas and that the limitation relates to the interaction of slope and wetness? Furthermore, what does the numerical value mean? How does the numeric value relate to the interpretive statement for picnic areas?

These questions depend on the opinion and judgment of an expert or team of experts. Fuzzy logic provides the ability to handle interactions and relative weights to interpret a soil interpretation, but expert opinion and judgments are necessary when assigning meaning to the fuzzy numbers. The decision on the values meaning in the context of the land use is decided by the experts.

Converting the Fuzzy Result to Rating Classes (Defuzzifying)

NASIS provides the option of assigning conventional rating classes as well as rating values (fuzzy values). Any number of rating values between 0 and 1 can be created and assigned rating classes. Expert opinions and judgments are the basis of the adjectives used and the values assigned to the rating classes.

It is possible to convert the fuzzy values to rating classes. Using the ongoing example of picnic areas where the overall rating of truthfulness is 0.6 (using the OR statement), Table 19-6 shows a set of conclusions that could be made about the interpretive results.

Rating Classes	
Not limiting	0.4
Somewhat limiting	0.6
Limiting	0.75
Very limiting	0.99
Extremely limiting	1.0

Table 19-6. Rating Classes for Picnic Area

Understanding how to read the fuzzy result in terms of rating classes is important yet may not be apparent. When entering rating classes, enter the maximum rating value associated with each range. In Table 19-7,

- a value greater than 0 and less than .4 is not limiting;
- a value greater than .4 and less than .6 is somewhat limiting;
- a value greater than .6 and less than .9 is limiting;
- a value greater than .9 and less than 1 is very limiting; and
- a value equal to 1 is extremely limiting.

Lesson Summary

NASIS User Guide

In this lesson, an interpretive statement for picnic areas was written, fuzzy math was applied to the statement to get a fuzzy result, and the fuzzy result was converted to rating classes. This is the general procedure to build interpretive criteria.

Chapter 21 demonstrates how to use the NASIS Rule and Evaluation editors, to build interpretive criteria. It is best to become familiar with the Reporting Interpretations before proceeding. The Report Manager will be used for printing interpretations in Chapter 20.