Chapter 14 Introducing Interpretations

Before you learn to use the NASIS tools to generate interpretations and create interpretive criteria, read this chapter. It will help you understand some of the basic concepts underlying NASIS interpretations: interpretive statements, fuzzy logic (also known as approximate reasoning), and converting fuzzy results to rating classes (defuzzifying). These concepts are essential for using NASIS to generate interpretations (Chapter 15) and create interpretive criteria (Chapter 16).

Developing Interpretive Statements

The first step in learning to develop interpretive criteria is to learn to articulate an interpretive statement. An interpretive statement is a basic statement that says something about 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 thinking of interpretations is a way to prepare yourself for thinking in terms of fuzzy logic.

Suppose you are evaluating a site for the construction of a picnic area. (This simple example will be used throughout this lesson.) You might determine that “a site has limitations for picnic areas if it is too wet or too steep.” On the other hand, you might say that “a site has no limitations for picnic areas if it is not too wet or too steep.” The perspective from which you articulate the interpretive statement depends on personal preference. Regardless of the perspective you choose, the statement must contain the three elements of land use, limiting features (soil features affecting land use), and the relationship (or logical connection) between the limiting features. The following example, which will be used throughout this lesson, is from the positive 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, you need to determine what “too steep” and “too wet” mean in the given context of picnic areas. As an expert (or a team of experts), you might think about the meaning in a variety of ways. Table 14-1 below is a template for filling in the meanings you determine for each limiting feature.

Limitations for Picnic Areas				
property	slight	moderate	severe	restrictive feature
				too steep
				too wet

Table 14-1. Table for Defining the Meaning of Limiting Features

The meaning of “too steep”

What property would you evaluate in determining whether a soil is too steep for a picnic area? For this example, *slope* has been determined to be the most likely property to evaluate. Enter *slope* in the property column in Table 14-1.

Next, think about class limits for slope. Based on these requirements of a picnic area—that it contain a wood or concrete table and bench and a fire pit—you may conclude that a slight limitation would be less than 8 percent, a moderate limitation would be 8-15 percent, and a severe limitation would be any slope greater than 15 percent. For this demonstration, you may want to enter those values into Table 14-1.

The meaning of “too wet”

Determining a property for “too steep” was fairly straightforward. However, *wetness* may 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, define further what is meant by picnic areas and their expected use. 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, however, use *minimum depth to water table*. Given what we know about the land use and requirements, let’s determine that a slight limitation would be greater than or equal to 100cm; a moderate limitation would be 20-99 cm; and a severe limitation would be less than 20cm. You can enter those values into your template, as shown here in Table 14-2.

Limitations for Picnic Areas				
property	slight	moderate	severe	restrictive feature
slope (pct)	<8%	8-15%	>15%	too steep
minimum depth to water table (cm)	≥100 cm	20-99 cm	<20 cm	too wet

Table 14-2. Table of Limiting Features for Picnic Areas

The populated table above begins to look very similar to the ISU evaluations used for interpreting soils. The rating classes of slight, moderate, and severe are referred to as “crisp” limits. The next section reviews a well-known limitation of crisp limits.

The Limitation of Using Crisp Limits

The main limitation of rating classes, or crisp limits, is that they do not indicate a fine enough distinction of gradation. For example, referring to Table 14-2 above, crisp rating classes define both 8% and 15% slope as having moderate limitations for picnic areas. Furthermore, whereas 15% slope is of moderate limitation, 16% is considered severe. Therefore, different slopes get the same rating, and slopes that are nearly the same get different ratings.

Given this limitation, let's explore the fuzzy logic approach to rating affecting features. Fuzzy logic uses numerical values instead of rating classes.

Introducing Fuzzy Logic

What if we could have a continuous evaluation of a property? What if our degree of limitation increased continuously as slope increased? Fuzzy logic makes this possible.

The fact that something is true does not exclude the possibility that it is also false. Fuzzy logic (or approximate reasoning) is built upon this precept. With fuzzy logic, you can get a complete gradation of how true (or false) an interpretive statement is. Fuzzy logic allows you to translate 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, currently the percentage slope for picnic areas is rated as:

< 8	slight
8-15	moderate
> 15	severe

Minimum depth to water table is rated as:

≥ 100	slight
20-99	moderate
< 20	severe

With fuzzy logic, we can show a value in the middle or anywhere along a continuum. The easiest way to see this is to set up a graph. Notice that in Figures 14-1 and 14-2, 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. (Of course, you might choose a different type of curve; but for this simple example, we will use a linear curve.)

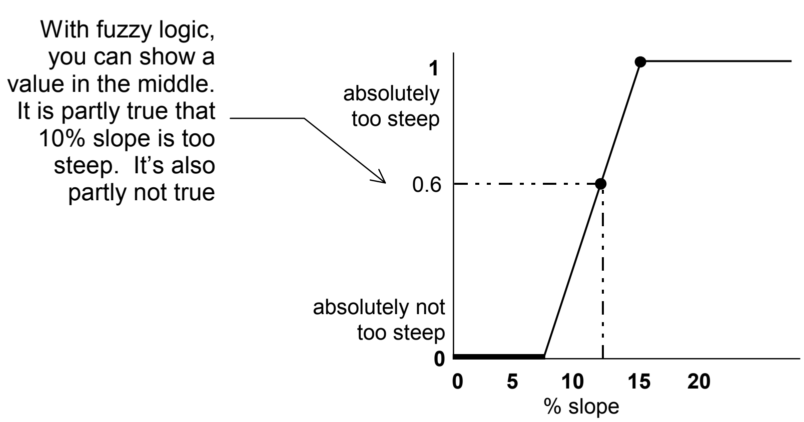

Figure 14-1. Percent Slope Along a Continuum

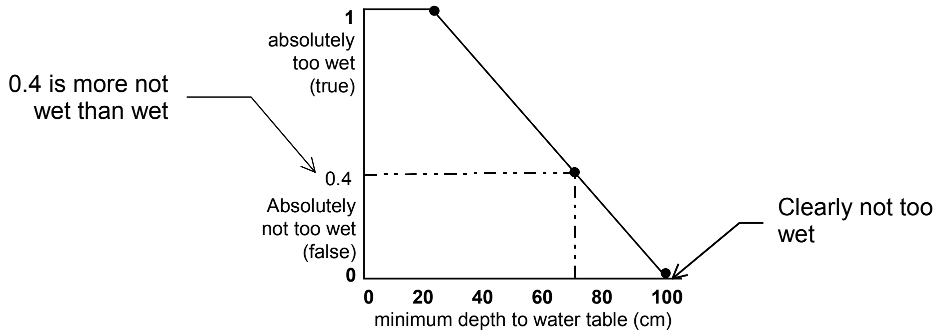

Figure 14-2. Minimum Depth to Water Table Along a Continuum

Compare the graphs in Figures 14-1 and 14-2 to Table 14-2. The difference is, instead of crisp limits, you can now have gradational limits. To see how this really helps to improve the development of interpretive criteria, you will need to understand some concepts of fuzzy math.

Although in this demonstration the numerical values for too steep and too wet seem arbitrarily determined, they would actually be based on opinions and judgments of experts like yourself. Once you have numerical values for too steep and too wet, the possibilities of dealing with interactions and relative weights become real.

Understanding fuzzy math concepts

Applying fuzzy math opens up soil interpretations to the realm of handling interactions. For example, you can do interpretations on the interaction of slope and water table, where, as slope increases, water decreases. Fuzzy logic also allows the handling relative weights, such as when slope may have more importance to the interpretation than depth to water table. Before we discuss fuzzy math, let's examine our conventional way of thinking.

As stated previously, the fact that something is true does not exclude the possibility that it is also false, although our 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 14-3 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 14-3. Conventional Math Concepts

Now let's turn to fuzzy math. Figure 14-3 on the next page shows two fuzzy math rules relevant to our discussion.

Fuzzy Math

A OR B ≈ Max [A, B]
A AND B ≈ Min [A, B]

Figure 14-3. Fuzzy Math Rules for OR and AND Operators

Table 14-4 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 OR B ~ 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 14-4. Fuzzy Math Using OR Operator

Table 14-5 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 AND B ~ Min [A, B], the conditions are expressed for the AND statement.

The 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 14-5. 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, next you will insert into the equation the fuzzy values shown in the following graphs: Figures 14-4 and 14-5.

A

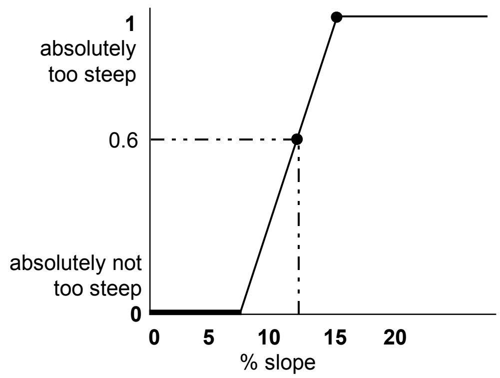

Figure 14-4. Fuzzy Logic Applied to Percent Slope

B

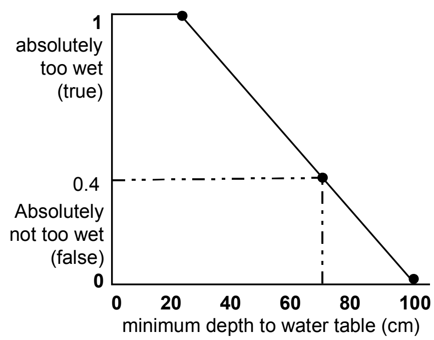

Figure 14-5. Fuzzy Logic Applied to Minimum Depth to Water Table

Remembering our interpretive statement and applying the fuzzy values from the graphs above, refer to Figure 14-6 below for a picture of how it fits together.

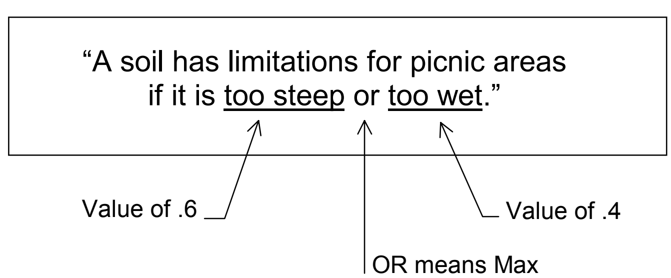

Figure 14-6. Interpretive Statement with Fuzzy Values for Picnic Areas

Finally, let's compute the interpretive result given that we are dealing with the OR operator:

A	**OR B**	**Then**
$T^{.6}$	$T^{.4}$	$T^{.6}$

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

What if you had chosen to construct your statement of limitations this way: "A site has limitations for picnic areas if it is too wet *and* too steep?" You would use the math for AND statements and the result would be a 0.4 truthfulness that the site has limitations for picnic areas.

A	**AND B**	**Then**
$T^{.6}$	$T^{.4}$	$T^{.4}$

You may wonder, 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, once you derive a numerical value, what does it mean? How does it relate to the interpretive statement for picnic areas?

As always, it depends on the opinion and judgment of an expert or team of experts. Fuzzy logic gives you the ability to handle interactions and relative weights to interpret a soil interpretation, but you still need to use expert opinion and judgments when assigning meaning to the fuzzy numbers. As the expert, you decide what the values mean in the context of the land use.

Converting the Fuzzy Result to Rating Classes (Defuzzifying)

In NASIS, you have the option of assigning conventional rating classes as well as rating values (fuzzy values). What is different, however, is that you can assign any number of rating classes and name them what you want. Your expert opinions and judgments are the basis of the adjectives you use and the values you assign to the rating classes.

Some people may want to convert the fuzzy values to rating classes. Using the on-going example of picnic areas where the overall rating of truthfulness is 0.6 (using the OR statement), Table 14-6 shows a set of conclusions you could make about the interpretive results.

Rating Classes	
Not limiting	0.6
Limiting	0.9
Very limiting	0.99
Extremely limiting	1.0

Table 14-6. 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 14-7, a value greater than 0 and less than .6 is not 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

In this lesson, you wrote an interpretive statement for picnic areas, applied fuzzy math to the statement to get a fuzzy result, and converted the fuzzy result to rating classes. You will follow this general procedure to build interpretive criteria. Chapter 16 fully demonstrates how to use the NASIS tools, the Rule and Evaluation editors, to build interpretive criteria. Before you reach Chapter 16, however, you need to familiarize yourself with the Reporting Interpretations. You will use the Report Manager for printing interpretations in Chapter 15.