9

Introduction to Fuzzy Sets and Logic

9.1 Measurement and Language

Every language has words that describe measurements regardless of the system used (e.g., Metric, English, Apothecary). People communicate measurement information using objective, or "crisp," language; for example, the distance between city A and city B is 592 kilometers; this wetland has an area of 4.3 acres; that medicinal pill contains 45 grains of active ingredient. Depending on the measuring device, resolution differences are identified at greater or lesser scales.

Languages have other words for measurements, words that do not crisply define magnitude. These words capture the concept of relative, rather than exact, amount. For example, city A is *far* from city B, the wetland is *small,* the pill contains a *large* amount of medicine. These subjective, *linguistic variables* are imprecise, vague, and *fuzzy*. Everyone has a concept of *far*, *large*, *expensive* and *heavy* but the magnitude each person assigns to the terms differ. And, what is meant by *large*, for example, varies with the context. A large meal is measured on a different absolute scale than is a large house. The result of all this fuzziness leads to confusion and misunderstanding unless the fuzzy linguistic variables are quantified.

Fuzzy linguistic variables also include those concepts that do not have an underlying measurement. Everyone understands what is meant by a *beautiful* sunset or an *acceptable* price. But, we cannot describe what we mean very easily or consistently. Both types of fuzzy linguis-

tic variables (those having an underlying measurement and those that are purely abstract) are found in environmental impact assessments.

9.2 From Subjectivity to Objectivity

The subjective nature of *significance*, the inability to collect very large data sets on baseline conditions, and the uncertainties about future conditions under a set of project alternatives are all reasons why traditional approaches to environmental impact assessment should be replaced with tools that use advances in mathematics, the increased power of small computer systems, and mature aspects of artificial intelligence.

Among the techniques within the broad category of computational intelligence are fuzzy logic, approximate reasoning (IF-THEN models), evolutionary/genetic algorithms (the terms are used interchangeably), artificial neural networks, Bayesian-based reasoning (using expectations based on past experience), belief networks and Dempster–Shafer theory of evidence-based reasoning.

Approximate reasoning is a mathematical subject "with emphasis on the design and implementation of intelligent systems for scientific and engineering applications. Approximate reasoning is computational modeling of any part of the process used by humans to reason about natural phenomena" (from the mission statement of the *International Journal of Approximate Reasoning*). In other words, it is ideally suited to be a basis for a modern approach to environmental impact assessment. Put another way, approximate reasoning is concerned with formal models of reasoning under uncertainty.

In order to understand why fuzzy sets, fuzzy logic, and approximate reasoning can overcome the shortcomings documented in the first part of this book, and to understand how to use fuzzy system models most effectively in conducting an environmental impact assessment, some background is necessary. The mathematics will be minimal and are there for those who want this level of understanding; most of the explanation is effectively communicated by text and drawings. This chapter is not a comprehensive explanation of fuzzy sets, fuzzy logic, or fuzzy system models. For more depth and completeness see [3, 9, 20, 45]. The contents of this chapter provide basic understanding