Chapter 3
Design and Implementation of a Fuzzy Inference Model for Mapping the Sustainability of Energy Crops

Fausto Cavallaro
University of Molise Via De Sanctis, Italy

Luigi Ciraozo
University of Messina, Italy

ABSTRACT

Energy crops are positioned as the most promising renewable energy sources. Over recent years, the use of biomass has been growing significantly, especially in countries that have made a strong commitment to renewable sources in their energy policies. One of the aspects of the use of biomass for energy is that it is still controversial with regard to full environmental sustainability. Unfortunately, the existing environmental evaluation tools in many cases are unable to manage uncertain input data. Fuzzy-set-based methods, instead, have proved to be able to deal with uncertainty in environmental topics. The idea of this chapter is to reproduce a solution by decoding it from the domain of knowledge with the calculus of fuzzy “if-then” rules. A methodology based on Fuzzy Inference Systems (FIS) is proposed to assess the environmental sustainability of biomass.

1. INTRODUCTION

Energy crops are positioned as the most promising renewable energy sources. They are specifically targeted at the production of biofuels (solid, liquid and gaseous) and the development of vegetal products with specific attributes that make them suitable for industrial processing and transformation into energy.

Controlling energy consumption and greater reliance on energy from renewable sources, together with energy saving and increased energy efficiency, are all important and necessary measures to reduce greenhouse gas emissions. Over recent years the use of biomass has been growing significantly, especially...
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in countries that have made a strong commitment to renewable sources in their energy policies. This growing interest in bio-energies also originates from EU policies, such as Directive 2009/28/EC, which promotes the use of renewable energy sources. Among the measures contained in the Directive, there is the obligation on each Member State to use a minimum quota of 10% of renewable energy in the transport sector by 2020. It is easy to imagine, therefore, that biofuels will play a leading role in the future.

One aspect of the use of biomass for energy purposes that is still controversial concerns their full environmental sustainability. Considering the crucial importance of this problem, numerous authors have carried out evaluations of the environmental impact of the various types of biomass by means of several approaches. Although some of these methods are excellent environmental evaluation tools they are unfortunately unable to manage uncertain input data.

Fuzzy-set based methods have proved to be able to deal with uncertainty in environmental topics. Fuzzy-set theory was introduced by Lofti Zadeh (1965) with the publication of a paper that still constitutes a milestone. It is unlikely that Zadeh imagined what an impact this theory would have on so many disparate fields, from control to modelling to the programming of calculators and decision support systems. The innovative contributions proposed by fuzzy logic relate, on the one hand, to the representation of vague, imprecise and uncertain information, and on the other, to handling such information using fuzzy rules and tools. Today, many control systems apply this logic and the number of applications in the field of decision-making systems is greatly increasing.

A fuzzy inference system (FIS) constitutes the practice of formulating mapping from the input to an output using fuzzy logic. This approach offers a solution to the problem of human interpretation (data expertise, etc.). The idea is to reproduce a solution by decoding it from the domain of knowledge with the calculus of fuzzy IF-THEN rules.

An inference engine is responsible for fuzzification of crisp data inputs, fuzzy reasoning and defuzzification of the output. In the fuzzification step input-output vectors are converted in fuzzy sets and their membership functions are defined. The main part of the FIS model is the fuzzy `if-then’ rules defined on the basis of expert knowledge or a database of the input-output history. Finally the defuzzification process consists in converting the fuzzy output into a numerical value.

In this chapter a methodology based on fuzzy inference systems (FIS) is proposed to assess the sustainability of production and use of crops dedicated for energy purposes.

2. FUZZY SETS AND UNCERTAINTY

The use of fuzzy set theory has yielded very good results for modelling qualitative information. Fuzziness measures to what extent something is found or to what degree a condition holds. The introduction of fuzzy logic therefore modifies considerably all the underlying principles of traditional logic. Fuzzy systems are an alternative to traditional notions of logic that have their origins in ancient Greek philosophy.

Zadeh highlights the gap existing between mental representations of reality and traditional mathematical representations. Classical logic based on exact numbers is too rigid to account for classes of objects of the physical world in which membership appears as a gradual notion (Dubois, Ostasiewicz, & Prade, 2000).

Traditional mathematics is well-suited to modelling and finding solutions to crisp problems or problems in which vague parameters are stochastic. Vagueness includes phenomena that are inherently imprecise (Zimmermann, 1983; Munda, Nijkamp, & Rietvald, 1994). The result of any decision-making model