A Fuzzy Decision-Making Tool for Livestock Production Systems in Pantanal Region

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ABSTRACT

This paper describes the construction of a fuzzy inference system (FIS) based on rules to assess the sustainability of farms in the Pantanal. Sustainability of biomes is founded on three dimensions: environmental, social and economical. This paper presents a fuzzy approach to integrate sustainability indicators to quantify and simplify phenomena that are accessible to all users and assist decision makers for understanding of complex systems. This work also describes two tools to support the construction of fuzzy systems, called FuzzyGen and WebFuzzy. They were developed by Embrapa Agricultural Informatics and Embrapa Pantanal. The use of sustainability indicators is an efficient strategy to evaluate and formulate development policies. The monitoring of real production systems of beef cattle in the Pantanal was the basis for the definition of variables to represent the performance of the activity. The validation was performed from scenario simulation in a fuzzy inference system (FIS). Scenarios were constructed to critical evaluation of producers until convergence analysis results from the experience of producers.
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Keywords: production systems, livestock, beef cattle, sustainable indicators, fuzzy inference system, decision-making tool.

1. INTRODUCTION

Sustainability of biomes is founded on three axes: environmental, social and economical. To maintain the balance of these three aspects in the Pantanal is important to define a policy which assists farmers to maintain and save Pantanal. The definition of sustainability indicators of livestock production system requires the use of a methodology to assess the economic and social variables and their interactions.There are several methods, tools and indicators of sustainability assessment proposed in the literature, but none can be applied in the Pantanal region (Azadi, 2009, Cornellisem, et al. 2001).
This paper presents a fuzzy tool that implements sustainability indicators to quantify and simplify the monitoring and evaluation of the sustainability of Pantanal farms. The definition of the indicators involved the specification of parameters related to the

production system. Thereafter, indicators were defined for each one of the parameters through participative team meetings. Categories of evaluation (quantitative and qualitative) have been established to each indicator or criteria characterized and validated in the field.

Due to the complexity of factors involved in sustainability assessment, fuzzy logic (Fuzzy) was adopted as a technique for visualization and aggregation of indicators because the principle of the fuzzy logic is that the class values of a set are not crisps.

Rules were implemented to generate a fuzzy inference system (FIS) to each indicator, that result is an integrated index that aggregates these rules defined by scientists from detailed studies. In this approach, you can add "intelligence" to the indicators, making them tools to support decisions more powerful.

This tool provides results for each parameter in the form of a visual radar graphic, where you can see the indicators that are below the desired level or sustainable. The tool also provides the integrated analysis of all indicators considering the six aspects of management practices on the farm, as well as the evaluation of the productive potential. Thus, you can assess the strengths and weaknesses of the entire production system, pointing out the factors responsible for ensuring the sustainability of Pantanal farms .

This paper focus in the description of two tools generated to develop the fuzzy inference systems, called FuzzyGen and WebFuzzy, developed by Embrapa Agricultural Informatics. Finally, this work will also present the validation of these tools that was done by scenary simulations that were built and evaluated by the farmers.

The paper is organized as follows. Section 2 describes some concepts of the decision-making system and fuzzy logic. Section 3 presents the validation of this tool. Section 4 brings the main results obtained. Finally, section 5 shows the conclusions of this work as well as future work in our research project.

2. MATHERIAL AND METHODS

Sustainability is a multidimensional and multi-scale concept that has economical, environmental and social dimensions. To maintain the balance of these three aspects in the Pantanal it is important to establish differentiated policy that assists producers to maintain Pantanal productive and conserved. Providing support to the process of decision making and economic and social development. The definition and use of sustainability indicators is an efficient strategy to evaluate and formulate development policies. The definition of sustainability indicators of livestock production system needs to use a simple methodology to assess the economic and social variables and their interactions. Besides expressing the dynamics of the environmental characteristics of the region (Abreu & Santos, 2010).

This paper aims, through the methodology of fuzzy sets (FS), to build economic, environmental and social indicators and validate them to compose an index of sustainable farm.

2.1 Proposed Approach

In the Pantanal, the production of beef cattle is the main economic activity and it is an important economical sector at regional and national levels. Therefore, this work adopted a Pantanal farming as basic unit, which interacts in different scales. Due to the complexity of the landscape of the Pantanal is necessary to develop tools that enable the monitoring and evaluation of the different ecosystems in a holistic manner. The sustainability of production systems depend on the impact of the system itself as well as the impacts caused by external factors.
In the literature, there are several methods of sustainability assessment based tools and indicators (Azadi, 2009, Cornellisem, et al. 2001), but none can be applied at the Pantanal region. Rigby et al. (2001) built indicators to assess the sustainability of farm using the evaluation of `input` instead of impact assessment, as it is proposed in this work.
The implementation of this tool is based in a methodology developed by multidisciplinary team of scientists involved in the region and it is a tool for monitoring and evaluation of the sustainability of Pantanal farms (Santos et al., 2013) . The definition of the indicators specified the main parameters related to the production system in three dimensions: environmental, social and economical. Besides the parameters linked to the livestock industry was considered in the productive potential of the farm. Each indicator or criteria has established categories of quantitative and qualitative evaluation which are validated in the field. Lima et al.(2012) presents an example of analysis and validation of indicators in the economical aspect.

2.2 Application of Fuzzy Logic

In this work, the fuzzy logic proposed by Lofti A. Zadeh has been used as a well-suited tool to handle the vague, uncertain, and polymorphous concept of sustainability (Zadeh, 1994). A new branch of computing called "Soft Computing" has involved the methodologies that aim to exploit tolerance for imprecision and uncertainty to achieve tractability, robustness and low cost solutions.

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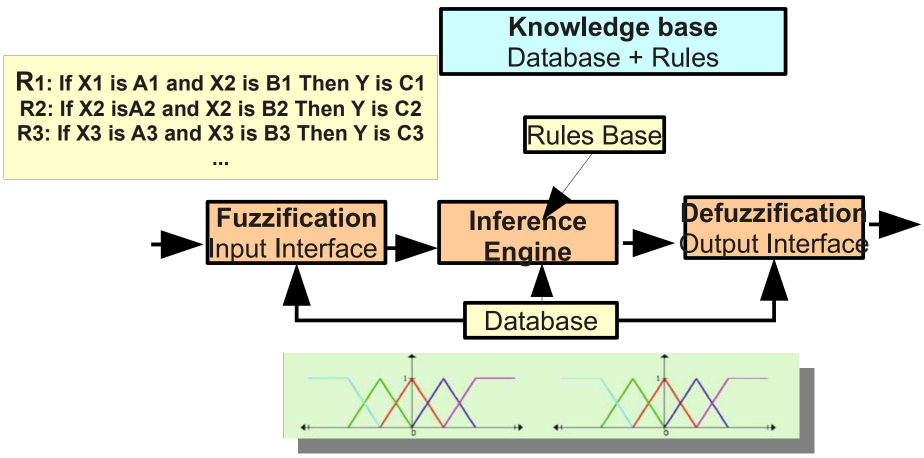

Fig. 1. Architecture of a FRBS

In this context, it is used "Fuzzy Rule Based System" (FRBS) to represent the variables and their interactions. The essential parts of a FRBS are the knowledge base (KB) and the inference engine (IE). The KB is divided into the data base (DB) and the rule base (RB). The generic structure of a FRBS can be seen in Figure 1.

KB are described in linguistic terms associated with the variables of the problem and their membership functions that describe its semantics. Each variable has an associated problem of fuzzy partition of your domain, formed by the fuzzy set associated with each linguistic term. This approach may be considered as a type of continuous areas where discretization is to establish a membership function for each linguistic term and there is an overlap between them. Figure 2 shows an example of fuzzy partition.

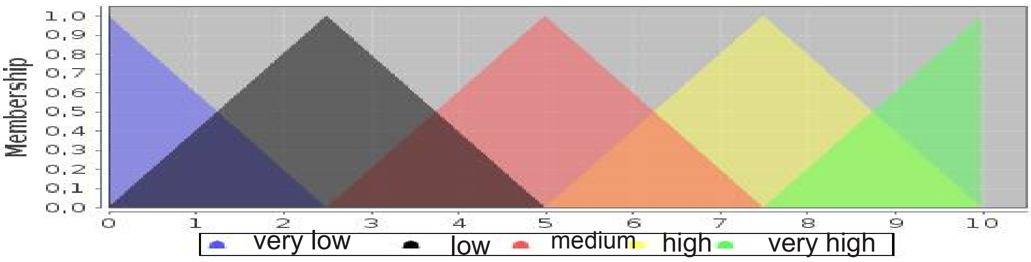

Fig. 2. Example of *fuzzy partition*.

The RB describes a set of fuzzy rules associated with the problem on the basis of linguistic terms of BD. It plays a key role in the FRBS. The meaning of the rules is the knowledge represented in the system. The IE is able then to process the rules from known facts, according to a given method of reasoning, providing a conclusion. The format of the fuzzy rules in a FRBS follows the pattern:

```
IF a set of conditions are satisfied
THEN a set of causes can be inferred
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The functioning of a FRBS also depends on the inference model adopted and will be discussed later. There are two main inference models of FRBS in the literature due to its success in practical applications. Both antecedents of rules are composed of linguistic variables and their linguistic terms are defined in the BD. The main difference is in the subsequent of rules, namely:

- **Linguistic or Mamdani:** The subsequents of rules are also formed by linguistic terms of the BD. The output is formed from the union of fuzzy set inferred from each activated rule in rules base, generating an aggregated fuzzy set, which is then applied a process to turn it into a numeric value output (Mandani, 1977) ;

- **Funcional or Takagi-Sugeno:** The subsequents of rules are polynomial functions applied to input values. The output is formed from the weighted average of the result of the function of each rule RB. The weights correspond to the degree of activation of each rule. This approach approximates a nonlinear system from the various linear systems (Takagi and Sugeno, 1985).

The inference model used in the context of this work is Mamdani, since it is more intuitive and suitable for human intervention. Their basic steps are outlined below:

- **Fuzzification:** It is the mathematical process where the numerical value (crisp) of an input variable is converted to a value of membership to a fuzzy set (linguistic term). This process has been illustrated in Figure 3. In the example, we observe that given the input value 370.0 for the variable, its degree of membership is 0.25 to 0.75 and BAD to REGULAR.

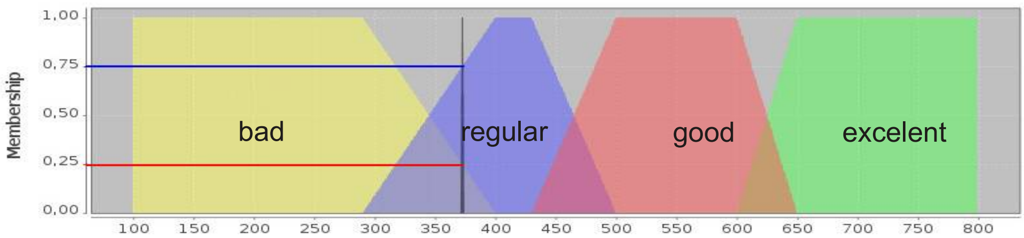

Fig. 3. Fuzzification process.

- **Inference:** It is the process of reasoning which are activated rules where the antecedent has fuzzy set (linguistic terms) that had membership degree greater than zero in the fuzzification. The fuzzy set generated to each rule activated are then inferred according to some operation applied to the membership degree of each FS in the antecedent, that in the inference method of Mamdani is the operator the minimum (MIN). Taking the example of Figure 3, the rules R1 and R2 would be activated, while R3 would not be:

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R1: IF X is REGULAR THEN Y IS MEDIUM
R2: IF X is BAD     THEN Y IS LOW
R3: IF X is GOOD    THEN Y IS HIGH
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Defuzzification: It is the mathematical process which the fuzzy set are converted to a numeric value. The fuzzy set of output values are aggregated and a method to convert fuzzy set to a numeric value (crisp). To solve this, several mathematics expressions are used:

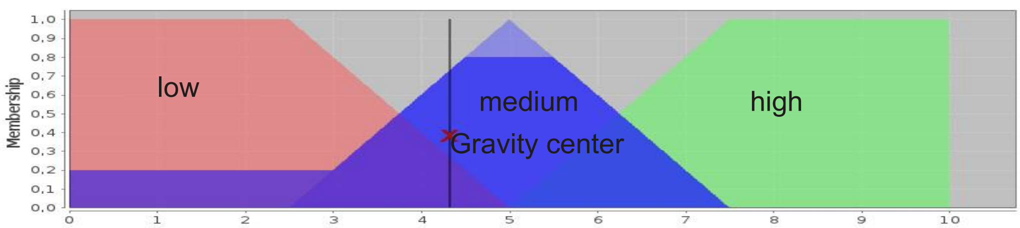

Fig. 4. The defuzzification Process.

2.3 Tools

Although there are software packages available that facilitate the construction of fuzzy inference systems, such as fuzzy toolbox of Matlab ®, these softwares are expensives and difficult to incorporate in applications related to the final user. These shortcomings have motivated the development of proprietary tools, which would enable the aggregation of knowledge from researchers in different areas of the Embrapa research for Brazilian agribusiness.

At first, there was a need to develop a tool for modeling and construction of FRBS, which was able to offer a user-friendly interface, providing it with all the basic components described above. In this context, the tool was created FuzzyGen (Lima et al., 2009) based API jFuzzyLogic and architecture for Java SE desktop (Cingolani, 2011). Through FuzzyGen, you can define a FRBS using standard FCL (Fuzzy Control Language) for interoperability (IEC 1131, 2008). The interface of this tool can be seen in Fig 5.

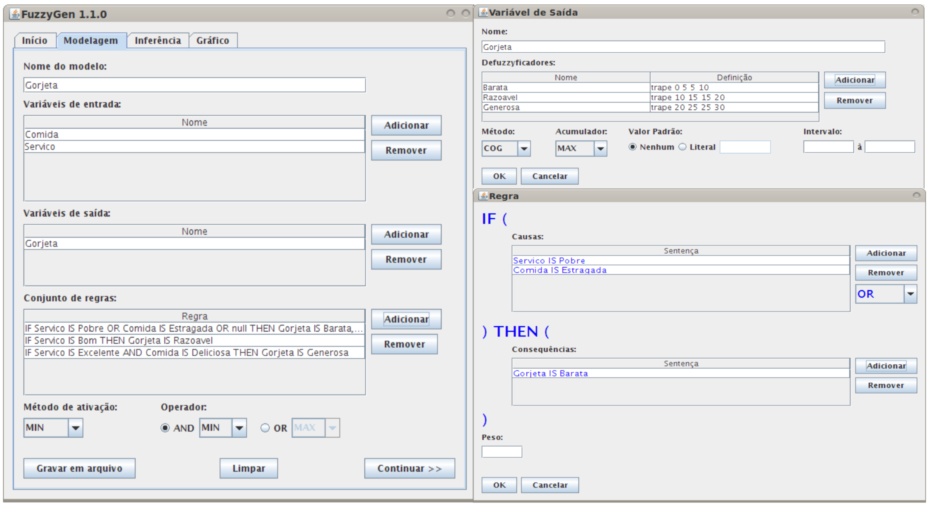

Fig. 5. Interface do FuzzyGen.

However, FuzzyGen covers only the construction phase, not allowing more accurate analysis of the inferences about the models built. It is proved that it is necessary to build an application that can provide models to be used by the final user, providing facilities of maintenance. Then, the WebFuzzy was developed as an application server on the Internet for models in standard FCL (Lima et al., 2011, Lima etal, 2012)). It uses an architecture focused on web-based Java language. The constructed models were defined in the tool FuzzyGen and become available to users on the web to inferences through WebFuzzy, where it was also possible to simulate scenarios and validate the models.

4. RESULTS AND DISCUSSION

The use of FRBS allows connection between quantification and evaluation of the concept of sustainability with the qualitative and quantitative indicators. It provides an analytical framework that allows the evaluation of sustainability by the expert in a single index that represents the measure of "value" of sustainability. Furthermore, FRBS are able to enter the modeling uncertainties that characterize sustainability assessment as ambiguity, generality and vagueness.

The fuzzy set (FS) and rules bases (RB) are at the heart of FRBS, is also the most important characteristic for the interactions necessary for sustainability assessment. The applicability of fuzzy models for sustainability also depends on the plausibility of the FS and RB defined for indicators. Especially, the proper knowledge how to build them should always represent both a scientific and practical, seeking maximum interpretation with the real phenomenon. In this paper, these aspects are well represented by experts (researchers from Embrapa) and a heterogeneous group of leading farmers of the Pantanal region.

The use of FRBS allows for intelligent modeling of something intangible and diffuse. This is particularly true in the case of this work, where evaluation requires that indicators are combined to form an index to quantify the cumulative sustainability.

Based on the application and adoption of the tool generated by producers, management actions can be designed in order to correct performance of the farm in the evaluation of the indicators, including understanding the criteria used (activated during the inference rules). The degrees of membership to the FS of each indicator may serve as a guide to monitor progress in relation to what could be considered an acceptable level of sustainability. The tool analyzes and shows graphically a qualitative comparison between the values of the provided indicators and evaluation of the model. Figure 6 shows us an example of the results provided in the form of a visual radar graphic, where you can see the indicators that are below the desired level or sustainable.

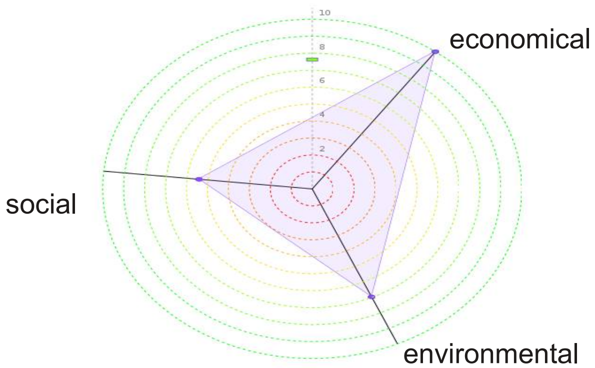

Fig. 6. Example of economical indicators (input) and environmental and social indicators (output).

5. CONCLUSIONS

Firstly, the FRBS was used to assess the economical dimension of the decision support system. This validation proved that this methodology is an appropriated alternative for the incorporation of knowledge that otherwise would be lost or dispersed, resulting in an integrated assessment of sustainable livestock production system in the Pantanal and having great potential to assist decision makers like government and development agencies (Lima et al, 2012). This tool has been evaluated in other dimensions, environmental and social.

The tools and FuzzyGen and WebFuzzy were effective in replacing commercial packages. They showed efficiency and low cost of FRBS in internet applications. These tools has showed a great potential for application in various areas, including agribusiness.

The construction and validation process adopted for the FRBS, including fuzzy set, the rule base and general behavior of the model, based on simulations of various situations, batch analysis, with subsequent presentation of results and discussion with producers, presented results approved by the target audience .

However the monitoring of real systems should be constant, because as the market is dynamic, rules and methods for assessing sustainability must always be reassessed to maintain compliance with the real production systems.

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