



<http://www.ijmp.jor.br>  
ISSN: 2236-269X  
DOI: 10.14807/ijmp.v9i2.756

v. 9, n. 2, April - June 2018

## A FUZZY SYSTEM TO STIMULATE THE PLANTING OF BEANS IN BRAZIL

*Frederico Silva Valentim Sallum*  
*Fuzzy Consultoria LTDA, Brazil*  
*E-mail: frederico.sallum@gmail.com*

*Luiz Flavio Aufran Monteiro Gomes*  
*Ibmec/RJ, Brazil*  
*E-mail: luiz.gomes@ibmec.edu.br*

*Maria Augusta Soares Machado*  
*Ibmec/RJ, Brazil*  
*E-mail: maria.machado@ibmec.edu.br*

*Submission: 10/11/2017*

*Accept: 06/03/2018*

### ABSTRACT

Beans are traditional elements on the table of the Brazilian population. In spite of this, the production of beans has been falling in Brazil in the last years. This article tries to identify the causes for the lack of motivation for growing beans in Brazil. It also aims to point out which factors are the most relevant for obtaining an expressive plantation and bean harvest. Given this, we were able to develop a system based on fuzzy logic that can be useful for measuring the expected loss until the bean harvest. With the output from such system the farmer can be provided incentives to start planting once that loss is considered acceptable. In order to generate the rules of the system the multicriteria TOPSIS method is used. The prototype fuzzy system explained and proposed in this article can be further expanded by agricultural experts thus leading to a large scale planting of beans.

**Keywords:** Planting beans; Expected loss; Fuzzy logic; TOPSIS method



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## 1. INTRODUCTION

The decision making of a grain producer when it comes to the planting is associated to the risks that should be faced during the entire plantation process and the way they can interfere in the harvest. Many of these risks are associated with the soil's conditions according to the amount of macronutrients. These macronutrients are necessary for the beans' good growth and are directly entailed in the harvest's success. Sure enough, a soil which is rich in macronutrients required by the beans will have a bigger chance to have a good growth and will be less likely to suffer crop losses.

Beans are very traditional food in the Brazilian household, it is an important source of protein, iron and carbohydrates in the human diet and it is present in approximately 100 countries all around the world. However, the little importance given to this product in the world, combined with the lack of knowledge and small consumption in the developed countries is a topic that has been put forward for discussion among experts (CONAB, 2013). This fact limits the expansion of the beans' world trade, since all beans producing countries are also large consumers (EMBRAPA, 2002).

The way the computational intelligence has been modeling and assisting many stages of the decision-making process in many different areas of research may also be considered an invitation to stimulate the agricultural production of legume (SALLUM, 2015). In this regard, the computational intelligence can be used as an important tool to stimulate the planting of beans, helping the producer predict the expected crop losses, through the chemical analysis, which presents the amount of macronutrients and micronutrients in the soil.

Quite often, a producer decides not to plant beans because his/her soil does not present an appropriate amount of all the macronutrients required for a good planting, to correct this situation, an expense with fertilization and a time for the soil to absorb the macronutrients will be needed. However, if the producer has the opportunity to learn the expected beans' crop losses in relation to the current state of his/her soil, he/she may decide to plant beans since the acceptable loss of planting is being considered.

A tool which is able to measure the expected loss of the beans' planting may, many times, show the producer the harvest's ability to succeed, motivating him/her to start planting. Since, in some situations, without this information this producer would not adopt the planting of beans. This paper aims at developing a system based on the fuzzy logic capable to measure the expected beans' crop losses, given the amount of the main macronutrients in the soil which are required for the harvest's success. In order to establish the rules used in this system, the multicriteria method TOPSIS will be used. Each rule is an alternative and each curve modelled in the input variables is the criteria.

## **2. LITERATURE REVIEW**

### **2.1. Beans Consumption and Production in Brazil**

According to EMBRAPA (2002), the per capita consumption of beans in Brazil over the last 40 years presents a downward trend of 1,3% per year, while the population grew 2,2%. Still, beans are still relevant food because of their economic, social, nutritional and cultural aspects. However, data shows that urbanization is the main cause for the beans consumption reduction. According to Hoffmann (1995), urbanization is responsible for the consumption drop from the mid-70s to the end of the 80s. And, according to the 2010 census, about 84% of the Brazilian population is concentrated in the cities.

Despite this, Brazil imports a great quantity of beans' goods to meet the domestic supply, with Argentina and Bolivia as its main import sources. However, as of 2007, the country began to receive a significant quantity of the product from China, surpassing Argentina in 2008 and 2012 (CONAB, 2013).

That happens because there is vulnerability associated with the planting of beans. That is, since beans are a legume, most part of its stem is located into the ground and its fruit close to the ground, in other words, the plant's fruit does not grow and it is visible like most of other plantations. In this regard, there is a greater loss risk in the planting of beans due to any phenomenon of nature than in other plants where their fruits are more visible (SALLUM, 2015).

Therefore, when a farmer chooses to plant corn or cotton, for example, there is lower loss risk in relation to the beans. Figure 1 presents grown beans.





Figure 1: Beanstalk in the ground

Source: <http://www.sistefafaep.org.br/recuo-no-plantio-ameaca-encarecer-o-feijao.html>

Another important aspect that may discourage the farmer to plant beans is the volatility in the selling price of the bag. With this instability, the bean farmer assumes the risk of not being able to sell his/her production for a lucrative price. In this respect, the price change is another risk faced by the farmer who decides to plant beans. Figure 2 presents the price change of a 60-kilo bag of black beans from 2005 to June/2015. The chart presents a comparison between the national average price (orange line) and the State of Parana's average price (blue line), an important Brazilian State in terms of the planting of beans (SEAB, 2013).

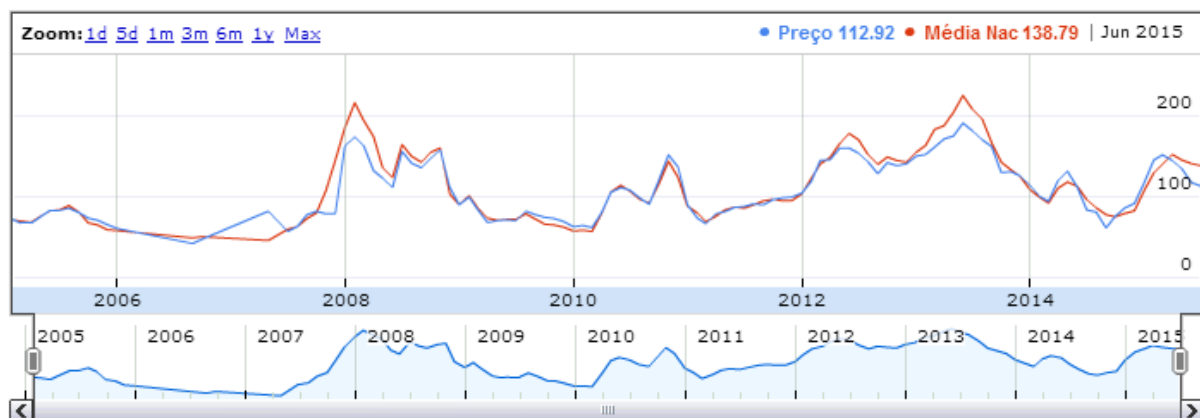


Figure 2: The price change of a 60-kilo bag of black beans chart

Source: <http://www.agrolink.com.br/cotacoes/historico/rs/feijao-preto-sc-60kg>

An additional reason why many times the planting of beans is not stimulated is that beans are not as exportable as other products, for instance, the soybean (EMBRAPA, 2002). That happens because the major producers are the developing countries and they are also the major consumers. Besides that, the developed countries consume a very little amount of beans.

Despite all these facts mentioned above, beans are still the staple diet of the majority of the population and it is ideal that the consumption is met, increasing the domestic production (CONAB, 2013). Consequently, the fact that Brazil imports beans from other countries should be an invitation to stimulate an increase in this legume's plantation in the Brazilian soil.

## **2.2. The Soil's Macronutrients**

As stated in the previous section, the main reasons why farmers lose motivation to plant beans are: the beanstalk's vulnerability, instability in the price of the bag and being a slightly exportable product. Nevertheless, Brazil does not meet the beans' internal demand and this fact should be an incentive to stimulate the planting of beans.

In order to obtain a good planting of beans and a low level of crop losses, it is necessary that the soil where this legume is going to be planted is rich in certain macronutrients, they are: Nitrogen (N), Phosphorus (P), Potassium (K), Calcium (Ca), Magnesium (Mg) and Sulphur (S). Each one has a certain importance for the seed's good development (SERRAT et al, 2002).

Plants produce their organic compounds, but they need mineral nutrients that are present in the soil and in the fertilizers. Therefore, they will be able to grow and produce fruit. The mineral nutrients are divided into macronutrients, primary and secondary, and micronutrients, the absence of any one of them diminishes the plants' growths, reducing the agricultural and forestry production (SERRAT et al, 2002).

The macronutrients are called as such because they are absorbed in great quantity by the plants. The primary macronutrients are usually commercialized as fertilizers and they are more expensive to the producer. The primary macronutrients are: N, P and K. The secondary macronutrients are: Ca, Mg and S. Table 1 presents the function of these nutrients to the plants.

According to Leal and Prado (2008), the most limiting macronutrients to the beans' growth in the Brazilian soil are N and P. Many published papers about the beans fertilization demonstrate that the fertilization of nitrogen and phosphate fertilizers is high, compared to other macronutrients. Beans demand N and, many times, even if the inoculation is appropriate to N's fixation, it does not meet the

beans' demands to obtain the grains' high productivity (CTSBF, 2012). According to this source, beans need N to grow and there is a certain difficulty in retaining this macronutrient.

**Table 1: The Macronutrients Functions**

<b>Macronutrient</b>	<b>Function</b>
N	Increase the protein content; stimulate the formation and development of flowers and fruit; promote more vegetation and tillering
P	Participate in the production of energy from the plant; accelerate the roots' formation; increase fructification; speed up the fruit's maturation; increase the carbohydrate, oil, fat and protein values; assist nitrogen's symbiotic fixation
K	Increase the sugar, oil, fat and protein values; increase resistance to droughts, frosts, plagues and diseases; improve water usage; stimulate grain filling, decreasing crossing; stimulate vegetation and tillering in grassy plants; assist nitrogen's symbiotic fixation
Ca	Collaborate with the plant's structure; stimulate the roots' development; increase resistance to plagues and diseases; promote a higher flowering ripening; assist nitrogen's symbiotic fixation
Mg	Collaborate with Phosphorus; it is a part of the chlorophyll (the plant's green pigment)
S	Increase fructification; increase the carbohydrate, oil, fat and protein values; assist nitrogen's symbiotic fixation

Source: Adapted from Serrat et al, 2002

Still according to CTSBF (2012), in general, there are not many Ca, Mg, S and micronutrients deficiencies on beans. Most soils present a good availability of these nutrients and their application has not been significantly increasing the plantations performance. In line with the presented reading, N and P are the most important nutrients for the plant's development. N is essential for the beans and there is a certain difficulty in absorbing it by the plant. K is important, but less than N and P, whereas Ca, Mg and S are still less important than K.

To discover the soil's state, a farmer can undertake a chemical analysis, which is the first step to know the amount of nutrients the soil can retain and then pass them to the plants. The soil's chemical analysis evaluates the fertility and availability of nutrients for the plants. And, through this type of analysis, the farmer knows the correct need of using fertilizers for his/her soil. This type of analysis must be done from 1 to 3 months before planting starts. (SERRAT et al, 2002).

### **2.3. Fuzzy Logic**

The fuzzy logic, one of the computational intelligence's applications, was the tool chosen to be studied in this paper because it presents characteristics in its modelling that are proximate to the nature of how the amount of macronutrients in the soil is defined (PERUZZI et al, 2012). The classical logic or Boolean logic carries





a dichotomous stiffness in classifying if a certain individual or element belongs or not to a certain grupo, and to be classified as a member of this group an element must fully belong to it.

The fuzzy logic seeks to associate possibilities to this question, since it allows a certain individual or element to belong partially or totally to a certain group. The fuzzy logic, consequently, tries to measure the strength with which the element belongs to a group by the degree of pertinence. The degree of pertinence varies on a scale from 0 to 1, where the value of pertinence 0 means that the element does not belong to the group and the degree of pertinence 1, means that the individual totally belongs to the studied group (MACHADO et al, 2016).

Any element that has a degree of pertinence between 0 and 1, partially belongs to a certain group, this point is not addressed by the classical logic. This classification of elements with a degree of pertinence attributed to the strength of the element inside the group, this approach allows that many daily situations and academic researchers are modelled through this type of logic. This type of logic may be similar to the behavior of countless situations that require a greater sensitivity, that is, situations where it is not possible to state that an individual totally belongs to a certain group (ISLAM; MANDAL, 2017).

This line of thinking started in the 60s when Professor L. A. Zadeh, from the University of California in Berkeley, in the United States of America, was researching about artificial intelligence and noticed that the classical logic's stiffness was incompatible to a satisfactory elaboration of expert systems. Therefore, due to the need of a greater sensitivity to model some situations, he started to develop a new theory of sets where going from "belonging" to "not belonging" was gradual and not abrupt. Thus, the theory of fuzzy sets emerged.

The gradual transition from "contained" to "not contained" can be exemplified by the transition from white to black. In the classical logic, a white set would be totally white until the barrier that ends the group and the colour becomes totally black, because it would be inside the set of the black colour until the barrier of this set. In the fuzzy logic, this would happen differently. The white colour still inside the group would be completely white in the beginning of the set barrier and it would

darken gradually and become completely black only in the end of the black set barrier.

Situations, which have inaccurate information, can be similar to fuzzy sets. The fuzzy logic provides a method of translating vague, inaccurate and qualitative verbal expressions, which are common in human communication in numerical values (MARÇAL; SUSIN, 2005). The inaccuracy that the fuzzy logic considers in its modelling may, many times, be able to transmit the human experience in a way that is computationally understandable, for a machine (BILOBROVEC, 2005). Therefore, the technology is allowed to have a practical value considering the human experience to assist the decision making and process control, especially in the case in which there is a divergence among specialists or lack of them, for example. The following subsections address the steps for the fuzzy logic modelling.

### **2.3.1. Fuzzyfication**

The fuzzyfication step is the association of the qualitative groups' degrees of pertinence created by the responsible for the quantitative treatment of the system's data. This degree of pertinence comes from a pertinence function defined based on the specialist's perception in relation to the function's proximity to the variable to be modelled inside the groups. These functions of pertinence can be triangular, trapezoid or Gaussian, etc. The numerical values are transformed into degrees of pertinence associated with a qualitative variable (MATTOS, 2001).

### **2.3.2. The Basis for Rules**

This step consists of establishing rules that will be the way through which the controller will read the system, that is, under which conditions should the system function. These rules should be made through the experience of a specialist in the matter (OLIVEIRA JUNIOR; MACHADO, 2015).

The most common procedure to establish rules are: if premise, then consequence. A basis for rules is close, in its formulation, to human intuition, because, in many cases, there is not a mathematical formulation involved in the solution for the problem, but a specialist's knowledge (MACHADO et al, 2016).

### **2.3.3. Inference**





To take the type of formulation of standards as an example: if premise, then consequence; the side contains conditions called antecedents which constitute the premise. The side, then, contains one or more actions called consequents (ISLAM; MANDAL, 2017).

The antecedent is directly correspondent to the associated degrees of pertinence during the fuzzyfication. Each antecedent has its degree of pertinence indicated as a result of fuzzyfication, being its modelling. Therefore, when the standard evaluation is done by the system, the inference is made based on the antecedents values and are indicated to the rules fuzzyficated outputs (BILOBROVEC, 2005).

### **2.3.4. Defuzzyfication**

It is the step where the conversion of a fuzzyficated rule to a correspondent classical value occurs. In the defuzzyfication, everything that was put into the system so that the inference was possible is transformed into an output value, which corresponds to how the rules were elaborated, before fuzzyfication. All the fuzzy logic steps can be summed up by observing the Figure 3.

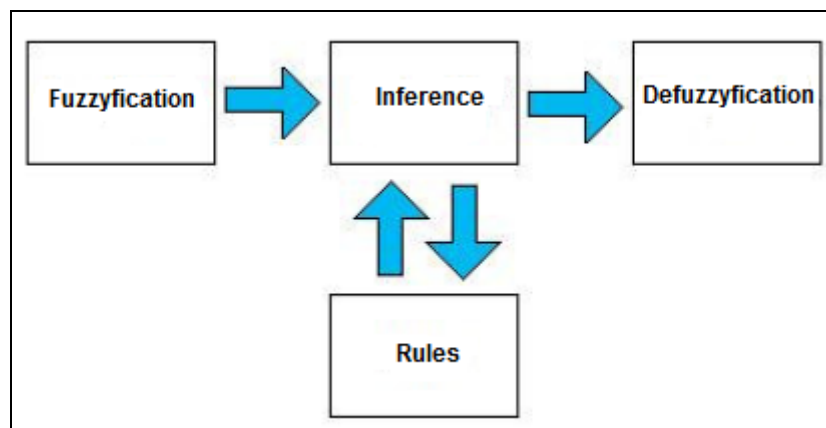


Figure 3: The fuzzy logic steps  
Source: Adapted from Carneiro, Nedjah and Mourelle, 2010

## **3. FUZZY EXPERT SYSTEM FOR STIMULATING THE PLANTING OF BEANS RULES**

This system was created to measure the expected crop losses in the planting of beans from the amount of macronutrients in the soil before the beginning of plantation. These macronutrients ensure a good seed development throughout the

entire productive process. The Fuzzy Toolbox from software MATLAB® was used to elaborate this system.

The amount of macronutrients needed to obtain a good planting reducing loss is inaccurate, therefore, the fuzzy modelling is close to the definition established by the soil's chemical analysis report.

### 3.1. Input Variables

The input variables will be the essential macronutrients that guarantee the plant's good development, they are the Nitrogen (N), the Phosphorus (P), the Potassium (K), the Calcium (Ca), the Magnesium (Mg) and the Sulphur (S), all of them represented by the quantity measured in the soil. According to this paper's section 2.2 which describes each macronutrient's importance to the development of a legume, the N will be the first input variable, the P will be the second input variable, the K will be the third input variable and the macronutrients Ca, Mg and S will be the fourth input variable, thus represented by a single input variable (Figure 4).

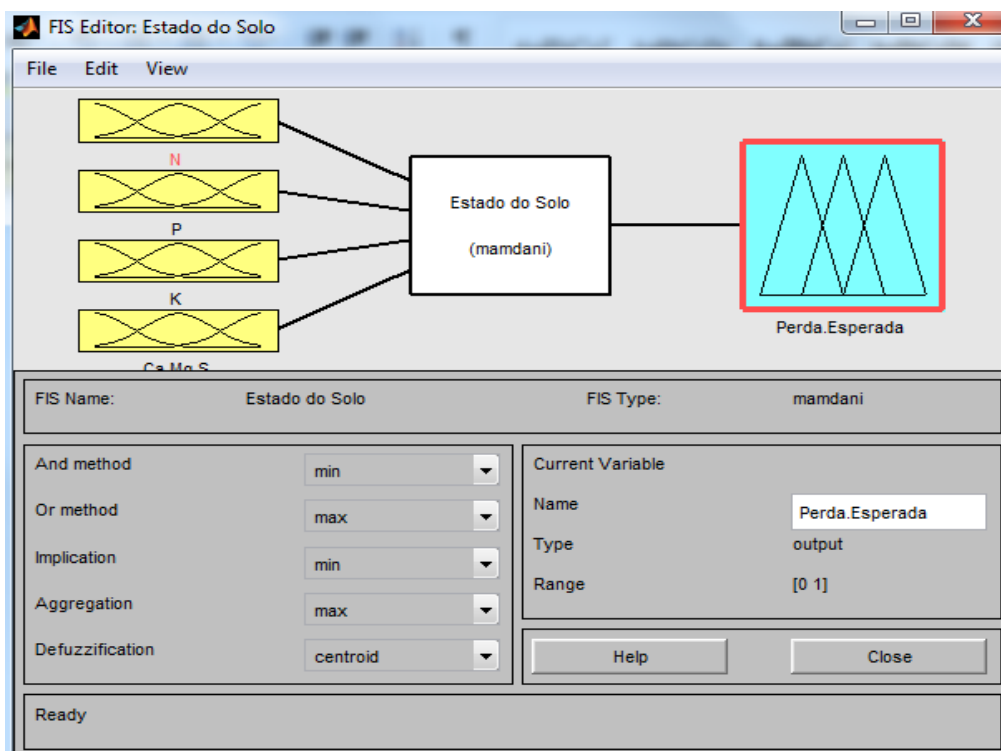


Figure 4: Input Variables  
Source: MATLAB®

Each input variable in the system is represented by the percentage of optimum quantity in the soil. That is, given the quantity of a certain macronutrient presented by a chemical analysis, the producer will insert how much this quantity

represents the optimum quantity of this macronutrient to avoid crop losses. Therefore, a value from 0 to 100% from the optimum quantity of the macronutrients in a certain soil mentioned above can be inserted into the system for each input variable. In this manner, the first input variable is modelled with 3 curves, curves 1, 2 and 3. Curve 3 represents 0% of the optimum quantity, that is, degree of pertinence 1 in 0. Curve 2 represents 50% of the optimum quantity, that is, degree of pertinence 1 in 0.5. Curve 1 represents 100% of the optimum quantity, that is, degree of pertinence 1 in 1. The same modelling is used for the input variables P and K.

The input variable Ca, Mg, S has 2 curves, curves 1 and 2. Curve 2 represents 0% of the optimum quantity, that is, degree of pertinence 1 in 0 and curve 1 represents 100% of the optimum quantity, that is, degree of pertinence 1 in 1. Figure 5 presents N's input variable modelling.

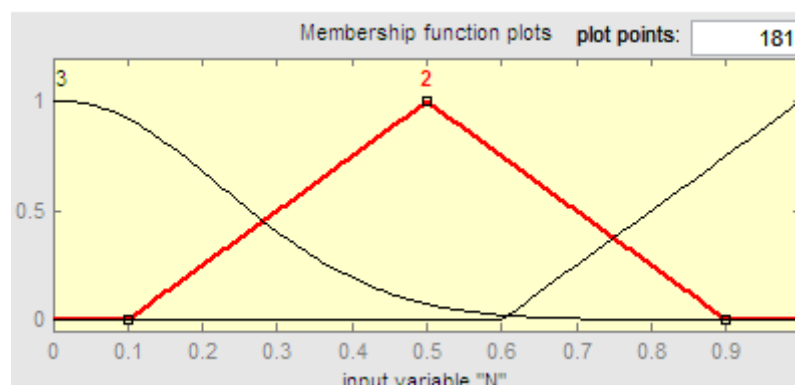


Figure 5: Input Variable N  
Source: MATLAB®

The choice of curves was made as follows: since the most important macronutrient is N it is hard to retain it in the soil, the gaussian curve represents low amount. In order to get out of the low amount state, there is a subtle pertinence loss. A triangular curve was used to represent the average and high amounts, to reach these stages there is a more accelerated loss of pertinence. Figure 6 presents P's input variable modelling.

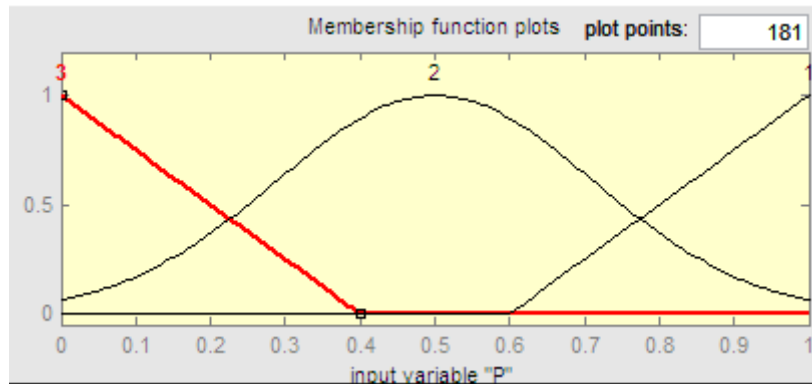


Figure 6: Input Variable P  
 Source: MATLAB®

The classification of the amount in 1, 2 and 3 was established in relation to the optimum quantity, the same way it was established for variable N. The choice of curves was made as follows: in stage 1, a triangular curve is used, since to get out of this stage there is a more accelerated loss of pertinence than N and, also, to reach a high stage of P. In stage 2, a Gaussian curve is used, because in order to obtain and stop obtaining this level of P a more gradual step was expected in relation to N. Figure 7 presents K's input variable modelling.

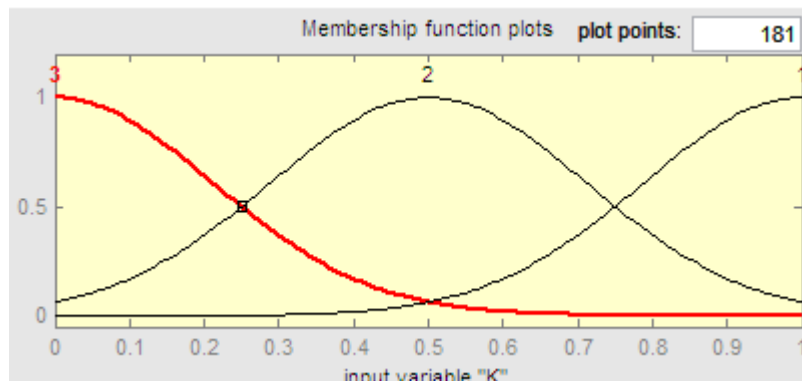


Figure 7: Input Variable K  
 Source: MATLAB®

The input variable K is modelled in 3 levels of classification of its optimum quantity in the soil, they are: 1, 2 and 3. This modelling was made according to this macronutrient's information, in which to leave the state of low amount it is more gradual than in some stages of macronutrients N and P. That's why the Gaussian curve is used in the 3 stages of the modelling classification of this input variable. Figure 8 presents Ca, Mg, S' input variable modelling.



Figure 8: Input Variable Ca, Mg, S'  
Source: MATLAB®

The amount of these 3 macronutrients was modelled in one variable due to its results during the plantation, presented in section 2.2, and its (little) importance when compared to the other macronutrients. This variable was classified with 2 levels, 1 and 2. The Gaussian curve was used for both classifications.

### 3.2. System Rules

The multicriteria method TOPSIS was used to elaborate the system rules. The steps to use this method can be found in Hwang and Yoon (1981). Since there are 3 curves in the input variables N, P and K and 2 curves in the input variable Ca, Mg, S, 54 rules were calculated for this system by multiplying the number of curves of each input variable.

In order to use a multicriteria method in the elaboration of rules in the fuzzy system, each rule is considered an alternative and each input variable is considered a criterion. The performance of an alternative in each criterion is given by the number of the curve that each alternative can take in a criterion. For that, every possible combination among alternatives and criteria must be made, that is, define every possible rule.

It is also important to notice that, in the input variables modelling, the curves with pertinence 1 in 100% of the macronutrients optimum quantity have number 1. Number 1, associated with a certain curve, will be applied into the TOPSIS multicriteria method as an alternative performance in an input variable. This number represents a performance lower than 2 and 3. Since it is desired to measure the expected crop losses, an alternative with performance 1 contributes to a lesser degree to the crop losses than a performance 2 or 3.

The TOPSIS method was chosen because, in its methodology, it is calculated how each alternative approximates more to the ideal solution and at the same time how each alternative distances itself from the non-ideal solution. The ideal and non-ideal solutions are defined according to the maximum and minimum performance values of the studied alternatives in the criteria. The criteria must be classified as cost or benefit criteria. For a benefit criterion, the bigger the values (that is, the values of each alternative's measure of performance), the more desirable an alternative is, whereas, for a cost criterion, the opposite happens.

The ideal positive solution maximizes the benefit criteria and minimizes the cost criteria and the ideal negative solution maximizes the cost criteria and minimizes the benefit criteria. The opposite happens for the ideal negative solution. In this paper, every input variable is used as a benefit criterion, because the higher the performance of an alternative in a criterion (the lesser the optimum quantity's percentage of a macronutrient in the analysed soil), the bigger the expected crop losses.

With the implementation of the TOPSIS method, a value that represents the relative proximity will be calculated for each rule. With this value it is possible to put the studied alternatives in order in a multicriteria context. The value of the relative proximity generated for each rule with the implementation of the TOPSIS method will be the output of each rule in the fuzzy system. The value of the relative proximity may vary from 0 to 1. Therefore, the values of the output variable of each rule will be modelled from 0 to 1.

In the TOPSIS method's implementation, the variable N has a 40% weight, the variable P has a 30% weight, the variable K has a 25% weight and the variable Ca, Mg, S has a 5% weight. These weights were arbitrarily chosen, but in order to follow the bibliographic review presented in section 2.2, that is, N should have a weight bigger than P, which should have a weight bigger than K, which should have a weight bigger than Ca, Mg, S. Table 2 presents the system rules and its outputs.

**Table 2: System Rules**

Rule	N	P	K	Ca, Mg, S	Output	Rule	N	P	K	Ca, Mg, S	Output
1	1	1	1	1	0,0000	28	2	3	3	2	0,6875
2	2	2	2	2	0,5019	29	3	3	3	1	0,9424
3	1	1	1	2	0,0576	30	3	3	2	1	0,7991
4	1	1	2	1	0,1949	31	3	3	1	2	0,6672
5	1	2	1	1	0,2321	32	3	1	3	2	0,6119





6	2	1	1	1	0,3125	33	3	2	3	1	0,7629
7	1	1	2	2	0,2009	34	2	3	3	1	0,6838
8	1	2	1	2	0,2371	35	1	3	3	2	0,4950
9	2	1	2	1	0,3810	36	3	2	2	1	0,6919
10	2	2	1	1	0,4131	37	3	2	1	2	0,5951
11	2	1	1	2	0,3162	38	3	1	2	2	0,5640
12	1	2	2	1	0,3043	39	2	2	3	1	0,5835
13	2	2	2	1	0,4981	40	2	3	2	1	0,6156
14	2	2	1	2	0,4165	41	2	3	1	2	0,5308
15	2	1	2	2	0,3844	42	1	3	2	2	0,4381
16	1	2	2	2	0,3081	43	1	2	3	2	0,4073
17	3	1	1	1	0,5050	44	2	1	3	2	0,4717
18	1	3	1	1	0,3881	45	3	1	1	2	0,5069
19	1	1	3	1	0,3328	46	3	1	2	1	0,5619
20	3	2	2	2	0,6957	47	3	2	1	1	0,5927
21	2	3	2	2	0,6190	48	2	3	1	1	0,5283
22	2	2	3	2	0,5869	49	2	1	3	1	0,4692
23	3	3	1	1	0,6646	50	1	1	3	2	0,3354
24	3	1	3	1	0,6097	51	1	3	2	1	0,4360
25	1	3	3	1	0,4931	52	1	2	3	1	0,4049
26	3	3	2	2	0,8051	53	1	3	1	2	0,3903
27	3	2	3	2	0,7679	54	3	3	3	2	1,0000

### 3.3. Output Variable

This system's output variable is the expected crop losses in light of the amount of macronutrients in the soil. The value of the expected loss for each rule was generated by the TOPSIS method's value of the relative proximity (Table 2).

The rules were established by the Mamdani type (PERUZZI et al, 2012), this output happens in the curve's centroid. The curve chosen was the triangular one by the proximity with the output variable's nature, the value of the relative proximity calculated by the TOPSIS method. In Figure 9, a modelling of the output variable can be observed:

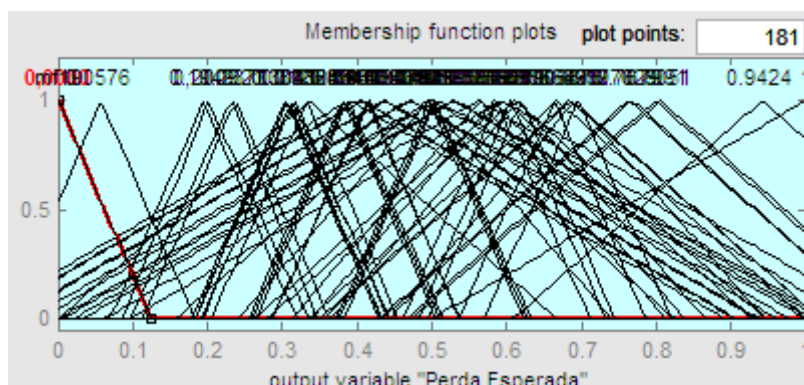


Figure 9: Output Variable  
Source: MATLAB®

#### 4. DATA ANALYSIS

In order to make the results analysis, 5 different situations in a soil state in relation to the quantity level of its macronutrients will be studied and the expected loss for each situation will be verified.

To analyse the first situation, it is considered that the quantity level of each macronutrient in the soil is 50% of its optimum quantity. Figure 10 illustrates this situation.

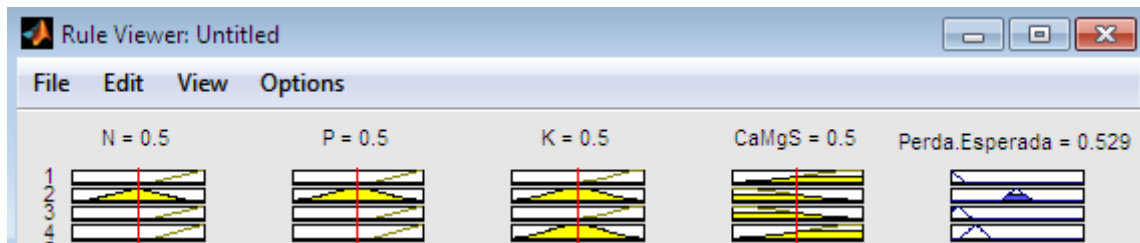


Figure 10: Situation 1  
Source: MATLAB®

In the first situation, it can be observed that for a level of 50% of optimum quantity of each macronutrient it is expected a crop loss of 52,9%.

To analyse the second situation, 88% of N, 88% of P, 50% of K and 50% of Ca, Mg and S will be put into the system. Figure 11 illustrates this situation:

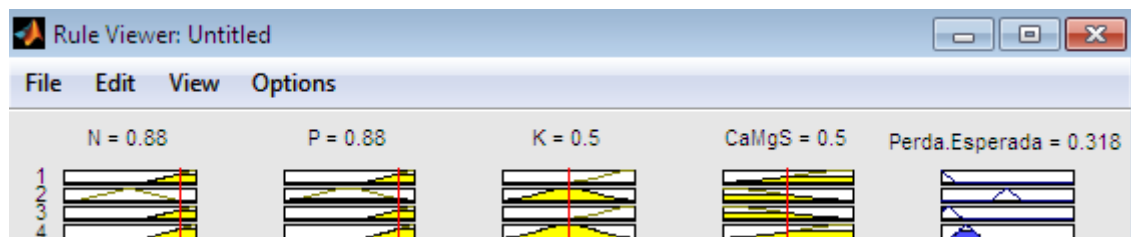


Figure 11: Situation 2  
Source: MATLAB®

In the second situation, a crop loss of 31,8% is expected. Comparing this situation to the previous one, the quantity levels of N and P were elevated, the most important and most relevant macronutrients for a minor loss, whereas the levels of K and Ca, Mg and S remained the same and, as a consequence, the loss suffered a reduction from 52,9% to 31,8%. That shows that the system responds coherently to the rules in its output.

In the third situation, the levels of N and P were axreduced to 3,25% and 5,03%, respectively, and the quantity levels of the other variables remained the same in 50%, according to Figure 12.

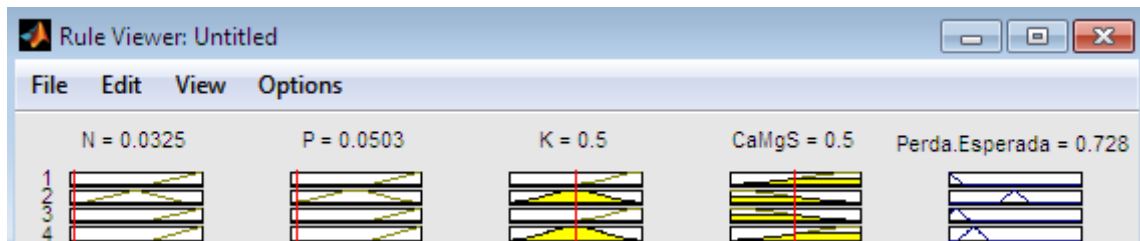


Figure 12: Situation 3  
 Source: MATLAB®

It can be noticed that the expected loss went up to 72,8%, which is also coherent to the rules, since the quantity level of the two most important macronutrients is low in a high degree of pertinence.

In the fourth situation, the levels of N and P remained low with high degree of pertinence 5,03% and 2,66%, respectively. The quantity level of K was reduced to 5,03% and the level of Ca, Mg and S was also reduced to 2,07%, according to Figure 13.

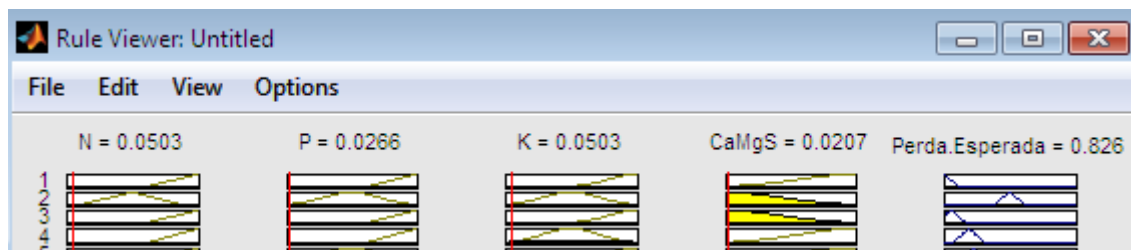


Figure 13: Situation 4  
 Source: MATLAB®

With these new levels, the expected loss increased in 9,8%, if compared to the previous situation, now of 82,6%. This fact demonstrates the system's sensitivity with the quantity decrease of the levels K and Ca, Mg and S.

In the fifth situation, the levels of the variables N and P are increased with a high degree of pertinence in each one and the levels of the variables K and Ca, Mg, S remain low with a high degree of pertinence in each one, but they are not the same from the previous situation (Figure 15).

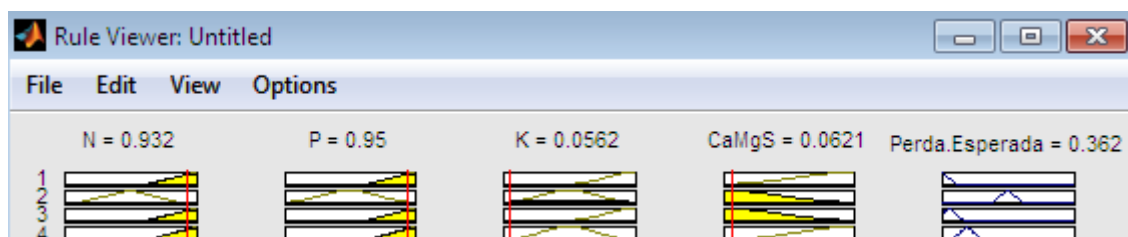


Figure 14: Situation 5  
 Source: MATLAB®

## 5. CONCLUSION

This study raised 3 points that discourage the planting of beans in the Brazilian soil, they are: vulnerability associated with the planting of beans, high volatility in the price of beans and the fact the beans are a slightly exportable product. However, it should be emphasized that Brazil needs to import beans to meet its demand, giving, thus, a reason to stimulate the planting of beans in the Brazilian soil.

The elements that bring success to the harvest of beans were also researched and, with that the soil's fertility is emphasized. That is, a soil rich in macronutrients, which are required for the beans' growth, will have a bigger chance of success in the harvest. With this, it was possible to determine that the quantity of these macronutrients was measured in a vague or nebulous way, the exact of opposite to the data treatment used in a fuzzy system.

In this manner, a system based on the fuzzy logic was created in order to measure the expected crop losses of beans, given the quantity of these macronutrients in the plantation soil. It is expected that with this information, a farmer may opt for the planting of beans for knowing previously the acceptable expected crop losses for the planting of beans.

This model still needs to be tested by a specialist who can validate the rules and results presented in the data analysis. The specialist's opinion about the elaboration of weights is also important, because it may, for example, increase the weight of variable N and decrease the weight of variable K in the TOPSIS method's implementation to generate the system rules. The TOPSIS method's implementation allowed a generation of system rules in a practical and coherent way according to the researched aspects. During the data analysis, the results' coherence with the elaborated rules by the TOPSIS method were noticed.

This paper may be extended with the inclusion of other variables, such as the micronutrients. Or in particular situations, in which there are other substances relative to certain soils that may decrease or increase the chance of crop losses. In this regard, it is intended to present a way to model the results of the expected beans crop losses through a fuzzy system in this paper. It should also be highlighted that the system needs to be tested and validated by specialists, but the proposed

research aims at presenting a start model to future research and improvements in its composition to generate a system fit for the producers' use and, with that, promote the stimulation of the planting of beans in the Brazilian soil.

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