G&P GESTÃO & PRODUÇÃO

ISSN 0104-530X (Print)
ISSN 1806-9649 (Online)

ORIGINAL ARTICLE

AHP & fuzzy logic hybrid method for decision making in project management in a forestry industry

Aplicação de metodologia híbrida AHP & lógica fuzzy para tomada de decisão na gestão de projetos em uma indústria florestal

Almir Lima Caggy[1], Ely Sena de Almeida[1]

[1] Universidade Federal do Amazonas – UFAM, Manaus, AM, Brasil. E-mails: almir_kggy@hotmail.com; elysenaa@ufam.edu.br

How to cite: Caggy, A. L., & Almeida, E. S. (2020). AHP & fuzzy logic hybrid method for decision making in project management in a forestry industry. *Gestão & Produção*, 27(2), e4225. https://doi.org/10.1590/0104-530X4225-20

Abstract: This paper aims to present the use of a hybrid tool to support decision making in a forestry industry in the state of Sao Paulo. It was applied the Analytical Hierarchy Process (AHP) and Fuzzy logic techniques in Microsoft's Excel® platform, aiming to disseminate an unrestricted tool of use across the company. A solid result was reached, where it was possible to rank all the qualitative aspects concerned by the company strategy, highlighting how the facility would be moving its efforts to achieve competitiveness gains within its projects.

Keywords: Decision making; Projects optimization; Forestry industry.

Resumo: O processo de tomada de tomada de decisão para a indústria florestal baseiam-se na avaliação de critérios pré-determinados culturamente e, neste cenário a análise multivariada vem a contribuir com a viabilidade de realizar análises precisas sobre o processo estudado. Desta maneira, o presente artigo propõe a aplicação de uma ferramenta híbrida para o apoio à tomada de decisão em uma indústria florestal no estado de São Paulo. Utilizaram-se as técnicas *Analytic Hierarchy Process* (AHP) e Lógica *fuzzy* na plataforma Excel® da *Microsoft*, na busca de disseminar uma ferramenta de uso irrestrito em toda companhia. Pôde-se obter um resultado satisfatório onde foi possível hierarquizar os aspectos qualitativos concernentes à estratégia da empresa, e como a mesma pode focar seus esforços na busca de ganhos em competitividade de seus projetos.

Palavras-chave: Tomada de decisão; Otimização de projetos; Indústria florestal.

1 Introduction

According to Embrapa Florestas (2016), the global area of planted forests has been increasing annually around 4,630,000 hectares. Brazil participates with 2.67% of the total forest plantations worldwide and, from 1990 to 2010, increased its area at an annual average rate of 1.8%. Regarding to productivity, Brazil has advantages that position it as a world leader in the production of wood (IBÁ, 2015). For instance, we

Received Aug. 11, 2017 - Accepted May 4, 2018
Financial support: none.

can list mainly two: the characteristics of climate and soil (edaphoclimatic) and forestry technological development. In addition, Batalha (1995) pointed the agro-industrial system (SAI) as responsible for an important part of the Brazilian economy. It is so that products of forest origin occupy the fourth place in the commercial balance of Brazilian agribusiness in 2016, responsible for 9.3% of it. Also, 625 thousand jobs in the sector were created in Brazil based on the year of 2015, which 177,000 of those were generated directly by the pulp and paper companies, according to the (SNIF, 2017).

However, the forest plantations occupy only about of 7.8 million hectares, of the 350 million hectares taken as arable in Brazil in 2015. Of these, 5.6 million represent the cultivation of eucalyptus. Mainly located in Minas Gerais (24%), Sao Paulo (17%) and Mato Grosso do Sul (15%) (IBÁ, 2016). In addition, considering the total area of 7.8 million hectares of trees planted in Brazil, 34% belongs to companies in the pulp and paper segment, followed by the independent producers segment, with 29%, in third appears the coal-burning and steel segment, which represents 14% of the planted area.

Regarding Moreira & Oliveira (2016), the costs for producing commercial forest depends on a diversity of aspects such as technological level, goal and scale of production, management techniques, soil fertility, pest control, soil type among other factors. Depending on these aspects, production costs may be lower than major agricultural crops and may even exceed the net income of agricultural activities on poorer soils.

Assuming the estimated harvesting area, the average gross production value is R$1,854.34 per hectare per year. In addition, according to Indústria Brasileira de Árvores (IBÁ, 2015), in marginal terms, each hectare of forestry plantations added R$7,800.00 to the national GDP in 2014. On the other hand, soybeans added R$4,900.00 per hectare planted, and livestock (R$2,700.00).

About the performance of the industry, it is important to notice that in 2015, Brazilian pulp production was 17.4 million tons, and the exported volume reached 11.5 million tons, representing respectively an increment of 5.5% and 8.6% compared to 2014. With these results, Brazil consolidated its position in the world market of the *commodity*, occupying 4th place in the ranking of major producers (IBÁ, 2016).

As we can assume on Figure 1, Brazil keeps its leadership in the Global forest productivity ranking with an average productivity of eucalyptus plantations of 36 m^3/ha. year. Moreover, on the past five years, eucalyptus productivity has increased annually by a rate of 0.7%, while pine has decreased by 1.1%, mainly due to conversion into eucalyptus areas.

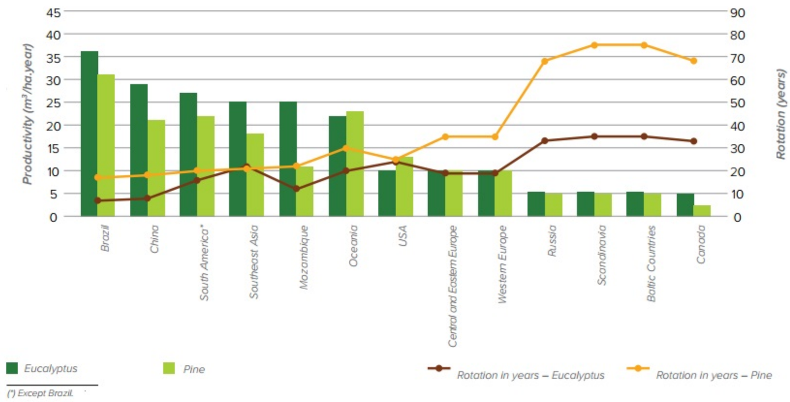

Figure 1. Productivity and average rotation of trees in Brazil *versus* worldwide players. Source: IBÁ (2016).

As it can be observed, Eucalyptus forests in Brazil presents an increase rate in the forestry industry, which raises the need to obtain information about the expected production of it.

Santana et al. (2008a) sustained the productivity of a forest been determined from the amount of solar radiation intercepted by the canopy and the efficiency of converting this radiation into biomass. However, as solar radiation and the CO2 concentration of the atmosphere are non-controllable variable; water, nutrients, and phytosanitary are the main action-oriented factors that influence forest productivity (Barros & Comerford, 2002).

In short, Stape et al. (2004) described the optimal biomass productivity determined by three layers regarding its defining factors, detailed in Figure 2. So, a usual productivity of a eucalyptus planting can reach up to 50 m^3/ha/year with the proper use of forest protection techniques as fighting pests, diseases and fires incidents. An attainable productivity can achieve between 50 to 100 m^3/ha/year, controlling factors such as water and soil nutrition, and finally the potential productivity of the eucalyptus of 100 m^3/ha/year or more, is estimated with the control of factors such as the appropriate genotype, temperature, CO2 level in the atmosphere and radiation, these being difficult factors to manage as previously exposed. In summary, the interactions between these factors will define the growth pattern of a culture (Santana et al., 2008b; Soares et al., 2009, 2010).

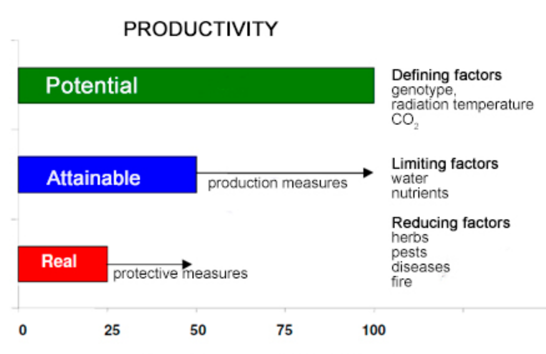

Figure 2. Real productivity, attainable and potential of eucalyptus. Source: Stape et al. (2004).

However, this productivity estimate considers the forest production with gains through conventional silvicultaris practices, including the breeding of Eucalyptus, done by crossing species more appropriate to the respective characteristics of the planting destination region. Nonetheless, a technique has been gaining space as a means of potential and expressive gains of biomass in forest cultures, which is genetic transformation.

In the 80's, the biotechnology techniques had come to join the conventional genetic improvement, allowing the discovery of genotypes (plants) with higher productivity and quality. Among these techniques, the genetic transformation takes an important role, which consists controlling the introduction of a gene or DNA fragment into the genome of a receiving cell and its posterior expression (Diouf, 2003).

Thus, the genetic transformation opens up new perspectives to the improvement programs, expanding and making new genes available for desired characteristics (Sartoretto et al., 2008). These genes can be introduced into already improved crops or genotypes, which associates the gains of the classical genetic improvement technique with those of genetic transformation.

Finally, a critical factor for the dissemination of genetic transformation, besides economic gains, is regarding the demand for timber products that is linked directly to population growth and economic development. Sartoretto et al. (2008) claims that up to 2018 the timber demand grows around 20%, resulting in an increase in the area with forest planting, yet considering the challenge of preserving ecosystems and biodiversity of Brazil. At this point genetic engineering assumes additional significance because it enables the introduction of a desirable gene in the process of improving forest species, resulting reachable gains of productivity that can avoid the need of additional planted areas and its pressure on native areas.

Given this context, since the forestry industry until the genetic transformation we introduce the company focus of this study. As a matter of confidentiality, the company target on this article will be kept confidential. However, a summary of its activity and positioning in the market in which it operates is relevant to the understanding of this present paper.

The company where we applied the decision-making tool is a world leader in biotechnology. Its activities are distributed on R&D structures in Brazil, USA, China, and Israel. The company focuses on increasing the competitiveness of the biomass produced from planted forests to supply, above all, the production of pulp, paper, bioenergy and biofuels (cellulose for ethanol). The main cultures in which the company acts are the Eucalyptus and sugar cane.

The company develops its main technologies, from gene discovery to the selection of gold Eucalyptus events in large-scale experimental plantations and areas with different features. What it positions within a select group of companies that develops a new product or research in a verticalized approach.

The business model of the company is based in the discovery and acquisition of technologies, prototyping commercial plants and negotiate technology to the captive markets, as well as create partnerships with main companies of the forest sector to broaden its portfolio.

Aware of the concepts addressed so far, we introduce the purpose of the present work as the intention to describe the construction and application of a decision-making tool into Brazilian forest sector with a focus on pulp and paper production, to improve the techniques assertiveness adopted by the company consisted by a hybrid methodology involving the knowledge of the AHP technique (*Analytic Hierarchy Process*) and fuzzy logic.

This methodology emerged as a solution to a management and communication issue, since the company's headquarters, located in Israel, needed to understand how projects in Brazil were managed regarding qualitative aspects. In summary, after tests was possible to analyze the degree of competitiveness of the company by prioritising the qualitative aspects inherent to its projects, as well as using the opinion of decision makers for the correct strategic classification of the company.

Considering the internal aspect, the company gains by having a tool of common understanding to all managers, which ensures the transmission of a mission with clear vision drives of future. Also, due to its activity being classified as high-value aggregated and high risks, the solution aims to minimize the company exposure to projects that do not represent expressive earnings in the Eucalyptus culture.

The gains from this article can also be reported as a contribution to the academic field, as little literature is available on the process of genetic transformation applied in forestry. Thus, bringing the context to surface can promote further research related to this topic. As well as social benefits are important to be mentioned, as the subject involves a variety of misguided or unknow information. So, demonstrate what aspects are under the company's perspective for investment decision making, contribute and promote clarity of questions that the reader may have.

For a clear and cohesive understanding, this work is structured from the introduction, a theoretical reference of the methods applied for the construction of the decision-making tool, the methodology used in the company and results achieved, and finally, the inferences obtained on the experiment, addressing also a vision of the future on the topic.

2 Theoretical framework

2.1 Decision making in the forest industry

As mentioned earlier, the Brazilian forestry industry has an important role in the national economy and with a strategic position in the international market, due to the high productivity of Eucalyptus culture in comparison to other competitors. Also, the sector has been strengthening its activities, investing in mechanization of manual activities, use and allocation of effective fertilizers and herbicides (Castro et al., 2017; Gonçalves et al., 2017).

Hence, it is essential that companies in this sector would be able to incorporate investments of an operational background that provide more cost reduction of sold product (CPV), and make sure that the *opportunity cost* of these companies is more attractive to investors both in Brazil and abroad.

Thus, it is crucial the use of decision-making techniques that provide a portfolio of highly competitive and long-term vision projects. Since considering the seven-year cycle of the Eucalyptus the investment should be sustainable with high reliability, so that in the harvest of culture the expected outputs can be obtained successfully (Trapp & Rodrigues, 2016).

However, even today many of the midsize and even large companies have no decision-making tools when it comes to positioning projects to be evaluated for implementation, due to factors such as: the complexity application of decision-making methodologies, the specificity of applications to some processes other than the company's focus, the use of s*oftware* that generate excessive cost and maintenance, and the lack of engagement by the company's employees.

Nevertheless, some studies already done in the forest industry demonstrated that giving relevance to the advances in decision-making techniques is a way of achieving even more efficient results. As an example, the study carried out by Brun (2002) as they used linear programming techniques to assess the mix of owned wood and market acquired to supply the industrial facilities, aiming to maximize the net present value of *International Paper* of Brazil LTDA's revenues. Another relevant study is the contribution of Gastaldi & Minardi (2012), which was searched under the perspective of an investment decision the harvest anticipation or postponement of a Eucalyptus forest considering the uncertainty about the price of wood. In this occasion it was applied the recombinant binomial model and the process of reversing the average price.

Other studies, such as from Sousa et al. (2012), used the linear programming in the analysis of wood transportation under the reducing optics for indoor logistics costs. Also, Branco (2013), proposed to define the procedures applicable to manager different forest sites through linear programming and, to indicate a methodology that would allow to determine the optimized distances plantation according to the site considered, regarding the perspective of the net present value. Finally, is relevant mention the work of Santos (2012) in which was applied linear programming as an aid tool in decision-making related to strategic industrial supply planning, considering the compliance with *Forest Stewardship Council* (FSC) standards and forest regulation.

In short, regarding Rodrigues (1991) the decision-making models for the forest industry are based mainly on the evaluation of the following criteria: decision of the Eucalyptus harvesting time, practices of reforestation, infrastructure and logistics.

Relevant studies already used the concept of linear programming. Mainly because the methodology is widely disseminated both in academia and industrial environment. Linear programming comes as an important tool to model constraints that a process, or a set of them, may have and regarding these constraints always find the best solution for the objective function. As instance to reduce production costs, set the minimum stock, maximize profit, or even define logistics that target the reduction of owned or third-party transportation (Akinc, 1995; Munhoz & Morabito, 2010; Guterres et al., 2012; Moura, 2013; Carvalho et al., 2017).

Surely the linear programming gains are quite expressive and have considerable reliability. However, the nature of its logic restricts more complex applications when involves evaluating interdependent factors. Thus, becoming a non-effective alternative on scenarios when data from production processes is becoming more accessible and cheaper and needs an intense and real time analysis aiming mostly the prediction of efficiency and reduction of activities that does not add value to the product.

In those cases, new methodologies are gaining space in the context of decision-making support. These have as the main differential, the multivariate analysis of *n* income by *n* o*utcome* of the process, that is, it is possible to capture the relationship of input and its interrelatedness to one, or more output. That is the case of multiple regression, multivariate variance analysis (NOVA), conglomerate analysis, among others.

2.2 Multivariate analysis

Regarding Viali (2017), the multivariate analysis refers to all statistical methods that simultaneously analyze multiple measures in an individual or object under investigation. However, it should be emphasized the challenge when working with multivariate analysis techniques which is choosing the most appropriate technique to detect the expected patterns or output from your data. An incoherent choice may lead to misguided or unsatisfactory results for the aid of inferences regarding the interventions carried out or monitored by the researchers.

Even with the advancement of data analysis techniques, we still find an information loss issue due to the necessity of reducing a set of data to be represented by its average or a sample. The same is true when you apply a multivariate technique, because by reducing the dimensionality of a problem you also lose information (Vicini & Souza, 2005). Thus, the role of the researcher is crucial for carrying out the choice and methodology to be applied, as well as the importance of validate the results obtained from the analysis.

In fact, as previously mentioned, multivariate analysis is contributing strongly with accurate data and analysis of a process under investigation. However, in addition to these advantages, new platforms are gaining market space in order to add more value and scalability to the data analysis. For instance, the *Google Analytics*, *Office* 365 and Azure from *Microsoft* and Predix from *General Electric*. These solutions bring great benefits to corporations, by lifting the level how information is available, providing analysis and interventions in real time. However, these platforms may still find a great blockade of implementation in the routine of Brazilian companies, due to the lack of widespread knowledge of its processing capability and high cost to implement and maintain.

After introducing the important foundations of the tool built and reported through this work, it is now worth discussing the two methodologies applied, which are the Analytic Hierarchy Process (AHP) and the fuzzy logic.

2.3 Analytic Hierarchy Process (AHP)

The method known as Analytical Hierarchy Process (AHP) was created by Thomas Saaty in the early 70’s, being developed since in several applications. Also, it's been gaining importance as a technique used for decision making in complex environments that plenty of variables and human perceptions are essential for the discovery of priority factors to be considered in a project or initiative (Vargas, 2010).

In addition to the already proven advantages of AHP, such as its easy applicability, it is also important to mention the flexibility factor, since the method can be linked with other tools, as in this case the fuzzy logic.

The use of AHP initiates by the decomposition of the problem in a hierarchy of criteria more easily to be analyzed and comparable in an interdependent way, as shown on Figure 3. From the moment this logical hierarchy is built, decision-makers systematically evaluate alternatives by making pairwise comparisons of the criteria chosen earlier.

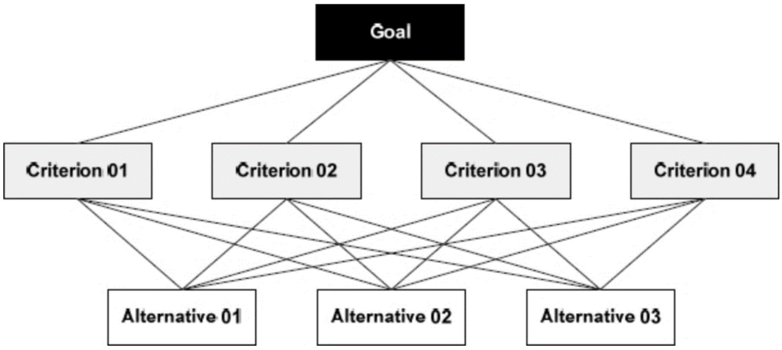

Figure 3. Example of a hierarchy of criteria/objectives. Source: Vargas (2010).

The AHP transforms the comparisons obtained through a brainstorming session into numeric values that are processed and compared. The weight of each of the factors allows the evaluation of the elements within the defined hierarchy (Vargas, 2010).

When all the commutations were performed and the relative weights between the criteria were established, the numerical probability of each of the alternatives is calculated. This probability determines the best alternative in order to meet an established goal. The higher the likelihood, the more that alternative contributes to the final goal of the portfolio.

An important point to be observed in this method is the consistency between the joint relationships analyzed. Saaty (1991) defines inconsistency as the violation of proportionality that may or might not mean the loss of the relativity analyzed between pairwise comparison. Saaty stresses that the importance is not the presence or not of the inconsistency, but rather its numerical representation. Thus, the AHP method considers an index up to 0.10 as an acceptable ratio inconsistency.

To determine the value of this consistency ratio (RC), we first calculate the value of the maximum or main eigenvalue, known as *λ* max. From it we than can estimate the consistency index (IC) of the matrix through Equation 1, and the consistency ratio according to the Equation 2 (Saaty, 2005).

$$IC = \frac{\lambda \max - n}{n - 1} \quad (1)$$

where: IC = consistency index matrix; λ max = maximum eigenvalue; n = number of items considered in the array.

$$RC = \frac{IC}{IR} \quad (2)$$

where: RC = Consistency ratio matrix; IR = Random index, corresponding to a table value, which depends on the number of items compared in the array, as represented on Table 1.

Table 1. Random Index.

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
0.00	0.00	0.58	0.90	1.12	1.24	1.32	1.41	1.45	1.49	1.51	1.48	1.56	1.57	1.59

Source: Saaty (2005).

In sum, it is worth pointing out that mathematical calculations involving AHP are usually complex, which make analysis and calculations exhaustive and are usually only viable using specific calculation software. However, for this specific work, the methodology was built in Excel, so it guarantees its scalability across the entire corporation. This particular issue will be approached during this paper in more details.

2.4 Fuzzy logic

The fuzzy logic it's based on the theory of fuzzy sets. Where the exact reasoning corresponds to an approximate set of variables, interpreted as a process of clustering composition (Almeida et al., 2010).

Unlike the binary logical systems, where output values can only assume true (1) or false (0). A fuzzy system represents a true value of a variable as an element on finite set or a Boolean logic. The truth values are expressed linguistically, for example: certain, true, not true, false, negative, where each linguistic term is interpreted as a subset fuzzy of a unit interval (Souza, 2008).

Fuzzy modeling requires techniques that handle qualitative information in a rigorous manner. Such techniques consider the way the lack of accuracy and uncertainty are described. Thus, becoming a powerful manner to manage knowledge in a convenient way.

In addition, the fuzzy logic theory handles the relationship between inputs and outputs, adding multiple process and control parameters. This allows the consideration of complex processes, so the resulting control systems may provide more accurate result, ensuring a stable and higher performance. Also, as we can see on Figure 4, the fuzzy logic even demonstrates precise relevance functions, which facilitate its understanding.

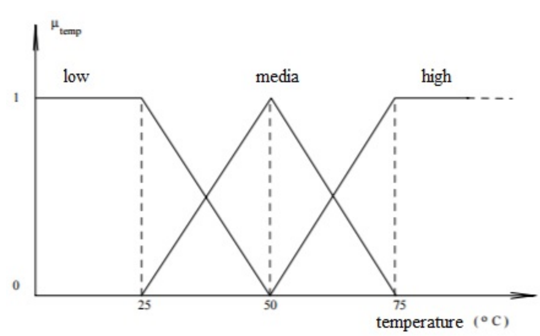

Figure 4. Fuzzy logic illustration for temperature setting. Source: Gomide & Gudwin (1994).

According to Wagner (2003), fuzzy logic is a methodology capable of capturing ambiguous information generally described in natural language and converting them to a numerical, easy-to-manipulate format.

In summary, the application of fuzzy logic in this paper was given in the following steps:

1. Stablishing the quantity and levels to be assigned on projects evaluation;
2. Specialists and/or operational team brainstorming regarding the company portfolio;
3. Operation of the eigenvector with the weight of each qualitative indicator, obtained in the AHP evaluation, to obtain the degree of belonging of the indicators in relation to the levels stipulated on Item 1;
4. Analysis of the values found.

3 Methodology

The techniques were used in a hybrid way (AHP & Fuzzy). Thus, none of the approaches were applied in its entirely theoretical form, but in a complementary way to each other.

Initially, we defined the dimensions to be evaluated for the company portfolio, and respectively its indicators obtained by internal benchmarking. Thus, we reached the following scenario presented in Table 2:

Table 2. Dimensions and criteria for decision making.

ID	Criteria
1	Time to reach the market
2	Technology maturity
3	Access to the use of technology
4	Patentable technology
5	Regulatory affairs
6	Effectiveness of the existing solutions
7	Technology coverage
8	Time for cash generation

Source: The author (2017).

Defined the dimensions and its indicators, the AHP is applied to understand which criteria have a higher priority in relation to others, consequently discovering the hierarchy of criteria and their respective weights in the context of obtaining a more competitive portfolio of projects.

As we can see on Table 3, the eight criteria were evaluated among themselves, through benchmarking using a scale of 5 levels and different weights: extremely more important (5.0), more important (3.0), indifferent (1.0), less important (0.3), and extremely less important (0.2).

Table 3. Application of AHP.

	TIME TO REACH THE MARKET	TECHNOLOGY MATURITY	ACCESS TO THE USE OF TECHNOLOGY	PATENTABLE TECHNOLOGY	REGULATOTY AFFAIRS	EFFECTIVENESS OF THE EXISTING SOLUTIONS	TECHNOLOGY COVERAGE	TIME FOR CASH GENERATION	
TIME TO REACH THE MARKET		equal	ext. less Imp.	less imp.	ext. less Imp.	less imp.	equal	ext. less Imp.	0.043
TECHNOLOGY MATURITY			less imp.	equal	ext. less Imp.	less imp.	less imp.	less imp.	0.045
ACCESS TO THE USE OF TECHNOLOGY				more imp.	equal	less imp.	less imp.	less imp.	0.120
PATENTABLE TECHNOLOGY					ext. less Imp.	less imp.	ext. less Imp.	ext. less Imp.	0.050
REGULATOTY AFFAIRS						ext. more imp.	more imp.	equal	0.249
EFFECTIVENESS OF THE EXISTING SOLUTIONS							more imp.	less imp.	0.143
TECHNOLOGY COVERAGE								less imp.	0.118
TIME FOR CASH GENERATION									.0234
	24.000	20.000	11.867	23.333	4.133	10.667	11.867	3.733	1.000

Source: The author (2017).

After the AHP matrix is completed, the consistency index of the tool must be verified so that the credibility of the result is proven. In the case, the given index to the matrix in the Table 3 was 11.8%, for a recommendation of less than or equal 10%, thus with a 1.8% deviation. However, this deviation is acceptable by the fact that a verification and validation of the result was carried out with those involved in the *benchmarking*.

In theory, the next step using the AHP technique would be to evaluate each indicator already with its respective weight of relevance for all projects to be analyzed by the company. However, this task becomes unfeasible by the amount of data and calculations to be done. Since, assuming a portfolio of 10 projects would generate 8 (number of criteria) in a 10x10 matrix (number of projects being evaluated in relation to themselves). This number worsens even more in the amount of evaluations that should be made by the experts: 320. For this reason, we chose to follow the hybrid approach attaching the fuzzy logic.

Then, right after the identification of the weights for each indicator, we adapt the model to apply the fuzzy approach. Following the steps: initially, each indicator won a four-phase scale, organized from least desirable to most desirable (Table 4). Example: in the technology maturity (R&D) criteria the undesirable situation is that the technology employed in the project is completely new or has not been approved in proof of concept; on the other hand, the most desirable situation is a scientifically proven technology in Eucalyptus culture.

This list shown in Table 4 was created to guide the opinion of the specialists on evaluate the projects. As this tool is in an experimental state, the evaluation made for each project was done by the author in a biased way and outside the current reality of the company for two reasons: to ensure confidentiality and to demonstrate a common scenario to most of companies when it comes to decision-making and investment related to a portfolio.

Table 4. Levels per indicator evaluated.

CRITERIA	OPTIONS	RANKING
TIME TO REACH THE MARKET	MORE THAN 10 YEARS	LOW
	FROM 7 TO 10 YEARS	MEDIUM
	FROM 3 O 7 YEARS	HIGH
	LESS THAN 3 YEARS	GREAT
TECHNOLOGY MATURITY	UNKNOWN/ NOT PROVEN	LOW
	TESTED AND PROVEN IN CERTAIN CROPS (BUT TREES)	MEDIUM
	TESTED AND PROVEN IN TREES CROPS	HIGH
	TESTED AND PROVEN ON EUCALYPTUS SPECIES	GREAT
ACCESS TO THE USE OF TECHNOLOGY	TECHNOLOGY OWNED BY A LARGE COMPANY	LOW
	TECHNOLOGY OWNED BY A SMALL-MIDDLE COMPANY	MEDIUM
	TECHNOLOGY OWNED BY A INNOVATION OR RESEARCH CENTER	HIGH
	TECHNOLOGY IS PUBLIC FOR USE	GREAT
PATENTABLE TECHNOLOGY	NOT PATENTABLE	LOW
	POSSIBLY PATENTABLE	MEDIUM
	KNOWN TECHNOLOGY, BUT IS PATENTABLE	HIGH
	UNPRECEDENTED AND PATENTABLE TECHNOLOGY	GREAT
REGULATOTY AFFAIRS	POSSIBILY WILL BE REJECTED	LOW
	LIKELY TO RESTRICTIONS WITH IMPACT ON BUDGET	MEDIUM
	LIKELY TO RESTRICTIONS WITHOUT IMPACT ON BUDGET	HIGH
	POSSIBILY WILL BE APPROVED	GREAT
EFFECTIVENESS OF THE EXISTING SOLUTIONS	CURRENT SOLUTIONS IS EFFECTIVE (>80%)	LOW
	CURRENT SOLUTIONS IS PARTIALLY EFFECTIVE (50% - 80%)	MEDIUM
	SOLUTIONS IS NON EFFECTIVE (<=50%)	HIGH
	THERE IS NO SOLUTIONS FOR CURRENT ISSUE	GREAT
TECHNOLOGY COVERAGE	CAN BE APPLYED ON <= 25% ON PLANED AREA	LOW
	CAN BE APPLYED ON 30% TO 70% ON PLANED AREA	MEDIUM
	CAN BE APPLYED ON 70% TO 90% ON PLANED AREA	HIGH
	CAN BE APPLYED ON 90% TO 100% ON PLANED AREA	GREAT
TIME FOR CASH GENERATION	IT WILL NOT GENERATE CASH RETURN	LOW
	AFTER HARVESTING	MEDIUM
	BEFORE HARVESTING	HIGH
	IMMEDIATE	GREAT

Source: The author (2017).

After the evaluation of the projects (Table 5), we build an array that has the basic function of carrying out the counting of that evaluation by classifying it from the low level to the highest, in analogy to the least desirable and most desirable, respectively, represented on Table 6.

Table 5. Evaluation of projects.

PROJECT	TIME TO REACH THE MARKET	TECHNOLOGY MATURITY	ACCESS TO THE USE OF TECHNOLOGY	PATENTABLE TECHNOLOGY	REGULATOTY AFFAIRS	EFFECTIVENESS OF THE EXISTING SOLUTIONS	TECHNOLOGY COVERAGE	TIME FOR CASH GENERATION
PROJETC 1	MORE THAN 10 YEARS	UNKNOWN/ NOT PROVEN	TECHNOLOGY IS PUBLIC FOR USE	UNPRECEDENTED AND PATENTABLE TECHNOLOGY	LIKELY TO RESTRICTIONS WITH IMPACT ON BUDGET	THERE IS NO SOLUTIONS FOR CURRENT ISSUE	CAN BE APPLYED ON 90% TO 100% ON PLANED AREA	AFTER HARVESTING
PROJETC 2	FROM 3 TO 7 YEARS	TESTED AND PROVEN IN CERTAIN CROPS (BUT TREES)	TECHNOLOGY OWNED BY A INNOVATION OR RESEARCH CENTER	KNOWN TECHNOLOGY, BUT IS PATENTABLE	LIKELY TO RESTRICTIONS WITH IMPACT ON BUDGET	CURRENT SOLUTIONS IS PARTIALLY EFFECTIVE (50-80%)	CAN BE APPLYED ON 70% TO 90% ON PLANED AREA	BEFORE HARVESTING
PROJETC 3	FROM 3 TO 7 YEARS	TESTED AND PROVEN IN CERTAIN CROPS (BUT TREES)	TECHNOLOGY OWNED BY A LARGE COMPANY	NOT PATENTABLE	POSSIBILY WILL BE APPROVED	SOLUTIONS IS NON EFFECTIVE (<=50%)	CAN BE APPLYED ON <= 25% ON PLANED AREA	IT WILL NOT GENERATE CASH RETURN
PROJETC 4	MORE THAN 10 YEARS	TESTED AND PROVEN IN TREES CROPS	TECHNOLOGY OWNED BY A INNOVATION OR RESEARCH CENTER	POSSIBLY PATENTABLE	POSSIBILY WILL BE REJECTED	CURRENT SOLUTIONS IS PARTIALLY EFFECTIVE (50-80%)	CAN BE APPLYED ON 70% TO 90% ON PLANED AREA	AFTER HARVESTING
PROJETC 5	MORE THAN 10 YEARS	TESTED AND PROVEN IN TREES CROPS	TECHNOLOGY IS PUBLIC FOR USE	KNOWN TECHNOLOGY, BUT IS PATENTABLE	LIKELY TO RESTRICTIONS WITH IMPACT ON BUDGET	THERE IS NO SOLUTIONS FOR CURRENT ISSUE	CAN BE APPLYED ON <= 25% ON PLANED AREA	IMMEDIATE
PROJETC 6	MORE THAN 10 YEARS	TESTED AND PROVEN ON EUCALYPTUS SPECIES	TECHNOLOGY OWNED BY A INNOVATION OR RESEARCH CENTER	KNOWN TECHNOLOGY, BUT IS PATENTABLE	POSSIBILY WILL BE APPROVED	THERE IS NO SOLUTIONS FOR CURRENT ISSUE	CAN BE APPLYED ON 70% TO 90% ON PLANED AREA	AFTER HARVESTING
PROJETC 7	FROM 7 TO 10 YEARS	TESTED AND PROVEN ON EUCALYPTUS SPECIES	TECHNOLOGY OWNED BY A LARGE COMPANY	NOT PATENTABLE	POSSIBILY WILL BE APPROVED	SOLUTIONS IS NON EFFECTIVE (<=50%)	CAN BE APPLYED ON 90% TO 100% ON PLANED AREA	AFTER HARVESTING

Table 5. Continued…

PROJECT	TIME TO REACH THE MARKET	TECHNOLOGY MATURITY	ACCESS TO THE USE OF TECHNOLOGY	PATENTABLE TECHNOLOGY	REGULATOTY AFFAIRS	EFFECTIVENESS OF THE EXISTING SOLUTIONS	TECHNOLOGY COVERAGE	TIME FOR CASH GENERATION
PROJETC 8	FROM 7 TO 10 YEARS	TESTED AND PROVEN IN TREES CROPS	TECHNOLOGY OWNED BY A SMALL-MIDDLE COMPANY	NOT PATENTABLE	POSSIBILY WILL BE APPROVED	CURRENT SOLUTIONS IS PARTIALLY EFFECTIVE (50-80%)	CAN BE APPLYED ON 30% TO 70% ON PLANED AREA	BEFORE HARVESTING
PROJETC 9	LESS THAN 3 YEARS	TESTED AND PROVEN IN CERTAIN CROPS (BUT TREES)	TECHNOLOGY OWNED BY A LARGE COMPANY	POSSIBLY PATENTABLE	LIKELY TO RESTRICTIONS WITH IMPACT ON BUDGET	CURRENT SOLUTIONS IS EFFECTIVE (>80%)	CAN BE APPLYED ON 70% TO 90% ON PLANED AREA	AFTER HARVESTING
PROJETC 10	FROM 3 TO 7 YEARS	UNKNOWN/ NOT PROVEN	TECHNOLOGY IS PUBLIC FOR USE	UNPRECEDENTED AND PATENTABLE TECHNOLOGY	POSSIBILY WILL BE REJECTED	CURRENT SOLUTIONS IS PARTIALLY EFFECTIVE (50-80%)	CAN BE APPLYED ON 30% TO 70% ON PLANED AREA	BEFORE HARVESTING

Source: The author (2017).

Each value of this matrix is then divided by the number of projects evaluated (10) aiming to convert them to values from 0 to 1, a premise for applying the fuzzy logic. Lastly, the operation is carried out to find the eigenvalue between the AHP evaluation performed and the fuzzy method (Table 7).

Table 6. Project evaluation matrix.

Criteria	Great	High	Average	Low
Time to reach the market	1	2	3	4
Technology maturity	2	3	3	2
Access to the use of technology	3	3	1	3
Patentable technology	2	3	2	3
Regulatory affairs	4	2	2	2
Effectiveness of the existing solutions	3	2	4	1
Technology coverage	2	4	2	2
Time for cash generation	1	3	5	1

Source: The author (2017).

Table 7. Project evaluation matrix (%) versus AHP.

Criteria	Great	High	Average	Low	AHP
Time to reach the market	0.10	0.20	0.30	0.40	0.043
Technology maturity	0.20	0.30	0.30	0.20	0.045
Access to the use of technology	0.30	0.30	0.10	0.30	0.120
Patentable technology	0.20	0.30	0.20	0.30	0.050
Regulatory affairs	0.40	0.20	0.20	0.20	0.249
Effectiveness of the existing solutions	0.30	0.20	0.40	0.10	0.143
Technology coverage	0.20	0.40	0.20	0.20	0.118
Time for cash generation	0.10	0.30	0.50	0.10	0.234

Source: The author (2017).

4 Results

Therefore, after the eigenvalue operation performed the following result was obtained (Table 8):

Table 8. Competitiveness of projects by AHPF methodology.

	Great	High	Average	Low
Competitiveness	0.248	0.268	0.295	0.188

Source: The author (2017).

So, the application of AHPF hybrid technique (AHP & *Fuzzy*) enabled to conclude that, as a non-random and biased assessment, the illustrated competitiveness portfolio is classified as "average", with a value of 0.295, the highest among others.

A brief table was assembled to compare benefits from this technique. So, we build an arithmetic mean from the results before applying the fuzzy logic, which suggests the following total (Table 9):

Table 9. Competitiveness of projects by arithmetic mean.

	Great	High	Average	Low
Competitiveness	0.225	0.275	0.275	0.225

Source: The author (2017).

Thus, performing only the arithmetic mean of the evaluation of the projects, we have an undefined and confusing status situation, since the ratings “high” and ” average” are tied in first, as well as levels “great” and “low” in second.

A second perspective build on competitiveness view was how much each qualitative aspect contributes to the result of the classification of the company's portfolio. This view basically consists of using the eigenvector of Table 3 and compare to the result obtained from Table 5. So, reaching the following scenario:

Table 10. Impact of aspects on company productivity.

RANKING (AHP)	Criteria	Impact	RANKING (COMPET.)
1	Regulatory affairs	0.250	5
2	Time for cash generation	0.272	1
3	Effectiveness of the existing solutions	0.265	2
4	Access to the use of technology	0.241	8
5	Technology coverage	0.254	4
6	Patentable technology	0.246	6
7	Technology maturity (R&D)	0.256	3
8	Time to reach the market (R&D)	0.242	7

Source: The author (2017).

Through the information in Table 10, it can be implied that the criteria *time for cash generation* with index of 0.272, is the indicator that most influences the definition of competitiveness for a company set as “average”. However, is the second in the ranking of AHP prioritization. This reversal of significance between ratings tells which aspects in the company can act to improve its strategic positioning, in the sense of get a competitive rating similar to the AHP ranking.

Finally, this tool demonstration illustrated that the improvement of the technique presented here should bring an increase in the competitiveness of the projects in medium and large companies, applying concepts of great scalability, requiring regular knowledge for the operation of the tool and reducing the uncertainties intrinsically attributed to the projects.

5 Conclusion

Certainly, the tool presented need continuous enhancement on the reduction of subjectivity in decision-making. However, considerable advances have been achieved, such as the prioritisation of criteria to have more competitive projects, and the classification of the company's portfolio into a competitiveness scale.

Improvements should be incorporated into the tool, such as the inclusion of quantitative aspects, which are crucial for the analysis of investments, as the net present value (NPV), internal rate of return (IRR) and *Pay Back*, for example. In addition, concepts such as the capital asset pricing model (CAPM) and the weighted average capital cost (WACC) would contribute to add risk visions and opportunity cost to the methodology presented.

The model addressed only relevant indicators to the gain for the company efficiency. However, it is worth emphasizing that, in order to create a methodology interconnected to the demands of both the market and consumers, it is suggested to integrate the vision of the TBL management (*Tripple Bottom Line*) as known in Brazil like the tripod of sustainability. In general terms, this model suggests that the sustainable growth of an organization must consider economic, social and environmental factors.

Therefore, with the economic indicators so well defined, attention might be conducted to the environmental and social indicators. The *Global Impact Investing Rating System* (GIRRS) is recommended as a guide for its widely adoption by medium and large sized companies, which addresses how companies can handle and measure socio-environmental aspects in a competitive way. In Brazil, more than 200 companies already use the system guidelines to report their impacts, and their benefits range from increasing positive values to the company's image and brand loyalty to the possibility of comparing performance between organizations (FIESP, 2013). Another guide regarding socio-environmental indicators are the 17 Sustainable Development Goals proposed by United Nations (ONU Brasil, 2015). These objectives are extensively disseminated in the first, second and third sector, which can help companies deciding which indicators to take into account for the decision making of the projects to be incorporated.

At last, in a not very abstract future, we believe that such tool presented here would be linked to the cloud. Which through artificial intelligence will position automatically and diffusely throughout the company ways of achieving competitive advantage. Certainly, this vision is not utopian, as initiatives such as the proposal have been developed on platforms such as Azure from *Microsoft* and *Google Analytics*. This advancement tends to meet not only the financial agenda, but it will bring less environmental impact, greater social gains and better approximation to the final consumer.

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