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SELECTION OF TOMATO CULTIVATION SYSTEMS UNDER SUSTAINABILITY CRITERIA

José M. Brotons[a]*, José M. Cámara-Zapata[b]

Greenhouse production is the most intensive plant production system, both in terms of yield and investment and inputs. There are different alternatives of farming systems among which producers can choose. To facilitate decision-making it is convenient to develop applications that analyze the alternatives from the point of view of sustainability. The analysis of the sustainability of greenhouse production must be carried out according to the criteria that affect all the processes that make up the agri-food value chain. In this work, the criteria and sub-criteria that influence the sustainability of greenhouse production are analyzed first. Next, the alternatives in the most important cultivation system in the production of greenhouse tomatoes in the Spanish Mediterranean Basin (soil, perlite and nutrient film technique, NFT) are evaluated. The work is carried out based on the opinion of ten experts from the integrated sectors of the agrifood value chain. The results indicate that the sustainability of greenhouse production increases in the order: soil < perlite < NFT due to a higher valuation of the latter alternative in relation to commercial, natural, human, material resources and management versus economic resources.

Keywords: *criteria; tomato; greenhouse; cultivation system; order; sustainability.*

JEL Classification: *Q13; Q15.*

1. INTRODUCTION

Greenhouse is a very competitive sector. Its analysis from the point of view of sustainability requires consideration of all the factors that influence the agri-food value chain. According to the Spanish Royal Academy of Language, sustainability is "especially in ecology and economy, the quality of something that

[a] Miguel Hernández University, Estudios Económicos y Financieros, Edificio La Galia, 03202 Elche, Spain. 034 96 665 89 67. Email: jm.brotons@umh.es

[b] Miguel Hernández University, Departamento de Física Aplicada, Escuela Politécnica Superior de Orihuela, Ctra de Beniel, s/n, 03312, Orihuela, Alicante, Spain. 034 96 674 97 30. Email: jm.camara@umh.es

* *Corresponding author*

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can be maintained for a long time without exhausting resources or causing serious damage to the environment." Therefore, the analysis of the sustainability of this sector can be done through criteria of resources (economic, commercial, natural, human and, finally, material and energy) and management.

1.1. SUSTAINABILITY OF GREENHOUSE PRODUCTION

Economic resources allow the acquisition of technologies that permit improvement of the conditions of the crop, as well as efficient irrigation management due to the scarcity of quality water in the main areas of greenhouse cultivation. Therefore, the economic value of the investment can be established as a criterion. The incorporation of technology into the greenhouse is correlated with an improvement in the production and the quality of the crops. The relationship between the cost of the investment and the improvement that is possible is not linear, so it is very important that the producer can estimate the benefit of an investment before deciding on the acquisition of the equipment. Another factor that affects sustainability is financing. The incorporation of technology into the greenhouse depends on the economic situation of the producer and/or, where appropriate, on the possibilities of financing, and the request for regional, national or European aid. In addition, the economic estimates derived from a technological investment must be accompanied by real economic results that allow the investment to be profitable within an appropriate time interval. That is, recovery is a third criterion to be taken into account in the analysis of sustainability (Figure 1).

The perishable nature of fruit and vegetables requires that the producer make his sale as soon as possible. Commercial resources increase the attractiveness of the product, both for marketers and consumers. In this sense, increasing the production schedule with respect to open-air cultivation increases the probability of selling and doing so at a better price. The fact that production is carried out according to certification standards helps the product to be incorporated into certain commercial circuits and ensures its presence in demanding and commercially interesting markets. In addition, the existence of logistic platforms, such as marketing centers and/or cooperatives of producers located in the production area favors the commercialization of the product and increases the probability of sale under more favorable conditions. Another criterion that can influence sustainability is the existence of adequate communication channels that facilitate the distribution of production.

The principal natural resources that influence greenhouse production are the soil, irrigation water and climate (temperature, humidity, concentration of CO2 and insolation). The management of the crop must avoid soil degradation, through changes in its structure, reductions in its content of organic matter, increases in the ratio of sodium absorption, increases in salinity or electrical conductivity of the saturation extract, etc. The high water requirements of greenhouse crops must be met with the lowest possible water losses and affecting as little as

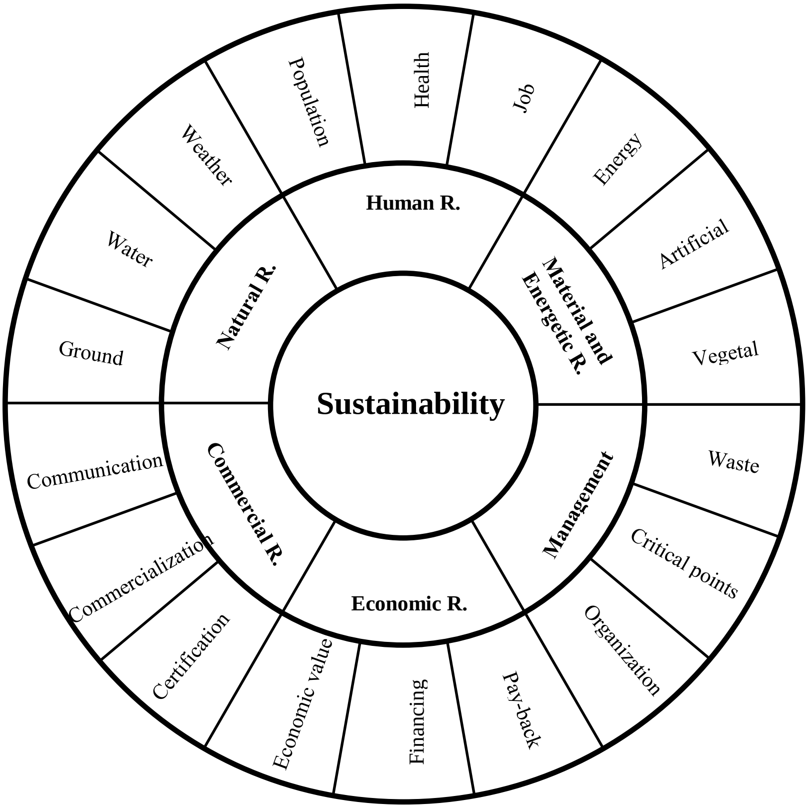

Figure 1. Sustainability criteria

possible the quality of the irrigation water. The integral processes of the agri-food value chain must be carried out with a reduced emission of greenhouse gases. The technology used in the cultivation in the greenhouse allows one to control the climate in the interior (temperature, humidity and concentration of CO2). Greenhouse production is favored by a high number of hours of high insolation.

Greenhouse cultivation is an intensive production system that usually shows great dependence on human resources. The workforce is usually low-skilled personnel with low wages, usually immigrants, with poor living conditions. One of the criteria that define the viability of greenhouse production can be job creation and its quality (health, safety and worker welfare). Another criterion that has to be considered is the importance of the existence of generational change that provides the fixation of the population, as well as its relationship with the quality of the workforce.

There are numerous material and energy resources that are fundamental for greenhouse production, such as plant material and other artificial ones (nutrients, pesticides, pollinators, predators, plastics, accessory materials, etc.). In addition, climate control and/or irrigation requires energy consumption. These criteria influence the sustainability of greenhouse production.

Greenhouse production is a complex process that can be simplified significantly when proper management is carried out. The organization of the tasks that make up the agri-food value chain (cleaning, order, etc.) allows considerable economic savings and improvements in production and quality. The activities to be carried out involve a large amount of labor and it is necessary to diagnose and, where appropriate, resolve the existence of critical points to avoid deficiencies in the production process. In addition, proper management must resolve the spills associated with fruit and vegetable production. The production process generates waste such as plant material at the end of the crop cycle, non-commercial production, packaging, plastics and other types of materials, etc. The percolation of the nutrient solution due to irrigation involves the contamination of underground aquifers that can be especially serious when dealing with certain ions, such as nitrates. Something similar can occur when it is necessary to perform soil disinfection with fungicides, such as methyl bromide. In addition, it is necessary to reduce the carbon footprint associated with these products due not only to their production but also to their marketing and transportation. The analysis of the sustainability of greenhouse production requires considering all the processes that constitute the agri-food value chain (FAO, 2018).

1.2. CULTIVATION SYSTEMS

Greenhouse cultivation is the most-intensive manner of production, as for production performance, as well as an investment or consumables (Singh *et al*., 2007). Worldwide, the most important crop is the tomato, with Almeria (Spain) being the leading producer and exporter area of fresh tomato in Europe (De Pablo and Uribe, 2015). There is a wide gamut of tomato production systems in greenhouses (soil and soilless; and within the latter, open systems, with losses of nutrient solution, and closed systems, where the nutrient solution is re-utilized). The open cultivation systems offer a simpler management, and can be adapted for use with low-quality irrigation water, although it also implies a greater consumption of water and fertilizers, and greater contamination problems due to leaching. The closed cultivation systems represent a considerable savings of water and fertilizers, and avoid contamination problems due to leaching, although their management is more complicated, require good quality water and favor the dispersion of root pathogens. Since a few years ago, the tomato producers have mostly opted for cultivation in substrate, although the economic crisis has favoured the return to soil cultivation.

Water was one of the first substrates utilized through techniques such as the Nutrient Film Technique (NFT; Cooper, 1975). In this technique, a shallow nutrient solution circulates in contact with the roots of the plants inside closed channels. Thus, the supply of water, oxygen and nutrients is adequate and the productivity of the plants is very high. However, plants grown with NFT are very vulnerable if power cuts occur. Initially, its use as a closed system implied a high initial investment, due to the construction of benches, as compared to substrate systems in bags or containers, so that it was hardly used. Posteriorly, more affordable NFT systems were developed, which resolved problems such as dispersion of pathogens, with the main inconveniences for their implementation being the use of good quality water, the difficulty in the management of irrigation, the high energy consumption, and the deficient reliability of the energy sources in the areas of production (with these soilless systems, a small cut in the energy supply can result in irreparable damages to the crop) (Garcia-Martínez *et al*., 2010; Alcón *et al*., 2010). Recently, a new type of NFT system, called the New Growing System (NGS ©), started to be commercialized, which reduces the water consumption due to the recirculation of the nutrient solution. The manufacturer of this new system has optimized its management to produce tomatoes with water savings, resulting in a mature and competitive technology.

The Spanish Mediterranean basin has an arid and semi-arid climate with scarce water resources, which are usually of low quality. The agricultural exploitation of the soil is compromised due to competition with other uses, such as housing or tourism, and the fragility of the ecosystems in the area. Entrepreneurial activities from some tomato-producing provinces, such as Murcia (a neighbour of Almeria), have been conducted with strategies to reduce costs by relocation to nearby places (e.g. Morocco). However, it is an inadequate strategy, given that the reduction of production costs is associated with a decrease in the quality of production and an increase in the difficulty of marketing. For Almeria, the alternative would be to optimize the costs system, or relocate their production, considering that the technology in the greenhouse structure is expensive, and obtaining loans/funds to carry out their investments is difficult (De Pablo and Uribe, 2015).

Previous experimental works analyze the tomato response to different cultivation systems by studying only the production process inside the greenhouse (Rodríguez-Ortega *et al*., 2019; Borowski and Nurzyński, 2012). However, from the point of view of sustainability, it is convenient to consider the effect of all the factors that affect the agrifood value chain. Therefore, in this work we use the opinion of different experts (producers, production technical, researchers, marketers, distributors, etc.). The sustainability of tomato production in greenhouse is first analyzed according to the criteria that influence it. Subsequently, the behaviour of the alternatives is evaluated according to the chosen criteria. Consequently, the results of this work can be much more interesting in order to obtain conclusions about the tomato production, from the point of view of the sustainability. In this work, three alternatives of tomato cultivation systems in the greenhouse are evaluated according to criteria of sustainability in the conditions of the Spanish Mediterranean Basin. The cultivation systems are the soil, the perlite substrate and the NFT system (NGS

©). The result is the order of alternatives from the point of view of the sustainability of greenhouse production.

2. METHODOLOGY

A common method used to order alternatives is the Analytical Hierarchy Process (AHP), proposed by Saaty (1980). However, the use of the AHP present some problems as pointed out Yang and Chen (2004). The AHP method does not take into account the uncertainty associated with the mapping of human judgment to a number by natural language; the ranking of the AHP method is rather imprecise; and the subjective judgment by perception, evaluation, improvement and selection based on preference of decision-makers have great influence on the AHP results (Sun, 2010). That is why many researchers have integrated the fuzzy logic theory in the AHP method in order to improve the uncertainty inherent in any ordering problem, such as Buckley (1985). However, the main problem of the AHP methodology is the fact the number of comparisons is very high, especially when the number or criterion are high. For this reason, we propose to adapt the methodology of Terceño *et al*. (2009). As a result, the expert will have to make a unique valuation for alternative, and the matrix of comparisons is obtained just comparing in a proper way the opinions given by the experts, based in fuzzy logic.

On the other hand, the technique to order preferences for similarity to the ideal solution (TOPSIS) is an analysis method of multicriteria decision initially developed by Hwang and Yoon (1981). TOPSIS defines an index called similarity to the positive-ideal solution and the remoteness from the negative- ideal solution. Then, the method chooses an alternative with the maximum similarity to the positive-ideal solution (Hwang and Yoon, 1981; Wang and Chang, 2007). Although it is a method with a high acceptation, sometimes it is difficult for a decision-maker to assign a precise performance rating to an alternative for the attributes under consideration. The use of a fuzzy approximation to assign the importance of each attribute is especially suitable. The fuzzy TOPSIS methods was proposed by Chen (2000) to solve multicriteria decision making problems under uncertainty. Wang *et al.* (2011) used TOPSIS to evaluate thirteen comprehensive agronomic characteristics of twenty-two wheat germplasm resources in order to check new and high resistant varieties to Sitobion avenae. Meimandipour *et al*. (2012) uses TOPSIS methods to compare the performance of laying hen fed with different levels of yeast. Vico *et al*. (2017) uses TOPSIS to evaluate four certain types of growing technologies of winter lettuce in greenhouses were ranked by two multi-attribute decision making methods.

Fuzzy set theory (Zadeh, 1965) has been used in decision problems to deal with uncertain information. It is an extension of the classic notion of a set, in which each element is assessed in binary term according to a bivalent condition- an element either belong or does not belong to the set (Liou *et al*., 2007; Wu and Lee, 2007)

A fuzzy set $\tilde{A}$ in X is defined by $\tilde{A} = \{(x, \mu(x)), x \in X\}$ in which $\mu_{\tilde{A}}: X \to [0,1]$ is the membership of function $\tilde{A}$ and $\mu_{\tilde{A}}(x)$ is the degree of pertinence of x in $\tilde{A}$. A triangular fuzzy number $\tilde{A} = (a, b, c)$ on R to be a triangular fuzzy number (TFN) if its membership is equal to the expression:

$$\mu_{\tilde{A}}(x) = \begin{cases} \frac{x-a}{b-a} & a < x < b \\ \frac{c-x}{c-b} & b \leq x < c \\ 0 & otherwise \end{cases} \quad (1)$$

We propose a model in the following steps:

A. Obtaining the weights of each category. A linguistic variable is a variable whose values are words in a natural language. Six basic linguistics terms are going to be used in the work (Table 1). Each variable is defined by a TFN whose elements represent the minimum value, the more possible value and the maximum value of the membership function.

Table 1. The linguistic scale and underlying triangular number

Fuzzy number (FN)	Linguistic label	Scale of fuzzy number
$\tilde{5}$	Very high	(4,5,5)
$\tilde{4}$	High	(3,4,5)
$\tilde{3}$	Weak high	(2,3,4)
$\tilde{2}$	Weak low	(1,2,3)
$\tilde{1}$	Low	(0,1,2)
$\tilde{0}$	Very low	(0,0,1)

Experts are required to value the importance of each criterion assigning a linguistic scale from Table 1. The total number of experts that assign each fuzzy number to every criterion are registered and summarized by $(\omega^{a*}, \omega^{b*}, \omega^{c*})$. In this way, if n_i experts answer with the linguistic label corresponded to the fuzzy number i, then:

$$({\omega^{a}}'_i, {\omega^{b}}'_i, {\omega^{c}}'_i) = \left(\frac{{\omega^{a*}}_i}{S_c}, \frac{{\omega^{b*}}_i}{S_b}, \frac{{\omega^{c*}}_i}{S_a}\right)$$

Where,

$$(\omega^{a*}, \omega^{b*}, \omega^{c*}) = \frac{1}{\sum_{i=0}^{5} n_i}(0 \cdot n_0 + 0 \cdot n_1 + \cdots + 4 \cdot n_{5,}$$

$$, 0 \cdot n_0 + 1 \cdot n_1 + \cdots + 5 \cdot n_5, 1 \cdot n_0 + 2 \cdot n_1 + \cdots + 5 \cdot n_5 \quad (2)$$

And S_a, S_b and S_c are the sum of the extremes of each expression (2).

Next, the Triangular Fuzzy Number (TFN) approximation of the category weight i is obtained.

Defuzzification of a TFN (a_i, b_i, c_i) is obtained according to expression (3):

$$C_i = \frac{(c_i - a_i) + (b_i - a_i)}{3 + a_i} \quad (3)$$

Considering that the sum of the weights $\sum_i C_i$ is not one, the final weight $(\widetilde{\omega}_i)$ is obtained dividing the weight of each category by the sum of weights

$$\widetilde{\omega}_i = ({\omega^a}_i, {\omega^b}_i, {\omega^c}_i) = \frac{({\omega^{a\prime}}_i, {\omega^{b\prime}}_i, {\omega^{c\prime}}_i)}{\sum_i C_i} \quad (4)$$

B. Weights of each sub-category. As in step A, the sub-categories are valued by experts and compared between them. The final weight for each subcategory is

$$\widetilde{\omega}_{i,h} = \left(\omega^a_{i,h}, \omega^b_{i,h}, \omega^c_{i,h}\right) \quad (5)$$

C. Alternative valuation. The scale showed in Table 1 is used for this purpose. Each alternative i is valuated according to each of the j sub-criteria. The aggregated opinion of the experts is obtained according to the following expression

$$\tilde{x}_{ij} = \left({x_{ij}}^a, {x_{ij}}^b, {x_{ij}}^c\right) = \frac{1}{\sum_{i=0}^{5} n_i}(0 \cdot n_0 + 0 \cdot n_1 + \cdots + 4 \cdot n_5,$$
$$, 0 \cdot n_0 + 1 \cdot n_1 + \cdots + 5 \cdot n_5, 1 \cdot n_0 + 2 \cdot n_2 + \cdots + 5 \cdot n_5 \quad (6)$$

Normalization. Dividing the valuation of each alternative by $u_j^+ = max_i\, x_{ij}^c$, the normalized matrix is obtained

$$\tilde{R} = \left[\tilde{r}_{ij}\right]_{m\times n} = \left[\frac{\tilde{x}_{ij}}{u_j^+}\right]_{m\times n} \quad (7)$$

D. Final weight of each sub-criterion $\widetilde{\varpi}_{i,h} = \left(\varpi^a_{i,h}, \varpi^b_{i,h}, \varpi^c_{i,h}\right)$. They are obtained multiplying the weight of the criterion i by the weight of the sub-criterion h.

$$\widetilde{\varpi}_{i,h} = \widetilde{\omega}_i \otimes \widetilde{\omega}_{i,h} \quad (8)$$

E. Construction of the weighted normalized matrix $\tilde{v}_{ij} = \left(v^a_{ij}, v^b_{ij}, v^c_{ij}\right)$. The $\tilde{R}$ matrix obtained in (7) must be multiplied by the weights obtained in (8)

$$\tilde{V} = \left[\tilde{v}_{ij}\right]_{m\times n} = \tilde{R} \otimes \widetilde{\varpi} \quad (9)$$

F. Definition of the positive (I^+) and negative (I^+) ideal solution. The positive ideal solution is the maximum value of the weighted normalized matrix, being the upper extreme, the central value and the lower extreme the maximum of the corresponding values of the weighted normalized matrix and the minimum in the case of the negative ideal solution.

$$I^{+} = [I_1^{+}, I_2^{+}, \cdots, I_m^{+}] \quad (10)$$

$$I^{-} = [I_1^{-}, I_2^{-}, \cdots, I_m^{-}] \quad (11)$$

G. Obtaining the distance between the weighted normalized matrix and the positive ideal solution (d_i^{+}) and the negative one (d_i^{-})

$$d_i^{+} = \sum_{j=1}^{n} d\left(v_{ij}, I_j^{+}\right) \quad (12)$$

$$d_i^{-} = \sum_{j=1}^{n} d\left(v_{ij}, I_j^{-}\right) \quad (13)$$

Where $d()$ denotes the Euclidean distance between two fuzzy number. For instance, the distance between the TFN $\tilde{x} = (x_a, x_b, x_c)$ and $\tilde{y} = (y_a, y_b, y_c)$ can be obtained as

$$d(\tilde{x}, \tilde{y}) = \sqrt{\frac{1}{3}\left((x_a - y_a)^2 + (x_b - y_b)^2 + (x_c - y_c)^2\right)} \quad (14)$$

H. Coefficient CC_i and ranking alternatives. From expressions (8) and (9) the coefficient CC_i is obtained as:

$$CC_i = \frac{d_i^{-}}{d_i^{+} + d_i^{-}} \quad (15)$$

Alternatives are ordered according to coefficient CC_i, being the one with a higher coefficient the preferred one.

3. RESULTS

Valuations come from the opinion of 10 experts about the criteria and sub-criteria of sustainability used in this work (Table 2). Four of the consulted experts develop his activity in production, three in marketing and three are quality auditors

Table 3 shows the valuation done by the experts about the importance of each criterion. The number of experts that have considered the importance of each criterion as very low, low, … or very high has been registered in this table. The column ($\omega^{a}*, \omega^{b}*, \omega^{c}*$) summarizes this information according to expression (2), the TFN approximation of weight of criterion i ($\omega^{a\prime}, \omega^{b\prime}, \omega^{c\prime}$) has been obtained; expression (3) has been used to obtain the defuzzified value (Centre), and finally, according to (4) dividing the TFN approximation of weight of criterion i by the centre, the weight of criterion i is obtained ($\omega^{a}, \omega^{b}, \omega^{c}$). This transformation has been done because the sum of the centres of the weight's approximation criteria do not sum one, as desirable. Sustainability valuation criteria shows a slight variation according to the professional profile of the experts (Table 3). However, global tendencies are present in the way that they can explain properly the weight of the sustainability criteria of tomatoes production in the greenhouse.

Table 2. Sustainability criteria for the production in greenhouse

Criteria	Sub-criteria
Economic resources	Economic value Financing Pay-back
Commercial resources	Certification Commercialization Communication
Natural resources	Ground Water Weather
Human resources	Job creation Health, security and welfare Population fixation
Energetic and material resources	Vegetal material Artificial Energy
Management	Organization Critical points Waste

Table 3. Criteria valuation

	0	1	2	3	4	5	n	$(\omega^{a*}, \omega^{b*}, \omega^{c*})$			$(\omega^{a}{}', \omega^{b}{}', \omega^{c}{}')$			Centre	$(\omega^{a}, \omega^{b}, \omega^{c})$		
Economic R.				4	4	2	10	2.8	3.8	4.6	0.10	0.17	0.29	0.19	0.09	0.16	0.27
Commercial R.			2	3	4	1	10	2.4	3.4	4.3	0.09	0.16	0.27	0.17	0.08	0.14	0.25
Natural R.			2	3	3	2	10	2.5	3.5	4.3	0.09	0.16	0.27	0.18	0.08	0.15	0.25
Human R.			2	3	5		10	2.3	3.3	4.3	0.09	0.15	0.27	0.17	0.08	0.14	0.25
Energetic and material R.				2	7	1	10	2.9	3.9	4.8	0.11	0.18	0.30	0.20	0.10	0.16	0.28
Management				4	3	3	10	2.9	3.9	4.6	0.11	0.18	0.29	0.19	0.10	0.16	0.27
							Sum	15.8	21.8	26.9			Sum	1.10			

With regard to the sub-criteria, we have proceeded in a similar way (Table 4). Results of the valuation of the growing system (soil, perlite, and NFT) made by experts show a great coherence. Economic sub-criteria (economic value, financing and pay-back) improve in the order NFT, perlite and soil. However, the valuation of the alternatives based on commercial sub-criteria changes. In this way, cultivation in soil is better from the point of view of the certification because employment is compatible with organic production. On the other way, it is possible to have some precocity if perlite or NFT is used, and from the point of view of commercialization and communication, the results of these alternatives improve. The valuation of the natural resources improves the order soil<perlite<NFT due to the intrinsic characteristics of the growing system. With

regard to human resources, and considering that the growing system with soil can create a higher job offer, the growing system perlite and NFT can improve the quality of the work and the population fixation. On the other hand, the growing system soil can affect negatively both to vegetal material due to the higher exposition to illnesses, and to artificial resources (phytosanitary products, pesticides, etc.)

Table 4. Valuation of sub-criteria

	0	1	2	3	4	5	n	$(\omega^a*, \omega^b*, \omega^c*)$			$(\omega^{a}', \omega^{b}', \omega^{c}')$			Centre	$(\omega^a, \omega^b, \omega^c)$		
Economic value					8	2	10	3.2	4.2	5.0	0.24	0.39	0.64	0.42	0.21	0.35	0.58
Financing			2	4	4		10	2.2	3.2	4.2	0.16	0.30	0.54	0.33	0.15	0.27	0.49
Pay-back				6	4		10	2.4	3.4	4.4	0.18	0.31	0.56	0.35	0.16	0.28	0.51
							Sum	7.8	10.8	13.6			Sum	1.11			
Certification			2	4	4		10	2.2	3.2	4.2	0.17	0.32	0.61	0.37	0.16	0.29	0.54
Commercialization			2	4	2	2	10	2.4	3.4	4.2	0.19	0.34	0.61	0.38	0.17	0.31	0.54
Communication			2	4	3	1	10	2.3	3.3	4.2	0.18	0.33	0.61	0.37	0.16	0.30	0.54
							Sum	6.9	9.9	12.6			Sum	1.12			
Ground				5	3	2	10	2.7	3.7	4.5	0.19	0.31	0.51	0.34	0.18	0.29	0.48
Water				2	4	4	10	3.2	4.2	4.8	0.23	0.36	0.55	0.38	0.21	0.33	0.51
Weather				4	3	3	10	2.9	3.9	4.6	0.21	0.33	0.52	0.35	0.19	0.31	0.49
								8.8	11.8	13.9			Sum	1.07			
Job creation				4	6		10	2.6	3.6	4.6	0.19	0.34	0.61	0.38	0.17	0.31	0.55
Health, security and welfare				2	8		10	2.8	3.8	4.8	0.21	0.36	0.64	0.40	0.19	0.32	0.57
Population fixation			2	5	3		10	2.1	3.1	4.1	0.16	0.30	0.55	0.33	0.14	0.26	0.49
							Sum	7.5	10.5	13.5			Sum	1.12			
Vegetal material			2	3	5		10	2.3	3.3	4.3	0.18	0.32	0.58	0.36	0.16	0.29	0.52
Artificial				6	3	1	10	2.5	3.5	4.4	0.19	0.34	0.59	0.37	0.17	0.30	0.53
Energy				6	2	2	10	2.6	3.6	4.4	0.20	0.35	0.59	0.38	0.18	0.31	0.53
							Sum	7.4	10.4	13.1			Sum	1.11			
Organization				3	4	3	10	3	4	4.7	0.22	0.34	0.55	0.37	0.20	0.32	0.51
Critical point				5	3	2	10	2.7	3.7	4.5	0.20	0.32	0.52	0.35	0.18	0.30	0.49
Waste				4	3	3	10	2.9	3.9	4.6	0.21	0.34	0.53	0.36	0.20	0.31	0.50
							Sum	8.6	11.6	13.8			Sum	1.08			

The energy consumption is higher in the growing system NFT. Finally, according to management sub-criteria, NFT presents the better valuation, because of the skill's reduction proposed for this growing system. In addition, NFT is supposed to be a technology that, being more complex, presents a higher improvement in management and critical points.

Table 5 shows the valuation of each growing system based on several sub-criteria. In this way, for the growing system soil, 10 experts have answered, three of them have considered it as a weak, four as a high and three as a very high. As a result, considering the fuzzy number scale of Table 1, it is possible to have an average TFN (a,b,c) equal to (3,4,4.7). For the remaining alternatives and sub-criteria, the process is similar.

Table 5. Valuation of each growing system (soil, perlite and NFT); n=10

		0	1	2	3	4	5	a	b	c
Economic value	Soil				3	4	3	3.00	4.00	4.70
	Perlite		3	4	3			1.00	2.00	3.00
	NFT	3	4	3				0.30	1.00	2.00
Financing	Soil				3	3	4	3.10	4.10	4.70
	Perlite				3	4	3	3.00	4.00	4.70
	NFT		3	4	3			1.00	2.00	3.00
Pay-back	Soil				3	4	3	3.00	4.00	4.70
	Perlite				3	3	4	3.10	4.10	4.70
	NFT		3	4	3			1.00	2.00	3.00
Certification	Soil				3	3	4	3.10	4.10	4.70
	Perlite	3	4	3				0.30	1.00	2.00
	NFT	3	4	3				0.30	1.00	2.00
Commercialization	Soil	4	3	3				0.30	0.90	1.90
	Perlite				3	4	3	3.00	4.00	4.70
	NFT				3	4	3	3.00	4.00	4.70
Communication	Soil			5	5			1.50	2.50	3.50
	Perlite				5	5		2.50	3.50	4.50
	NFT					5	5	3.50	4.50	5.00
Ground	Soil	4	3	3				0.30	0.90	1.90
	Perlite			5	5			1.50	2.50	3.50
	NFT					5	5	3.50	4.50	5.00
Water	Soil	5	5					0.00	0.50	1.50
	Perlite			3	4	3		2.00	3.00	4.00
	NFT					5	5	3.50	4.50	5.00
Weather	Soil	3	4	3				0.30	1.00	2.00
	Perlite			3	4	3		2.00	3.00	4.00
	NFT			3	4	3		2.00	3.00	4.00

		0	1	2	3	4	5	a	b	c
Job creation	Soil			3	4	3		2.00	3.00	4.00
	Perlite		3	4	3			1.00	2.00	3.00
	NFT	3	4	3				0.30	1.00	2.00
Health, security and welfare	Soil		3	4	3			1.00	2.00	3.00
	Perlite			3	4	3		2.00	3.00	4.00
	NFT				3	4	3	3.00	4.00	4.70
Population fixation	Soil		3	4	3			1.00	2.00	3.00
	Perlite			3	4	3		2.00	3.00	4.00
	NFT				3	4	3	3.00	4.00	4.70
Vegetal material	Soil		3	4	3			1.00	2.00	3.00
	Perlite				3	4	3	3.00	4.00	4.70
	NFT				3	4	3	3.00	4.00	4.70
Artificial	Soil		3	4	3			1.00	2.00	3.00
	Perlite		3	4	3			1.00	2.00	3.00
	NFT				3	4	3	3.00	4.00	4.70
Energy	Soil				3	4	3	3.00	4.00	4.70
	Perlite		3	4	3			1.00	2.00	3.00
	NFT	3	4	3				0.30	1.00	2.00
Organization	Soil		3	4	3			1.00	2.00	3.00
	Perlite			3	4	3		2.00	3.00	4.00
	NFT			3	4	3		2.00	3.00	4.00
Critical point	Soil		3	4	3			1.00	2.00	3.00
	Perlite			3	4	3		2.00	3.00	4.00
	NFT				3	4	3	3.00	4.00	4.70
Waste	Soil	5	5					0.00	0.50	1.50
	Perlite	3	4	3				0.30	1.00	2.00
	NFT					5	5	3.50	4.50	5.00

The normalized matrix of Table 6 is obtained according to (7), dividing the average TFN obtained in Table 5 (a,b,c) by the maximum of all of them, in this case 5. In this table, results are shown only for economic resources. For the rest of criteria, the process is similar. Once the matrix has been normalized, the valuation of the growing system soil with regard to the sub-criteria economic value is the TFN (0.60, 0.80, 0.94). Table 7 shows the weighted fuzzy matrix for economic resource sub-criteria, obtained according to (9). In this way, for the growing system soil, the corresponding one for economic value (0.01, 0.04, 0.14) can be obtained multiplying the normalized value of Table 6 (0.6, 0.8, 0.94) by the weigh obtained in Table 4 corresponding to the sub-criterion economic value (0.21, 0.35, 0.58) and for the weight corresponding to the criterion Economic resources (0.09, 0.16, 0.27).

Table 6. Normalized fuzzy decision matrix for economic resources sub-criteria

	Economic value			Financing			Pay-back		
Soil	0.60	0.80	0.94	0.62	0.82	0.94	0.60	0.80	0.94
Perlite	0.20	0.40	0.60	0.60	0.80	0.94	0.62	0.82	0.94
NFT	0.06	0.20	0.40	0.20	0.40	0.60	0.20	0.40	0.60

The positive ideal solution has been obtained as the maximum value of each extreme, that is the lower extreme of the ideal solution is the maximum of the lower extremes of the Soil, Perlite and NFT for Economic value, Financing, Pay-back, Certification, Commercialization, etc, and (0,0,0) is the ideal negative solution. Central and upper extremes have been obtained in a similar way. Table 8 shows the distance between each alternative and the positive ideal solution (or negative, depending on the case). In this way, the distance between the TFN soil (0.01, 0.04, 0.14) (Table 7) and the TFN (0.00, 0.01, 0.15), according to expression (14), is 0.00.

Table 7. Weighted fuzzy decision matrix for economic resources sub-criteria

	Economic value			Financing			Pay-back		
Soil	0.01	0.04	0.14	0.01	0.03	0.12	0.01	0.04	0.13
Perlite	0.00	0.02	0.09	0.01	0.03	0.12	0.01	0.04	0.13
NFT	0.00	0.01	0.06	0.00	0.02	0.08	0.00	0.02	0.08

Finally, Table 9 shows the CC_i obtained according to expression (11) and the final ranking, as it can be checked, is NFT>Perlite>Soli, being NFT the ideal solution with a CC_i of 0.654 and soil the least preferred with a CC_i of 0.493

Table 8. Distance of each alternative from A+ and from A- to each criterion

	Economic value	Financing	Pay-back		Economic value	Financing	Pay-back
d(Soil,A+)	0.00	0.02	0.01	d(Soil,A-)	0.07	0.05	0.05
d(Perlite,A+)	0.04	0.02	0.01	d(Perlite,A-)	0.03	0.05	0.05
d(NFT,A+)	0.05	0.04	0.04	d(NFT,A-)	0.01	0.02	0.03

The final order is: NFT>perlite>soil (Table 9). The growing system soil presents higher score in economic criteria due to fact that the cost of acquisition is much higher than in other alternatives. However, natural and human and material resources, as well as management improve the score of the alternative NFT and perlite.

Table 9. CC_i y final rank

	CC_i	Rank
Soil	0.457	3
Perlite	0.566	2
NFT	0.611	1

4. CONCLUSIONS

The work carried out has yielded an analysis of the sustainability of tomato production in the greenhouse, based on the result of the evaluation of different criteria that influence it. The evaluation of the importance of the criteria corresponded to different experts in all sectors integrated in the agro-food value chain. In this way, the sustainability of a process, such as greenhouse production, is subordinated to that of the entire process, from the sowing of the seeds to the consumer. Three alternatives of system of cultivation of tomato in greenhouses have been analyzed from the point of view of the sustainability, yielding the following order: NFT > perlite > soil. Although these are preliminary results, it is convenient to carry out studies of this type and of an applied nature to evaluate the potential of this NFT technology in greenhouse tomato production.

We are aware about the fact that the new research can develop the technologies related with NFT or perlite. The alternatives of production must be evaluated, not only in terms of efficiency of production, but also in terms of sustainability. That is why knowledge transfer must be assisted in order to improve the sustainability of the greenhouse tomato production.

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