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Optimal Agricultural Land Use: An Efficient Neutrosophic Linear Programming Method

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Abstract: The increase in the size of the problems facing humans, their overlap, the division of labor, the multiplicity of departments, as well as the diversity of products and commodities, led to the complexity of business and the emergence of many administrative and production problems. It was necessary to search for appropriate methods to confront these problems. The science of operations research, with its diverse methods, provided the optimal solutions. It addresses many problems and helps in making scientific and thoughtful decisions to carry out the work in the best way within the available capabilities. Operations research is one of the modern applied sciences that uses the scientific method as a basis and method in research and study, and its basic essence is to build a model that helps management in making decisions related to difficult administrative problems. For example, the military field, financial aspects, industry, in construction for building bridges and huge projects to evaluate the time taken for each project and reduce this time, financial markets and stocks and forecasting economic conditions, in hospital management and controlling the process of nutrition and medicines within the available capabilities, in agriculture Agricultural marketing and many other problems that have been addressed using classical operations research methods. We know that the agricultural sector is one of the important sectors in every country, and the agricultural production process is regulated by those responsible for securing the needs of citizens. Also, those responsible for the agricultural sector are responsible for rationalizing the agricultural process so that the surplus is saved. Due to the difficult circumstances that the country may be going through, in this research, we will reformulate the general model for the optimal distribution of agricultural lands using the concepts of neutrosophic science.

Keywords: Operations Research; Neutrosophic Science; Neutrosophic Linear Programming; Optimal Agricultural Land Use Model.

1. Introduction

Securing the needs of citizens is necessary and one of the major responsibilities that falls on officials in the state. This matter requires a scientific study of the reality of the state's situation and optimal exploitation of the available capabilities, that is, organizing work in all sectors of the state in a way that guarantees citizens a stable life in all circumstances. This matter prompted scientists and researchers are prepare scientific studies that help decision-makers make ideal decisions to manage the work of these sectors. The classical linear programming method was one of the most widely used methods [1-3], and it was relied upon even though the solutions it provided were appropriate solutions for conditions similar to those in which, data is collected about the case under study. Any change in this data will affect the optimal solution and thus the decisions of decision-makers, which requires us to search for a new scientific method that provides us with optimal solutions suitable for all circumstances and takes into account all changes that may occur. In the work environment, we find that using the concepts of neutrosophic science, the science that takes into account the changes that can occur in the work environment through the indeterminacy of neutrosophic values. So, we have to reformulate many practical issues using the concepts of this science, which can be viewed from what was presented by the American scientist Florentin Smarandache, the founder of this science, and many researchers in various scientific fields [4-19]. Given the importance of the linear programming method, we presented in previous research the neutrosophic linear models [20]. In another research, we presented one of the most important methods used to find the optimal solution for the models. Linear, which is the simplex neutrosophic method [21]. Among the uses of neutrosophic linear programming, we presented a study on its use in the field of education [22]. As a continuation of our previous work, we present in this research a study whose purpose is to reformulate the model of optimal use of agricultural land using the concepts of neutrosophic. This will help decision-makers obtain an optimal solution that secures the needs of citizens for agricultural crops in all circumstances that the country may go through.

The structure of this paper is organized as follows. In Section 2, we briefly examine the concept used for solving the problem. In Section 3, we apply the introduced approach to a case study and discuss the obtained results. In Section 4, we discuss the conclusions of the paper in Section 3.

2. Materials and methods

The most important stage in linear programming is the stage of creating a linear programming model, and we mean expressing realistic relationships with assumed mathematical relationships based on the study and analysis of reality. In order to formulate a linear programming model, the following basic elements must be present:

- Determine the goal in a quantitative manner
  It is expressed by the objective function, which is the function for which the maximum or minimum value is required. It must be possible to express the goal quantitatively, such as if the goal is to achieve the greatest possible profit or secure the smallest possible cost.

- Determine the constraints
  The constraints on the available resources must be specific, that is, the resources must be measurable, and expressed in a mathematical formula in the form of inequalities or equals.

- Determine the goal in a quantitative manner
  This element indicates that the problem should have more than one solution so that linear programming can be applied because if the problem had one solution, there would be no need to use linear programming because its benefit is focused on helping to choose the best solution from among the multiple solutions [1].

3. Results and discussion

3.1 Problem definition

We will apply the above in Section 2, to the model of optimal use of agricultural land, using the concepts of neutrosophic science. We will take data that is affected by the surrounding conditions, and neutrosophic values.

- Text of the issue:

Let us assume that we have n agricultural areas (plain or cultivated), the area of each of which is equal to $A_1, A_2, \cdots\cdots, A_n$, we want to plant it with m types of agricultural crops to secure the community's requirements for it. Knowing that we need of crop i the amount b_i , if the average productivity of one area in plain j of crop i is equal to Na_{ij}tons/ha. Where $j = 1,2, \dots \dots, n$ and $i = 1,2, \dots \dots, m$, and the profit returned from one unit of crop i equal to Np_i, Where Np_i is a neutrosophic value, an undefined non-specific value that designates a perfect and can be any neighbor of the value a_{ij}, also Np_iwhich can be any neighbor of p_i.

- Required:

  Determine the amount of area needed to be cultivated with each crop and in all regions to achieve the greatest possible profit and meet the needs of society.

- Formulation of the mathematical model:

  We symbolize by x_{ij} the amount of area in area j that must be cultivated with crop, and we place the data for the problem in Table 1.

Table 1. Issue data.

Regions / *Crops*	1	2	$\dots\dots$	n	*Order amount* b_i	*profit amount* Np_i
1	Na_{11} x_{11}	Na_{12} x_{12}	$\dots\dots$	Na_{1n} x_{1n}	b_1	Np_1
2	Na_{21} x_{21}	Na_{22} x_{22}	$\dots\dots$	Na_{2n} x_{2n}	b_2	Np_2
$\dots\dots$	$\dots\dots$	$\dots\dots$	$\dots\dots$	$\dots\dots$	$\dots\dots$	$\dots\dots$
m	Na_{m1} x_{m1}	Na_{m2} x_{m2}	$\dots\dots$	Na_{mn} x_{mn}	b_m	Np_m
Available space a_i	a_1	a_2	$\dots\dots$	a_n		

Then we find that the conditions imposed on the variables x_{ij} are:

1. Space restrictions

   The total area allocated to various crops in area j must be equal to a_j, that is, it must be:

$$\mathrm{x}_{11} + \mathrm{x}_{12} + \cdots\cdots + \mathrm{x}_{m1} = \mathrm{a}_1$$
$$\mathrm{x}_{12} + \mathrm{x}_{22} + \cdots\cdots + \mathrm{x}_{m2} = \mathrm{a}_2$$
$$\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots$$
$$\mathrm{x}_{1n} + \mathrm{x}_{2n} + \cdots\cdots + \mathrm{x}_{mn} = \mathrm{a}_n$$

2. Conditions for meeting community requirements

   The total production of crop i in all regions must not be less than the amount b_i, that is, it must be:

$$\mathrm{Na}_{11}\mathrm{x}_{11} + \mathrm{Na}_{12}\mathrm{x}_{12} + \cdots\cdots + \mathrm{Na}_{1n}\mathrm{x}_{1n} \geq \mathrm{b}_1$$
$$\mathrm{Na}_{21}\mathrm{x}_{21} + \mathrm{Na}_{22}\mathrm{x}_{22} + \cdots\cdots + \mathrm{Na}_{2n}\mathrm{x}_{2n} \geq \mathrm{b}_2$$
$$\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots$$
$$\mathrm{Na}_{m1}\mathrm{x}_{m1} + \mathrm{Na}_{m2}\mathrm{x}_{m2} + \cdots\cdots + \mathrm{Na}_{mn}\mathrm{x}_{mn} \geq \mathrm{b}_m$$

3. Find the objective function

   - We note that the profit resulting from the production of crop i only and from all regions is equal to the product of the profit times the quantity and i.e.:

$$\mathrm{Np_i}(\mathrm{Na_{i1}}x_{i1} + \mathrm{Na_{i2}}x_{i2} + \cdots\cdots + \mathrm{Na_{in}}x_{in})$$

Thus, we find that the objective function, which expresses the total profit resulting from all crops, is equal to:

$$Z = \mathrm{Np_1}\left(\sum_{j=1}^{n} \mathrm{Na_{1j}}\, x_{1j}\right) + \mathrm{Np_2}\left(\sum_{j=1}^{n} \mathrm{Na_{2j}}\, x_{2j}\right) + \cdots\cdots + \mathrm{Np_m}\left(\sum_{j=1}^{n} \mathrm{Na_{mj}}\, x_{mj}\right) \to \mathrm{Max}$$

- From the above, we get the following mathematical model:

Find the maximum value of

$$Z = \mathrm{Np_1}\left(\sum_{j=1}^{n} \mathrm{Na_{1j}}\, x_{1j}\right) + \mathrm{Np_2}\left(\sum_{j=1}^{n} \mathrm{Na_{2j}}\, x_{2j}\right) + \cdots\cdots + \mathrm{Np_m}\left(\sum_{j=1}^{n} \mathrm{Na_{mj}}\, x_{mj}\right) \to \mathrm{Max}$$

Within restrictions:

$$x_{11} + x_{12} + \cdots\cdots + x_{m1} = a_1$$
$$x_{12} + x_{22} + \cdots\cdots + x_{m2} = a_2$$
$$\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots$$
$$x_{1n} + x_{2n} + \cdots\cdots + x_{mn} = a_n$$

$$a_{11}x_{11} + a_{12}x_{12} + \cdots\cdots + a_{1n}x_{1n} \geq b_1$$
$$a_{21}x_{21} + a_{22}x_{22} + \cdots\cdots + a_{2n}x_{2n} \geq b_2$$
$$\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots$$
$$a_{m1}x_{m1} + a_{m2}x_{m2} + \cdots\cdots + a_{mn}x_{mn} \geq b_m$$

$$x_{ij} \geq 0 \quad ; i = 1,2,\cdots\cdots,m\, , j = 1,2,\cdots\cdots,n$$

3.2 *Example*

Let us assume that we want to exploit four agricultural areas A_1, A_2, A_3, A_4, and the area of each of them, respectively, is 60,150,20,10, by planting them with the following crops: wheat, barley, cotton, tobacco, and beet, from which we need the following: 800, 200,600,1000,2500 Let us assume that the regions' productivity of these crops and their prices are given in Table 2.

Table 2. Example data.

Regions / Crops	A_1	A_2	A_3	A_4	The order	Price per ton
wheat	{4,6}	*4*	3	*6*	*2500*	{1400,1600}
barley	7	*5*	*4*	{3,5}	*1000*	{900,1100}
cotton	*4*	{9,11 }	*8*	*5*	*600*	{4500,6000}
tobacco	6	{2,4}	*0*	*0*	*200*	{4000,5000}
beet	*3*	{10,14}	*10*	6	*800*	{400,700}
Space	*60*	*150*	*20*	*10*		

- Required:

Formulate the mathematical model for this issue so that the production value is as large as possible. To formulate the mathematical model, we extract the following linear conditions:

- Space restrictions

$$x_{11} + x_{21} + x_{31} + x_{41} + x_{51} = 60$$
$$x_{12} + x_{22} + x_{32} + x_{42} + x_{52} = 150$$
$$x_{13} + x_{23} + x_{33} + x_{43} + x_{53} = 20$$
$$x_{14} + x_{24} + x_{34} + x_{44} + x_{54} = 10$$

- Order restrictions

$$\{4,6\}x_{11} + 4x_{12} + 3x_{13} + 6x_{14} \geq 2500$$
$$7x_{21} + 5x_{22} + 4x_{23} + \{3,5\}x_{24} \geq 1000$$
$$4x_{31} + \{9,11\}x_{32} + 8x_{33} + 5x_{34} \geq 600$$
$$6x_{41} + \{2,4\}x_{42} + 0x_{43} + 0x_{44} \geq 200$$
$$3x_{51} + \{10,14\}x_{52} + 10x_{53} + 6x_{54} \geq 800$$

- Non-Negative restrictions

$$x_{ij} \geq 0 \ ; i = 1,2,3,4,5 \quad \text{and} \quad j = 1,2,3,4$$

- Objective function that express the value of production is:

$$\begin{aligned} Z = \ &\{1400,1600\}(\{4,6\}x_{11} + 4x_{12} + 3x_{13} + 6x_{14}) \\ &+ \{900,1100\}(7x_{21} + 5x_{22} + 4x_{23} + \{3,5\}x_{24}) \\ &+ \{4500,6000\}(4x_{31} + \{9,11\}x_{32} + 8x_{33} + 5x_{34}) \\ &+ \{4000,5000\}(6x_{41} + \{2,4\}x_{42} + 0x_{43} + 0x_{44}) + \{400,700\}(3x_{51} \\ &+ \{10,14\}x_{52} + 10x_{53} + 6x_{54}) \to \text{Max} \end{aligned}$$

- Mathematical model:
  - Find the maximum value of

$$\begin{aligned} Z = \ &\{1400,1600\}(\{4,6\}x_{11} + 4x_{12} + 3x_{13} + 6x_{14}) \\ &+ \{900,1100\}(7x_{21} + 5x_{22} + 4x_{23} + \{3,5\}x_{24}) \\ &+ \{4500,6000\}(4x_{31} + \{9,11\}x_{32} + 8x_{33} + 5x_{34}) \\ &+ \{4000,5000\}(6x_{41} + \{2,4\}x_{42} + 0x_{43} + 0x_{44}) + \{400,700\}(3x_{51} \\ &+ \{10,14\}x_{52} + 10x_{53} + 6x_{54}) \to \text{Max} \end{aligned}$$

  - Within restrictions:

$$x_{11} + x_{21} + x_{31} + x_{41} + x_{51} = 60$$
$$x_{12} + x_{22} + x_{32} + x_{42} + x_{52} = 150$$
$$x_{13} + x_{23} + x_{33} + x_{43} + x_{53} = 20$$
$$x_{14} + x_{24} + x_{34} + x_{44} + x_{54} = 10$$
$$\{4,6\}x_{11} + 4x_{12} + 3x_{13} + 6x_{14} \geq 2500$$
$$7x_{21} + 5x_{22} + 4x_{23} + \{3,5\}x_{24} \geq 1000$$
$$4x_{31} + \{9,11\}x_{32} + 8x_{33} + 5x_{34} \geq 600$$
$$6x_{41} + \{2,4\}x_{42} + 0x_{43} + 0x_{44} \geq 200$$
$$3x_{51} + \{10,14\}x_{52} + 10x_{53} + 6x_{54} \geq 800$$
$$x_{ij} \geq 0 \ ; i = 1,2,3,4,5 \quad \text{and} \quad j = 1,2,3,4$$

  - It is a linear model; we use the simplex method to obtain an optimal solution.

4. Conclusions

In this study, the authors presented a new formulation of the model for optimal use of agricultural land using the concepts of neutrosophic science, where we took data that are affected by the surrounding conditions. Neutrosophic values take into account fluctuations in ambient conditions, from natural factors that can affect crop yields to price fluctuations that can affect profit. We obtained a linear neutrosophic mathematical model that can be solved using the simplex neutrosophic method that was presented in previous research. Then, the optimal solution is the values of the variables that express the areas that can be allocated in each of the regions for each crop.

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Data availability
The datasets generated during and/or analyzed during the current study are not publicly available due to the privacy-preserving nature of the data but are available from the corresponding author upon reasonable request.

Conflict of interest
The authors declare that there is no conflict of interest in the research.

Ethical approval
This article does not contain any studies with human participants or animals performed by any of the authors.

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