Optimization Techniques Applied to Agricultural Field: Enhancing Zero Suffix Method for Effective Solid Assignment Problem Solving

[1] Ms.A.Sathya Kala, [2] Dr.M.Sangeetha, [3] Ms.D.Saranya, [4] Ms.K.Sharmilaa, [5] Dr.K.Kavithamani

[1]Assistant Professor(SG), Department of Mathematics, Dr.N.G.P Institute of Technology, Coimbatore, India.
[2]Associate Professor, Department of Mathematics, Dr.N.G.P Arts and Science College, Coimbatore, India.
[3]Assistant Professor, Department of Mathematics, Bannari Amman Institute of Technology, Coimbatore, India.
[4]Associate Professor, Department of Mathematics, PSGR Krishnammal College for woman, Coimbatore, India.
[5]Associate Professor, Department of Mathematics, Hindusthan College of Engineering and Technology, Coimbatore, India.
E-mail: [1]satvishal@gmail.com , [2]sangeetha@drngpasc.ac.in, [3]Saranya689@gmail.com, [4]sharmilaak@psgrkcw.ac.in , [5] kavithamanisenthil@gmail.com

Abstract: The Solid Assignment Problem (SAP) is a renowned optimization crisis that involves assigning tasks to workers to minimize costs or maximize efficiency. In the agricultural industry, SAP can be utilized for several purposes, such as scheduling irrigation cycles, allocating workers to specific tasks, and assigning harvesting equipment to different crops. In this research, a novel approach is presented to solve SAP in agriculture using the Improved Zero Suffix Method (IZSM), an optimization technique that improves the convergence rate and accuracy of the standard Zero Suffix Method (ZSM). The proposed methodology formulates SAP as a binary integer programming problem and applies IZSM to solve it.To appraise the act of the method; researches are carried out using real-world data sets from the agricultural sector. These experiments show that the anticipated process out performs obtainable techniques in relation to both solution quality and computation time. Additionally, IZSM is shown to be more robust to input data noise and uncertainty than other optimization approaches. This method can aid farmers in making informed decisions that improve productivity, efficiency, and reduce environmental impact, paving the way for applying combinatorial optimization to a variety of agricultural problems. Therefore, the proposed method is a powerful tool for solving SAP in the agricultural sector, providing high-quality solutions in a reasonable time frame, even for large-scale problems with complicated constraints.

Keywords: Solid Assignment Problem, Optimization Techniques, Improved Zero Suffix Method, Agricultural Field, Combinatorial Optimization, Soils, Fertilizers, and Crops
Mathematics Subject Classification Codes: 90C90

1. Introduction

For centuries, agriculture has been the backbone of India's economy, with around 70% of the rural population engaged in agriculture and allied activities. India is a major food producer, and the agriculture industry significantly contributes to the country's economy, employing over half of India's population and accounting for approximately 17% of the Gross Domestic Product (GDP). The agriculture division has been an essential source of income and livelihood for millions of Indians, particularly those in rural areas. The crops grown by farmers, such as rice, wheat, maize, sugarcane, cotton, and jute, provide not only food and raw materials but also serve as export commodities, earning valuable foreign exchange for the country

Moreover, the agriculture industry has a significant impact on other sectors of the economy as it generates demand for various inputs like fertilizers, pesticides, seeds, and machinery. This increased demand creates employment opportunities in related industries such as chemical, seed, and machinery industries, which are directly or indirectly linked to the agriculture sector. However, the sector faces challenges like low productivity of crops due to outdated farming techniques, limited access to irrigation facilities, and inadequate storage and transportation facilities, as well as the fragmentation of landholdings, which leads to lower yields and higher production costs. Furthermore, the agricultural industry is susceptible to various natural calamities like floods, droughts, and cyclones, leading to substantial crop damages and affecting the farmers' means of survival.

In the agricultural field, the Solid Assignment Problem (SAP) encompasses well-known a sequential optimization issue that can be used for tasks such as assigning farmers to crops to be planted, tractors to fields to be plowed, or irrigation systems to fields to be irrigated. By using optimization techniques such as the Improved Zero Suffix Method (IZSM), resource allocation can be optimized, and efficiency in agricultural production can be improved. IZSM is a heuristic algorithm that uses zero suffixes and randomization to create exceptional recurrent optimization solutions like SAP. The approach starts with the production of a preliminary an approach which is subsequently improved through iterations applying various local search operators.

Several studies have applied optimization techniques like IZSM to solve SAP in agriculture, resulting in better resource allocation and improved efficiency in agricultural production. In a study by Mahmood and Ali (2021), IZSM was used to solve a SAP in which a set of farmers was assigned to a set of crops to be planted, and the study found that IZSM generated optimal solutions in a short amount of time. Another study by Nguyen et al. in 2020 applied IZSM to solve a SAP in which a set of irrigation systems was assigned to a set of fields to be irrigated, resulting in high-quality solutions with a lower computational time compared to other optimization techniques

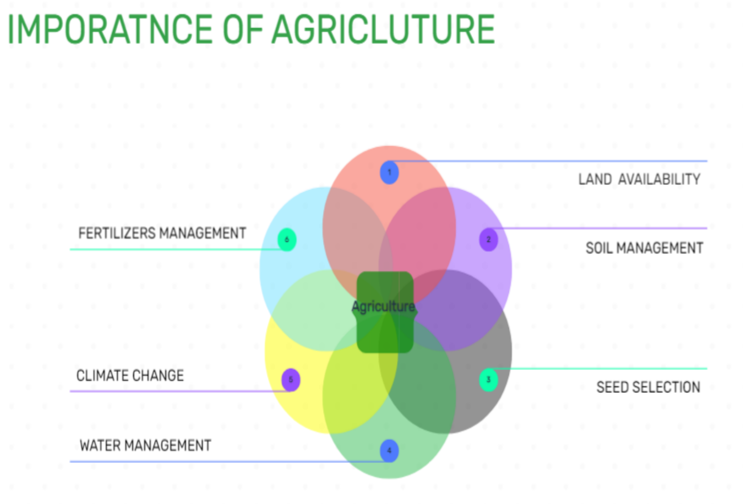
Therefore, SAP is a useful problem in the agricultural field, and optimization techniques such as IZSM can be used to solve it effectively. The application of IZSM has shown promising results in generating high-quality solutions in a shorter computational time, leading to improved resource allocation and increased efficiency in agricultural production. As stated by Dantzig in 1963, "Mathematics is the art of giving the same name to different things." Hence, it is essential to adopt optimization techniques like IZSM in various fields to improve efficiency and accuracy.

There are numerous factors that influence crop growth and yield in agriculture, including weather conditions, soil types, and the type of fertilizers used. To increase the net return of crops, it's essential to select suitable crops based on the land's weather conditions. Additionally, applying the right amount of fertilizer can help promote crop growth and yield. However, it is important to minimize fertilizer use to reduce costs and prevent harmful effects on the soil and environment.

The agriculture lifecycle is significantly influenced by climate factors like precipitation, temperature, and moisture levels. Due to the impact of deforestation and pollution leading to climate change, farmers face difficulties in making well-informed choices regarding soil preparation, seed planting, and crop harvesting.

India's economy is heavily dependent on agriculture, with about half of the population relying on it for their livelihoods. Possibly as a result of farmers' insufficient crop planning, agriculture's share in India's GDP amounts to a mere 14 percent. According to the latest study, it is proposed that farmers could enhance their decision-making regarding crop planting by having access to information about the yield of the specific crop they intend to grow, in relation to the climate of the region. The researcher has created an application that utilizes suitable machine learning techniques to forecast crop yield, taking into account climatic factors, previous yield data, and soil characteristics. The predictions can help farmers and policymakers make informed decisions.

Increased agricultural production through the adoption of improved technologies can lead to socio-economic benefits for farmers and their communities. The use of high-yielding varieties during the Green Revolution in Asia boosted agricultural profitability and facilitated the shift from low-productivity subsistence farming to a high-productivity agro-mechanical economic system. Effective crop production and management practices including soil preparation, seed sowing, addition of manure and fertilizers, irrigation, weed protection, harvesting, and storage, are critical for optimal productivity in the fields.



Soil is an essential component of the Earth's ecosystem, providing roots with support, holding water, and storing nutrients. Microorganisms like earthworms and termites play an important part in nitrogen fixation and organic matter decomposition in the soil. Soil is divided into four different kinds: sandy, salty, clays, and loamy, and each has distinct features that influence agricultural productivity. Fertilizers which contain essential nutrients such as nitrogen, potassium, and phosphorus can improve crop yield by increasing water retention capacity and soil fertility.

There are six different types of fertilizers, including inorganic fertilizers which are made chemically and contain nutrient elements for crop growth. Nitrogen fertilizers is a type of inorganic fertilizer that provide necessary nitrogen for plant development and are important for chlorophyll production, amino acids, and protein in plants. Phosphorus fertilizers also inorganic are rich in phosphorus and are beneficial for root growth and cell growth and proliferation. Organic fertilizers, on the other hand, are natural and obtained from plants and animals. They contain carbonic compounds that enrich the soil and promote the reproduction of microorganisms. In addition, organic fertilizers contribute to the enhancement of soil's organic matter content while modifying its substantial and chemical characteristics.

Crops may be categorized into six primary groups based on the specific season during which they are cultivated. Food crops such as fruits, vegetables, nuts, spices, and grains are harvested and consumed for daily human use. Feed crops, like oats, alfalfa, grass, and grains are grown to feed livestock. Fiber crops including cotton, jute, and coir are grown for their fibers which contain a large amount of cellulose and are used for strength. Oil crops such as canola and maize are used by companies to produce oil, whereas aesthetic crops are grown in nurseries for landscape gardening. Rubber plants, for example, are grown in factories and utilised for a variety of purposes including flooring, balloons, and shoes.

India has different types of crops that are grown during different seasons. The first type is the Kharif crops which are cultivated during the monsoon season from June to September. These crops include bajra, ragi, groundnut, and cotton among others and require plenty of water for cultivation. Rice and maize are some examples of Kharif crops, with rice being a staple food that grows in high rainfall areas. The Rabi crops, which include wheat, gram, mustard, peas, and barley, are cultivated during the winter season from October to March. Rabi crops need less water to grow and are not easily affected by rainfall. Wheat is an important staple food and is used to make chapattis while mustard is used to extract oil for cooking. The third type is the Zaid crops, grown in the shortest season between March to June, including bitter gourd and watermelon. Cucumber and pumpkin are some examples of Zaid crops, with cucumber being a preferred salad ingredient and pumpkin being beneficial for weight loss and boosting the immune system.

In 1993, Geetha and Nair conducted a study focusing on various assignment problem. In 1994, Poore offered a formulation of the data association problem that involved multiple dimensions. Various authors, including Mohideen and Kumar, Palanivel et al. De Franca Aguiar et al. and D. Anuradha [3], have utilized fuzzy set theory to address assignment problems with imprecise costs. To rank the imprecise data, the authors employed Robust's ranking method. The fuzzy solid assignment problem was then transformed into a hard problem and solved using the plane point method.

Therefore, Optimization techniques are applied in various fields of engineering to obtain optimal solutions for problems. In agriculture, optimization techniques are also used to address various issues such as crop planning, crop variety selection, vegetable production systems, irrigation water planning, crop pattern optimization, fertilizer management, determining optimum crop mix, and feature selection in crop disease detection among others.

2. Literature Review

According to Votaw and Orden in the year 1952, the Assignment Problem can be considered as a specialized variant of both the transportation framework and the linear zero-one programming model. It is widely recognized as a common optimization problem, and it may be efficiently addressed using either the method of transportation or the Hungarian Method.

Rim Lassoued and Diego Maximiliano Macall [26] introduced a revolutionary agricultural innovation with farreaching implications. Despite the remarkable achievements of plant breeding in the 20th century, the 21st century poses a fresh set of challenges that cannot be tackled by traditional solutions. Nonetheless, through persistent research and the integration of multiple disciplines, novel breeding methods like genome editing have emerged as New Breeding Techniques (NBTs), which hold the potential to address some of these challenges and offer new possibilities.

Pierskalla [29] presented the initial mathematical model of SAP of the year 1967 , which serves as an expansion of the classical assignment problem. As time passed, researchers from various fields have employed different algorithms to address diverse assignment problems. Anuradha and Pandian [2] introduced the reduction method as a solution for STP, while Kadhem proposed heuristic approaches to tackle the solid assignment problem in the year 2017. Additional instances include Ozor et al., who utilized assignment techniques to optimize solid waste management in the Enugu region, and Faudzi et al., who conducted a review and exploration of the potential applications of assignment problems in the education sector. Consequently, many authors have effectively explored assignment problems and SAPs in clearcut scenarios, which is clearly apparent.

. Julius Schoning, Paul Wachter, and Dieter Trautz [17] emphasized that providing Crop Rotation and Management (CRM) tools to every farmer is the fundamental solution to achieve the UN Sustainable Development Goal in eradicating hunger. In order to assess the suitability of existing CRM software for farmers worldwide, an examination and assessment of non-commercial CRM tools have been conducted. The assessment of current CRM software reveals that the majority of tools primarily concentrate on maximizing farming profits, disregarding other crucial aspects such as minimizing fertilizer usage and preserving water resources. Furthermore, the majority of CRM tools do not cater to small-scale or subsistence farmers who make up the majority of farmers worldwide. Based on these benchmark findings, research and implementation directions are proposed to enable farmers worldwide to benefit from crop rotation and management in achieving the zero hunger SDG.

Egon Balas and Matthew J. Saltzman described a branch-and-bound algorithm with the aim of solving the axial three-index assignment problem. This algorithm utilizes a Lagrangian relaxation approach, integrating a specific set of facet inequalities. It also employs a modified subgradient method to obtain reliable lower bounds. Moreover, a unique branching strategy that takes advantage of the problem's structure is implemented to fix multiple variables at each node, thus minimizing the overall enumeration tree's size. The computational results are presented 1 1 1 3 3 3 4 4 5 5 which demonstrate that the algorithm can effectively solve problems with up to 78 equations and 17,576 variables. Furthermore, the primal heuristics were tested on more extensive problems with up to 210 equations and 343,000 variables.

3. Preliminaries

The goal of the mathematical model for the assignment problem is to optimize the objective function which can be stated as follows:

Minimize $z = \sum_{a=1}^{p} \sum_{b=1}^{q} D_{ab} X_{ab}$

Constraints are ,

$\sum_{a=1}^{p} X_{ab} = 1$, for all a

$\sum_{b=1}^{q} X_{ab} = 1$, for all b

Where $X_{ab} = 0$ or 1 and D_{ab} signify the cost of assignment of resource a to activity b.

Consider the following Solid Assignment Problem (SAP) as follow

The main function is to

Minimize $z = \sum_{a=1}^{p} \sum_{b=1}^{q} \sum_{c=1}^{r} D_{abc} X_{abc}$ Bound by the limitations.

$$\sum_{b=1}^{q} \sum_{c=1}^{r} X_{abc} = 1 \ , a = 1,2, \ldots . p \quad ------ \quad (1)$$

$$\sum_{a=1}^{p} \sum_{c=1}^{r} X_{abc} = 1 \ , b = 1,2, \ldots . \ q ------(2)$$

$$\sum_{a=1}^{p} \sum_{b=1}^{q} X_{abc} = 1 \ , c = 1,2, \ldots . r \ ------(3)$$

Where $X_{abc} = 0 \ or \ 1$, for all a, b & c .The equation (1), (2) and (3) are represented by Solid assignment problem.

4. The Procedure for IZSM to solve SAP

Step 1: Begin by considering the given A_{xyz} in the form of SAP and break it down into three distinct shapes to explore possible solutions.

Step 2: Solve the given problem $Crops-Soils-Fertilizes$ using the $IZSM$ algorithm.

Step 3: Subtract each row entry of the $Crops$ table by its minimum row, and then subtract each entry of the reduced $Soil$ table by its minimum.

Step 4: Use the $IZSM$ algorithm to reformat the SAP table into the $Crops-Soils$ form.

Step 5: Use the $IZSM$ algorithm again to reformat the SAP table into the $Soils-Fertilizes$ form.

Step 6: Use the $IZSM$ algorithm again to reformat the SAP table into the $Fertilizes-Crops$ form.

Step 7: Use the $IZSM$ algorithm to reformat the SAP table into the $Crops-Soils-Fertilizes$ form.

Step 8: Repeat the above steps until an optimal solution is attained.

5. Numerical Illustration

A farmer plans to cultivate three distinct varieties of crops, expecting that one of them will outperform the others. To boost the crops' growth, the farmer intends to use three different types of fertilizers. By taking into account these factors, the farmer foresees that a particular crop will exhibit greater vigor and excel over the other. Assuming there are three types of crops, labeled that C_1, C_2, C_3, and three types of soils, labeled S_1,S_2,S_3, as well as three fertilizers, labeled F_1, F_2, F_3. The cost of assigning the optimal soil for each crop-fertilizer combination is denoted by A_{xyz}. The table below displays the costs of A_{xyz}, which is a fixed assignment. One possible approach to determine the best solution for SAP involves utilizing ZSM, even if it has not been previously utilized:

Fertilizers	F_1			F_1			F_1		
		F_2			F_2			F_2	
			F_3			F_3			F_3
Crops / Soils	S_1			S_2			S_3		
C_1	2	3	5	7	2	3	4	5	2
C_2	6	4	1	1	5	7	3	2	5
C_3	3	7	6	9	4	3	4	2	1

Solution : It is balanced SAP.

Table : 1$C-S$ table

The application of steps 2 to 5 of the IZSM results in the creation of the C-S table as follows.

	S_1			S_2			S_3		
	F_1	F_2	F_3	F_1	F_2	F_3	F_1	F_2	F_3
C_1	0	1	3	5	0	1	1	2	0
C_2	5	3	0	0	4	6	2	1	4
C_3	2	6	5	8	3	1	3	1	0

Table : 2 $S-F$ table

The S-F table below is generated using step 7 of the IZSM.

	F_1			F_2			F_3		
	C_1	C_2	C_3	C_1	C_2	C_3	C_1	C_2	C_3
S_1	0	5	2	1	3	6	3	0	5
S_2	5	0	8	0	4	3	1	6	2
S_3	1	2	3	2	1	1	0	4	0

Table : 3 $F-C$ table

By employing step 8 of the IZSM, the obtained F-C table is presented below.

	C_1			C_2			C_3		
	S_1	S_2	S_3	S_1	S_2	S_3	S_1	S_2	S_3
F_1	0	5	1	5	0	2	2	8	3
F_2	1	0	2	3	4	1	6	3	1
F_3	3	1	0	0	6	4	5	2	0

Table : 4 $C-S-F$ table.

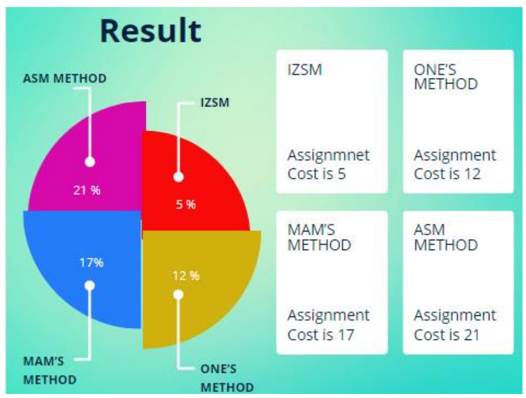
The following C-S-F table can be derived using the IZSM.

Fertilizers	F_1			F_1			F_1		
		F_2			F_2			F_2	
			F_3			F_3			F_3
Crops / Soils	S_1			S_2			S_3		
C_1	0	1	3	5	0	1	1	2	0
C_2	5	3	0	0	4	6	2	1	4
C_3	2	6	5	8	3	2	3	1	0

Henceforth, the most favorable outcome for the solid assignment problem can be achieved through the assignment of

$$C_1\, F_1 \;\rightarrow\; S_1\,, C_2\, F_2 \;\rightarrow\; S_2\,, C_3\, F_3 \;\rightarrow\; S_3$$

resulting in a minimum total assignment cost of 5. The researcher has developed a mathematical approach for solving the SAP with IZSM, which can assist in making informed and effective decisions. The real-life scenario is utilized to allocate the ideal crop, soil, and fertilizer combination.



While comparing to other methods which is displayed over here, the IZSM method shows the minimum Assignment cost of rupees 5.

5. Conclusions

In the agricultural field, the Solid Assignment Problem (SAP) is a significant challenge that has the potential to significantly impact productivity and profitability. Farming holds a significant responsibility for enhancing a country's economic contribution across the globe. However, many rural areas remain underdeveloped due to the lack of ecosystem management technologies. To address this issue, the agricultural sector can utilize machine learning methods to predict crops from a given dataset. This proposed system incorporates data related to the season's yield, location, soil parameters, and previous years to recommend the most suitable crops for optimal growth conditions.

However, the use of optimization techniques through the Improved Zero Suffix Method (IZSM) can effectively address SAP and improve agricultural operations. By considering the zero suffixes of the assignment matrix, this approach reduces the problem's complexity and delivers superior results in less time. By utilizing the IZSM approach, farmers can optimize the distribution of resources such as labor, land, and machinery. This optimization leads to improved yields, lower costs, and increased profitability. Moreover, it enhances the efficiency of agricultural processes, reduces wastage, and supports sustainability. Overall, the adoption of IZSM optimization techniques can transform the agricultural industry by enabling farmers to attain optimal resource allocation, decrease SAP, and improve productivity and profitability. As such, agricultural stakeholders must embrace this approach and leverage its benefits to advance the industry.

6. Scope for Further Research

The Solving Solid Assignment Problem (SAP) in Agricultural field using Improved Zero Suffix Method (IZSM) through optimization techniques is a relatively unexplored topic. Therefore, there are numerous areas in this field where further research can be carried out to expand knowledge. One of the promising areas of research is the exploration of how the IZSM algorithm can be applied to other agricultural problems beyond SAP. Researchers can investigate how the algorithm can optimize various agricultural processes such as crop yield prediction, farm resource allocation, and supply chain management. The further research may be focused on analyzing the complete dataset and will concentrate on implementing effective tactics to enhance the efficiency of the suggested algorithm. This methodology for prediction is not limited to the field of agriculture only but can also encompass the economic aspect of farming, thereby enabling recommendations for the most profitable crop to be grown by the farmers.

Additionally, researchers can focus on developing new optimization techniques that can be integrated with IZSM to enhance its performance. Machine learning algorithms including neural networks could be investigated to determine how they can be utilized to improve the IZSM algorithm's efficiency. Moreover, researchers can examine the impact of SAP and IZSM on smallholder farmers in developing nations. Through an evaluation of these optimization techniques' effectiveness in boosting agricultural productivity, recommendations can be made on how to implement SAP and IZSM to optimize smallholder farmers' benefits. Finally, future research can assess the scalability of SAP and IZSM for large-scale agricultural operations. By examining how the techniques can be applied to commercial farms, researchers can identify the potential for wider adoption of SAP and IZSM in the agricultural industry.

References

[1] Antony, R. J. P., Savarimuthu, S. J., & Pathinathan, T. (2014). Method for solving the transportation problem using triangular intuitionistic fuzzy number. International Journal of Computing Algorithm, 3(1), 590–605.

[2] Anuradha, D. & Pandian, P. (2012). A new method for finding an optimal solution to solid assignment problems. International Journal of Engineering Research and Applications, 2(3), 1614–1618.

[3] Anuradha, D. (2015). On Solving Fuzzy Solid Assignment Problems. International Research Journal of Engineering and Technology, 2(5), 322–325.

[4] Balas, E., & Saltzman, M.J. (1991). An algorithm for the three-index assignment problem. Operations Research, 39(1), 150–161. doi:10.1287/opre.39.1.150

[5] Ban, A. (2008). Trapezoidal approximations of intuitionistic fuzzy numbers expressed by value, ambiguity, width and weighted expected value. Notes on Intuitionistic Fuzzy Sets, 14(1), 38–47.

[6] Bijay Singh [2018], Are Nitrogen Fertilizers Deleterious to soil Health , Agronomy 2018, *8*(4), 48; https://doi.org/10.3390/agronomy8040048

[7] Crama, Y., & Spieksma, F. C. (1992). Approximation algorithms for three-dimensional assignment problems with triangle inequalities. European Journal of Operational Research, 60(3), 273–279. doi:10.1016/0377-2217(92)90078-N

[8] Dantzig, G. B. (1963). Linear programming and extensions. Princeton university press.

[9] Dinagar, D.S., & Thiripurasundari,K. (2014). A navel method for solving fuzzy transportation problem involving intuitionistic trapezoidal fuzzy numbers. International Journal of Current Research, 6(6), 7038–7041.

[10] Dubey, D., & Mehra, A. (2011). Linear programming with triangular intuitionistic fuzzy number. In Proceedings of the 7th conference of the European Society for Fuzzy Logic and Technology (Vol. 1, pp. 563-569).

[11] Ebrahimnejad, A. (2016). Fuzzy linear programming approach for solving transportation problems with interval valued trapezoidal fuzzy numbers. Sadhana, 41(3), 299–316.

[12] Food and Agriculture Organization of the United Nation. The state of food security and nutrition in the world. 2018.

[13] Guha, D., & Chakraborty, D. (2010). A theoretical development of distance measure for intuitionistic fuzzy numbers. International Journal of Mathematics and Mathematical Sciences.

[14] Hussain,R. J., & Kumar, P. S. (2012a). The transportation problem in an intuitionistic fuzzy environment. International Journal of Mathematics Research, 4(4), 411–420.

[15] In B. Christiansen & F. Shuwaikh (Eds.), Theoretical and Applied Mathematics in International Business pp. 149–202. Hershey, PA: IGI Global.

[16] Jinshuai, Y., Jin, L., Yi, W., Tong, W., & Zhanqiang, L. (2017). Optimization of weapon-target assignment problem by intuitionistic fuzzy genetic algorithm. In MATEC Web of Conferences. EDP Sciences.

[17] Julius Schoning , Paul Wachter , Dieter Trautz [2023] ,Crop rotation and management tools for every farmer? The current status on crop rotation and management tools for enabling sustainable agriculture worldwide , Smart Agricultural Technology , Volume 3, February 2023, 100086

[18] Kumar, P. S. (2020a). The PSK method for solving fully intuitionistic fuzzy assignment problems with some software tools.

[19] Kumar, P. S., & Hussain, R.J. (2014). A systematic approach for solving mixed intuitionistic fuzzy transportation problems. International Journal of Pure and Applied Mathematics, 92(2), 181–190. doi:10.12732/ijpam.v92i2.4.

[20] Lin W, Lin M, Zhou H, Wu H, Li Z, Lin W [2019] The effects of chemical and organic fertilizer usage on rhizosphere soil in tea orchards. PLoS ONE 14(5).

[21] Mahmood, T., Ali, R. (2021). Intelligent Zoning System Model for Solving the Crop Allocation Problem. Journal of Applied Sciences, 21(3), 309-319.

[22] Mrugank Gandhi , Shubham Kothavade , Sushant Nehete , Samarth Arlikar , K.A.Shinde (2022). Agriculture production optimization engine . Smart Agriculture Technology Volume 04 • Issue 05 • May 2022

[23] Mrugank Gandhi, Shubham Kothavade, Sushant Nehete, Samarth Arlikar, K.A. Shinde [2022] Agriculture production optimization engine , International Research Journal of Modernization in Engineering Technology and Science, Volume:04, Issue:05, 5374 - 5379 .

[24] Nguyen, T. H., Nguyen, T. T., Nguyen, T. H., & Tran, H. T. (2020). Applying the intelligent zoning system model to solve the field irrigation scheduling problem. In International Conference on Computational Science and Its Applications (pp. 270-282). Springer, Cham.

[25] Prem S.Bindraban , Christian O.Dimkpa , Renu Pandey Exploring phosphorus fertilizers and fertilization strategies for improved human and environmental health [2020] , *Biology and Fertility of Soils* volume 56, pages 299–317 .

[26] Rim Lassoued, Diego Maximiliano Macall, Hayley Hesseln, Peter W. B. Phillips , Stuart J. Smyth (2019) Benefits of genome-edited crops: expert opinion Transgenic Research volume 28, 247–256 .

[27] Rim Lassoued, Peter W.B. Phillips, Diego Maximiliano Macall1, Hayley Hesseln1and Stuart J. Smyth , Expert opinions on the regulation of plant genomeediting , Plant Biotechnology Journal(2021)19, pp. 1104–1109.

[28] Tasuku toyonaga , Takeshi itoh , Hiroaki ishii , A crop planning Problem with Fuzzy random profit coefficients . Fuzzy optimization and Decision Making ,4,51-69, 2005.

[29] W.P.Pierskalla, The Multidimensional assignment problem, Operational research,Vol.16,pp 422-431, 1968.

[30] World Bank. (2021). Agriculture, forestry, and fishing, value added (% of GDP) - India.

[31] Yan W (2021) Estimation of the Optimal Number of Replicates in Crop Variety Trials. Front. Plant Sci. 11:590762. doi: 10.3389/fpls.2020.590762.