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Cost Effective Agriculture Supply Chain Optimization using Evolutionary Algorithms

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***Abstract* –** Amidst concerns about food security and rising inflation, optimizing agriculture supply chains is gaining popularity as a cost-reduction measure. Given this industry's intricate and dynamic nature, effectively managing agricultural supply chains is crucial to sustain food security and ensure the delivery of high-quality products cost-effectively. However, it can take much work to optimize supply networks for agriculture. Evolutionary algorithms have emerged as valuable tools to overcome these challenges and improve various aspects of agricultural supply chains. This study employs evolutionary algorithms to optimize agrarian supply chains and enhance cost-effectiveness. Its primary objective is to minimize operating expenses while ensuring the delivery of high-quality products and maintaining efficient delivery systems. The research comprehensively considers all stages of the agricultural supply chain, including production, processing, storage, transportation, and distribution. The proposed technique involves studying and optimizing the agricultural supply chain using various evolutionary algorithms, such as Genetic Algorithm (GA), Red Deer Algorithm (RDA), and Social Engineering Optimization Algorithm (SEO). These algorithms utilize the principles of natural selection and evolutionary processes to address complex supply chain optimization problems. The research also explores the integration of these evolutionary algorithms with critical decision variables, such as order allocation, inventory control, and transportation routing. The results of this research will provide invaluable insights for designing and implementing cost-effective agricultural supply chain systems in practice. Farmers, distributors, and other stakeholders can employ optimized supply chain models to address their challenges, increase efficiency, improve productivity, and reduce costs.

Keywords – Agricultural Supply Chain, Optimization, Evolutionary Algorithms, Genetic Algorithms, Red Deer Algorithm, Social Engineering Optimization Algorithm, Cost-Effectiveness.

I. INTRODUCTION

The agricultural sector is crucial in sustaining food security goods [1]. Despite its significance, the farm supply chain faces several challenges, including fluctuating input costs, unpredictable weather patterns, market volatility, and the need to ensure both cost-effectiveness and sustainability [2]. Therefore, the success of the agricultural supply chain in terms of operational efficiency, waste reduction, cost reduction, product quality improvement, and timely delivery to consumers is highly dependent on various factors.

The quality and safety of food products and efficient cost management are becoming increasingly important for maintaining competitiveness in the global food production industry [3]. Optimizing the entire supply chain from farm to consumer is crucial, given the rising demand for food products [4]. This entails optimization procedures like seed selection, land preparation for planting, harvesting, post-harvest handling, packaging, storage, transportation, and distribution. In recent years there have been new developments in research on supply chain management like cost, lead time, and waste minimization [5,6,7]. For the manufacturing of pharmaceuticals [8], chemicals [9], electronics [10], and forest products [11], numerous researchers have created supply chain optimization models. However, there needs to be more research on the cost optimization of agricultural supply chains. This paper's goal is to structure the target cost model of the supply chain for green agricultural products and to provide an evolutionary algorithm-based optimizing solution to the problem, which can serve as a model for the global advancement of green agriculture.

Evolutionary algorithms have drawn much attention recently as practical optimization tools for tackling challenging issues in various fields, including supply chain management. These Algorithms, which draw their inspiration from ideas in genetics and natural evolution, emulate the processes of selection, crossover, and mutation to create and improve a population of potential solutions iteratively. Researchers and practitioners can enhance the performance of the agricultural supply chain by optimizing various phases, including production, transportation, processing, storage, and distribution. They can help determine the fastest and least expensive transportation routes and the routes with the shortest delivery times.

Several studies have explored the application of evolutionary algorithms in agricultural supply chain optimization. F. Altiparmak, M. Gen, L. Lin, & T. Paksoy proposed a multi-objective optimization model for plastic manufacturing and distribution using a genetic algorithm (GA) [12]. Their analysis showed that the GA efficiently optimized production scheduling, inventory control, and transportation routing, resulting in lower costs and better resource utilization. In a different investigation, S. M. Pahlevan, S. M. S. Hosseini, & A. Goli used the Red Deer algorithm (RDA) to improve the distribution of aluminium resources in a network of supply chains. According to their findings, the RDA successfully identified the best allocation strategies by considering variables like resource availability, demand, and transportation costs, which improved supply chain effectiveness [13]. Additionally, to improve the logistics network design in the recycling industry, S. Aghamohamadi, M. Rabbani, & R. Tavakkoli-Moghaddam used a Social Engineering optimization (SEO)-based strategy. Their research highlighted the importance of considering transportation costs, storage capacity, and market demand when designing an efficient logistics network [14].

These studies demonstrate how evolutionary algorithms can be used to overcome the difficulties associated with optimizing the agricultural supply chain. Stakeholders can efficiently optimize essential aspects of the supply chain by incorporating these algorithms into decision-making processes, increasing efficiency, lowering costs, improving product quality, and increasing sustainability. The study will enhance crucial decision factors, including order allocation, inventory management, transportation routing, and production planning.

The outcomes of this study will offer helpful information for designing and implementing improved agricultural supply chain systems. The results will benefit farmers, producers, distributors, and other stakeholders by enabling them to make knowledgeable decisions, boost productivity, reduce costs, and support sustainable agricultural practices.

II. Problem Definition and Model Formulation

The proposed agriculture supply chain model is depicted in Fig. 1. The network comprises producers, distribution centers, retailers, and customers.

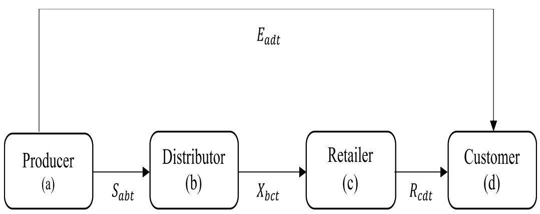

Fig. 1 The proposed Network Model

The flow of products from producer to distributor to customer is depicted in the figure. Additionally, consumers can buy products directly from producers. The various model elements, such as indices, variables, and parameters, are described in the following:

$a = 1,2,\dots,A$: The production locations

$b = 1,2,\dots,B$: The Fixed points of distribution locations

$c = 1,2,\dots,C$: The Fixed points of Retailer locations

$d = 1,2,\dots,D$: The Fixed points of Customer locations

$t = 1,2,\dots,T$: The production cycles

f_b : Fixed cost of opening distribution center

$TCab_{ab}$: Transportation Cost from producer to distributor

$TCad_{ad}$: Transportation Cost from producer to Customer

$TCbc_{bc}$: Transportation Cost from distributor to Retailer

$TCcd_{cd}$: Transportation Cost from retailer to customer

HC_{bt} : Holding cost of the distribution center at production cycle

PC_{at} : Production cost of Agri products at production cycle

$CAPa_a$: Storage capacity of producer

$CAPb_b$: Storage capacity of a distributor

d_{ct} : Demand of Agri products at production cycle

S_{abt} : Number of products transported from producer to distributor

X_{bct} : Number of products transported from distributor to retailer

R_{cdt} : Number of products transported from retailer to customer

E_{adt} : Number of products transported from producer to customer

Inv_{bt} : Inventory status of products at the distribution center at production cycle

Y_b :1 if the distribution center is established, 0 otherwise

This problem aims to specify the number of products that must be produced at each farm, the distribution of customers among distribution, collection, inspection centres, and the flow of materials. The proposed Agri-supply chain network design problem formulations using the notations above are presented. By extending the earlier works, these formulations were created [15].

$$FC = \sum_b f_b \times Y_b \tag{1}$$

$$TC = \sum_a \sum_b \sum_t TCab_{ab} \times S_{abt} + \sum_b \sum_c \sum_t TCbc_{bc} \times X_{bct} + \sum_c \sum_d \sum_t TCcd_{cd} \times R_{cdt} + \sum_a \sum_b \sum_t TCab_{ab} \times E_{adt} \tag{2}$$

$$PC = \sum_a \sum_t PC_{at} \times (\sum_b S_{abt}) \tag{3}$$

$$HC = \sum_b \sum_t HC_{bt} \times Inv_{bt} \tag{4}$$

This objective function minimizes the overall costs, which include fixed opening costs (1), transportation costs (2), production costs (3), and holding costs (4) at distribution centres. Several demands, network balance, and inventory capacity constraints are utilized in the study.

III. Solution Approaches

Solving supply chain problems requires effective methods to find the optimal solution. Here, we present three effective recent metaheuristics. Recently published papers have frequently used these techniques to resolve supply chain problems. The supply chain network design literature frequently used three efficient metaheuristic algorithms: GA, RDA, and SEO. Therefore, this study compares the performance of these three well-known methods on the proposed Agri-supply chain network. Proposed metaheuristics are explained in the following subsections to address the problems.

A. *Genetic Algorithm (GA)*

The genetic algorithm (GA) is a powerful optimization method that draws inspiration from genetics and natural evolution processes. By imitating the principles of natural selection, crossover, and mutation, it is frequently used to resolve challenging optimization problems. A population of potential solutions is the starting point for GA, which iteratively refines to find the optimal or nearly optimal solution.

The following is a genetic algorithm's fundamental tenets:

1) Initialization:

A randomly generated population of potential solutions, individuals, or chromosomes, is created. Each chromosome stands for a possible solution to the problem.

2) Evaluation:

Each person in the population is analyzed by employing a fitness function that gauges their level of quality or fitness about the problem's objectives.

3) Selection:

The higher fitness value of the individuals tends to have more probability of being selected for reproduction. Selection methods like tournament and roulette wheel selection produce a mating pool of chosen individuals.

4) Reproduction:

The chosen individuals in the mating pool undergo reproduction procedures like crossover and mutation. Crossover refers to exchanging genetic material between two parents to create offspring that possesses traits from both parents. Mutations alter each individual's genetic code slightly and randomly to maintain diversity in the population.

5) Replacement:

The offspring often replace a percentage of the existing population, typically those with lower fitness ratings. This ensures that the population matures toward better solutions over many generations.

6) Termination:

The evaluation, selection, reproduction, and replacement steps are repeated until the algorithm satisfies a termination condition. This requirement may be a maximum number of iterations, discovering a workable solution, or meeting a predetermined convergence criterion.

B. *Red Deer Algorithm (RDA)*

The Red Deer Algorithm (RDA) is a nature-inspired optimization algorithm that draws inspiration from the traits and behaviors of red deer in their natural environment. An intricate optimization problem can be solved using this population-based metaheuristic algorithm.

The RDA mimics red deer's social structure and foraging habits to explore the solution space efficiently. The algorithm includes the following crucial steps:

1) Population Initialization:

A set of potential solutions, individuals or deer, is generated randomly. Every deer symbolizes a possible solution to the problem at hand.

2) Fitness Evaluation:

To determine their fitness or quality in solving the problem, each member of the population is evaluated using an objective function.

3) Roaring:

In the roaring phase, dominant deer emit roars to assert their dominance and attract potential mates, inspired by the vocalizations of red deer.

4) Fighting:

During the mating season, male red deer confront physically to establish dominance and gain access to mates. This behavior is simulated in the RDA's fighting phase, replicating the competitive behavior among red deer for resources and power.

5) Adaptation and Evolution:

The RDA algorithm uses adaptive mechanisms like mutation and recombination to introduce diversity and explore better solutions. These mechanisms help the algorithm avoid getting stuck in local optima and move towards more effective solutions.

6) Termination:

The algorithm goes through several steps, including roaring, fighting, and evolution, until it reaches a termination condition. This could be a maximum number of iterations, achieving a satisfactory solution, or meeting a predefined convergence criterion.

The Red Deer Algorithm has proven effective in solving various optimization problems, such as engineering design, data clustering, image segmentation, and feature selection. Its unique features, including social hierarchy and adaptability, make it a promising solution for complex real-world optimization challenges.

C. *Social Engineering Optimizer*

The SEO algorithm is a metaheuristic optimization technique that takes inspiration from social engineering. This tool uses the principles of influence and persuasion to help with complex optimization problems. It mimics the tactics used by social engineers to guide the search process and find the best solutions. Social Engineering (SE) refers to using specific techniques to obtain information from people indirectly. The algorithm uses people's social connections and persuasive skills to help find better solutions. The critical components of SEO include:

1) Initialization:

A group of variable values called "person" is created randomly as a potential solution, and their qualities are identified as traits. The attacker is designated as the better solution when using an array, while the defender is the other option.

2) Training and Retraining:

This step demonstrates how the attacker can train to overcome the defender. The attacker can identify the most effective approach by testing each trait of the defender.

3) Spotting an Attack:

To spot potential attacks, four techniques are commonly used: obtaining, phishing, diversion theft, and pretext. These techniques are randomly employed to search for any possible attacks.

4) Respond to Attack:

Current and older positions of the defender are analyzed and compared with the previous position of the defender to select the best. To choose the best position for the attacker, the positions of the attacker and defender are exchanged and evaluated similarly.

5) Termination:

Like other metaheuristics, the user can determine the stop condition based on the maximum number of simulation iterations or the best solution quality.

The Social Engineering Optimizer takes a unique approach to optimization by using social influence and persuasion techniques. This helps it to explore the search space, take advantage of promising solutions, and adapt to changing environments. Results have been promising in various optimization problems, such as objective function optimization, parameter tuning, and feature selection.

IV. Experimental Analysis

To solve the proposed problem, we generated four small-scale problems with various combinations of producers, distribution centres, retailers, and customers based on the Chakwal City of Pakistan case study. Each issue is numbered P1, P2, P3, and P4, with different values for the number of producers, distribution centres, retailers, and customers. Specifically, P1 has values of 3, 3, 2, and 5; P2 has 5, 4, 3, and 6; P3 has 7, 8, 5, and 10; and P4 has 9, 11, 7, and 14. The fixed cost of constructing distribution centres is 500000 to 80000 PKR, the holding price of products is 43000 to 45000 PKR, transportation cost is 7000 to 8000 PKR varying with the distance between different facilities and production cost per unit of product is 60 to 80 PKR.

GA, RDA, and SEO parameters are tuned to solve the proposed model. The initial population for GA is set to 100, and for RDA, it is set to 250. The genetic algorithm parameters are considered as the Maximum number of Iterations is 150, Crossover percentage Pc is 0.6, and the Mutation percentage Pm is 0.2. In the Red Deer algorithm, parameters are regarded as the Maximum number of iterations is 100, the Male Red Deer population Nmale is 30, the percentage of mating in alpha harems is 0.8, the rate of mating in betta harems is 0.6, and the ratio of male commanders is 0.7. Similarly, the Social Engineering Optimizer algorithm parameters are considered as the Maximum number of iterations is 400, the rate of training is 0.25, the rate of spotting an attack is 0.1, and the number of connections is set to 40. All algorithms are coded in MATLAB, and the test problems are analyzed accordingly. Table 1 presents the results of different algorithms against each test problem. Performance comparison of different algorithms in terms of the best solution and computational time is illustrated in Fig 1 and 2, respectively.

Table 1. Results Comparison based on the Best Solution and Solving Time

RDA		SEO	
Best Solution	**Solving Time**	**Best Solution**	**Solving Time**
839,736.05	564.71	839,043.65	418.32
1,160,389.11	573.63	1,158,834.55	506.37
1,450,208.17	588.79	1,446,495.65	531.58
2,300,355.12	640.39	2,299,649.38	594.04

Test Problems	GA	
	Best Solution	Solving Time
P1	839,748.93	554.43
P2	1,159,392.81	582.62
P3	1,448,518.49	593.26
P4	2,305,509.67	664.20

Fig. 2 Comparison of GA, RDA, and SEO in terms of the best solution

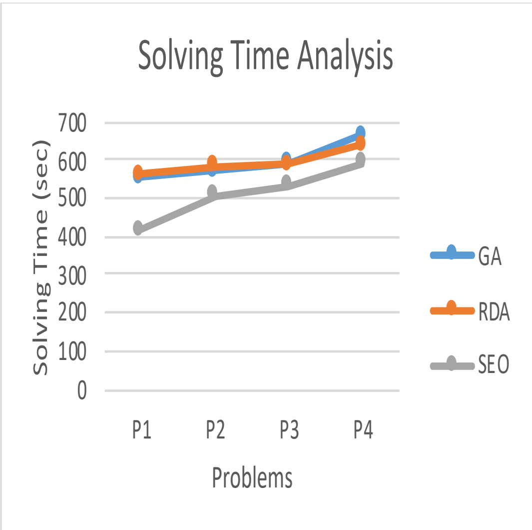

Fig. 3 Comparison of GA, RDA, and SEO in terms of solving time

V. CONCLUSION

The results show that Social Engineering Optimizer leads the best results regarding solution capability, followed by RDA and GA lack in performance among proposed algorithms. In terms of solving time, SEO took less time to solve problems, followed by RDA and GA. Overall the version of SEO is the best among all algorithms. This study focuses on minimizing costs in the agriculture supply chain by addressing four test problems. It considers various costs such as production, fixed construction, holding, and transportation costs. The employed metaheuristics were able to solve the proposed model efficiently.

Further costs can be employed for further research. Also, the network can be improved using multi-objective approaches considering environmental and social impacts. The metaheuristics can be further enhanced, and their hybrid versions can be developed for better results.

REFERENCES

[1] H. Ge, R. Gray, & J. Nolan, “Agricultural supply chain optimization and complexity: A comparison of analytic vs. simulated solutions and policies,” International Journal of Production Economics, vol. 159, pp. 208-220, January 2015.

[2] H. Ge, J. Nolan, R. Gray, S. Goetz, & Y. Han, “Supply chain complexity and risk mitigation – A hybrid optimization–simulation model,” International Journal of Production Economics, vol. 179, pp. 228-238, September 2016.

[3] R. D. Tordecilla, A. A. Juan, J. R. Montoya-Torres, C. L. Quintero-Araujo, & J. Panadero, “A review of simulation-optimization methods for designing and assessing resilient supply chain networks under uncertain scenarios,” Simulation Modelling Practice and Theory, vol. 106, January 2021.

[4] J. Chen and H. Yu, "Performance Simulation and Optimization of Agricultural Supply Chains," 2013 International Conference on Information Science and Cloud Computing, Guangzhou, China, 2013, pp. 131-137.

[5] Amit Raj Singh, P. K. Mishra, Rajeev Jain, M. K. Khurana (2012). “Design of global supply chain network with operational risks,” vol. 60, 2012, pp. 273-290.

[6] Mastrocinque, B. Yuce, A. Lambiase, & M. S. Packianather, “A Multi-Objective Optimization for Supply Chain Network Using the Bees Algorithm,” International Journal of Engineering Business Management, January 2013.

[7] Mohebalizadehgashti, H. Zolfagharinia, & S. H. Amin, “Designing a green meat supply chain network: A multi-objective approach,” International Journal of Production Economics, vol.219, pp. 312-327, January 2020.

[8] L. G. Papageorgiou, G. E. Rotstein, & N. Shah, "Strategic supply chain optimization for the pharmaceutical industries," Industrial & engineering chemistry research, vol. 40(1), pp. 275-286, January 2001.
[9] Q. Zhang, N. Shah, J. Wassick, R. Helling, & P. Van Egerschot, "Sustainable supply chain optimization: An industrial case study," Computers & Industrial Engineering, vol. 74, pp. 68-83, August 2014.
[10] Y. Zhao, Y. Cao, H. Li, S. Wang, Y. Liu, Y. Li, & Y. Zhang, "Bullwhip effect mitigation of green supply chain optimization in the electronics industry," Journal of Cleaner Production, vol. 180, pp. 888-912, April 2018.
[11] S. Shahi, & R. Pulkki, "Supply chain network optimization of the Canadian forest products industry. A critical review," American Journal of Industrial and Business Management, vol. 3(07), 2013, pp. 631-643.
[12] Altiparmak, M. Gen, L. Lin, & T. Paksoy, "A genetic algorithm approach for multi-objective optimization of supply chain networks," Computers & industrial engineering, vol. 51(1), pp. 196-215, September 2006.
[13] S. M. Pahlevan, S. M. S. Hosseini, & A. Goli, "Sustainable supply chain network design using products' life cycle in the aluminum industry," Environmental Science and Pollution Research, pp. 1-25, January 2021.
[14] S. Aghamohamadi, M. Rabbani, & R. Tavakkoli-Moghaddam, "A Social Engineering Optimizer Algorithm for a Closed-Loop Supply Chain System with Uncertain Demand," International Journal of Transportation Engineering, vol. 9(1), pp. 521-536, July 2021
[15] Cheraghalipour, M. M. Paydar, & M. Hajiaghaei-Keshteli, "A bi-objective optimization for citrus closed-loop supply chain using Pareto-based algorithms," Applied Soft Computing, vol. 69, pp. 33-59, August 2018