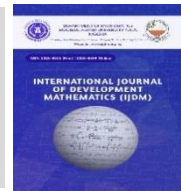




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A Systematic Review of Optimal Resource Allocation Techniques in Agriculture

Nasiru Abdullahi^a, Ishaku Bulus^a, Hassan Bukar^{b*} and Habiba B. Awwalu^c

^aDepartment of Mathematical Sciences, Nigerian Defence Academy, Kaduna, Nigeria

^bDepartment of Mathematics, Nigerian Army University Bui, Borno State, Nigeria

^cDepartment of Mathematics and Statistics, Hussaini Adamu Federal Polytechnic Kazaure, Jigawa State

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ABSTRACT

Linear Programming has a widely multifaceted application to practical, real life, as well theoretical Problems. As the name suggest Programming here mean planning how to optimize and objective function subject to constraints which are all linear in terms of a non-negative decision variables. Articles from 2020-2025 in the area of agriculture and optimal Land and Water allocation were reviewed. Research achieves were access base on the keywords: Agriculture, Land, Allocation and Linear Programming Problems were filtered. Model formulation of solution, Practical implementation of the most finding were analyzed. Finding shows that agricultural Practices were Linear Programming (formulation and solution) was applied to optimal of water and land resources turn out to provide optimal turnover of yields and curtail losses.

1. Introduction

Linear Programming (LP) is a mathematical method used to find optimal solutions for linear objective functions under specific constraints. Initially applied in military and industrial contexts, LP is now utilized across fields such as finance, marketing, manufacturing, and agriculture. In finance, LP supports capital budgeting and asset allocation. In marketing, it aids in market research and media selection. In agriculture, LP has transformed decision-making for farmers by providing efficient solutions for resource allocation, crop planning, and optimizing productivity. Studies, such as those by Fasakhodi et al. (2023) and Morgan and Chansa (2024), highlight the superior results of LP over traditional methods in agricultural resource management, yielding higher profits and better solutions. Li et al. (2025) discuss the foundational role of linear programming in understanding integer programming, noting that while LP is well-established, integer programming presents more challenges. The algorithms of LP often serve as tools within integer programming to establish upper bounds. Nimma et al. (2025) emphasize the integration of LP tools in managerial decision-making, which enhances strategic outcomes but also points out gaps in how these tools address managerial queries, particularly regarding sensitivity analysis. Prachi *et al.* (2024) addressed the challenge of optimizing agricultural resource allocation such as land, fertilizers, water, and crops through strategic farm planning. Using a linear programming model, the authors analyzed crop combinations for farmers in Gurugram, Haryana, focusing on both Rabi (winter) and Kharif (monsoon) seasons. The linear programming (LP) model was developed using the averages of the sampled data to maximize the net return at the end of the Kharif and Rabi seasons. The decision variables of the LP model were as under:

* Corresponding author. Tel.: +2347031521372

E-mail address: bukar.hassan@naub.edu.ng (Bukar Hassan)

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x_1 = acres allocated for Rice /wheat crop

x_2 = acres allocated for Jowar/mustard crop

x_3 = acres allocated for Barseem fodder crop

The linear programming model is

$$\text{Max } Z = c_1x_1 + c_2x_2 + c_3x_3$$

$$\text{subject to } x_1 + x_2 + x_3 \leq L \quad (\text{land constraint})$$

$$d_{11}x_1 + d_{12}x_2 + d_{13}x_3 \leq D \quad (\text{labour constraint})$$

$$d_{21}x_1 + d_{22}x_2 + d_{23}x_3 \leq R \quad (\text{Operating Capital constraint})$$

$$\& x_1, x_2, x_3 \geq 0$$

where, $d_{11}, d_{12}, d_{13}, d_{21}, d_{22}, d_{23}$ are constants.

The Rabi model incorporated wheat, mustard, and barley (joo), while the Kharif model included millet (bajra), radish, and rice. MATLAB was employed to solve the optimization problem, yielding land allocation strategies that enhanced decision-making quality. Results demonstrated a 24% increase in profitability for Rabi crops and a 6.7% improvement for Kharif crops under optimal conditions. Comparative visualizations illustrated the gap between current practices and the proposed solutions. To ensure model stability, variables like climate conditions and market price volatility were held constant. This approach underscores the potential of mathematical modeling to boost agricultural productivity within regional constraints. Morgan and Thelma (2024) studied the application of linear programming to maximize profits in commercial farms in Kalulushi District, Zambia. They aimed to assess how LP models aid farm management, evaluate the GSL model's effectiveness in dairy management, and propose strategies for promoting LP adoption. Their findings indicated that many farmers were unaware of LP's profit maximization potential and recommended government intervention for education on effective land use. Sree et al. (2025) highlighted the transformative impact of precision agriculture on productivity and resource optimization. They introduced a framework combining machine learning for crop yield prediction and resource management, demonstrating improvements in yield accuracy and resource efficiency for sustainable agriculture. Agrawal et al. (2025) developed an optimized irrigation plan to address water supply variations during paddy cultivation in India's semi-arid regions. Their plan significantly reduced water depth requirements and saved considerable water volume, emphasizing efficient irrigation practices. Qi et al. (2025) explored optimizing agricultural water and land resources through a refined water-carbon-economy model at Youyi Farm in China. Their research showed that optimized resource allocation improved crop management and increased carbon sequestration and grain yields, demonstrating the model's effectiveness in enhancing economic returns and food production.

Optimal resource allocation in agriculture is critical for balancing productivity, economic viability, and environmental sustainability. While linear programming (LP) is widely used to address practical real application, agriculture Inclusive, challenges, gaps remain in analyzing diverse LP models and solution approaches specific to land and water resource allocation. Now the problem is, are there sufficient literature on Linear Programming Application of land and water Resources in agriculture from 2020-2025, that were carried out in other to have a sustainable, enhance and scientific agricultural Practices.

2. Methodology

This overview explores the application of linear programming for the optimal allocation of land and water resources in agriculture. The methodology involved selecting relevant databases and refining keywords, establishing

criteria for including and excluding literature, categorizing articles, analyzing problem features, and identifying future research opportunities. The stages of our research methodology are as follows: The literature review began by defining the research scope and developing an initial set of keywords and terms. This initial phase is depicted as the first (and largest) outer layer, with the size of the layer ref The initial set of keywords and terms, along with their combinations, was utilized to search for relevant literature on Google. While the results from Google may not be strictly scientific, they offer valuable insights into commonly used field-specific terminology. This helps refine the initial list of terms and facilitates more effective searches in scientific databases, which can be particularly beneficial for researchers who are new to the field. The refined set of keywords and their combinations was then utilized to search within several major online scientific databases and search engines relevant to linear programming and resource allocation, including Google Scholar, IEEE Xplore, Scopus, ProQuest, ACM Digital Library, and ScienceDirect. Table 1 presents the search terms used in our research on linear programming is closely related to the optimal allocation of land and water resources in agriculture. We identified that many decision-making problems can be formulated as assignment or personnel assignment problems (PAP). To keep our focus narrow, we defined relevant assignment problems and distinguished them from resource allocation, which involves scheduling, unlike PAP that focuses on optimal matching.



Table 1: Refined search terms used to search the resources

S/No	Search term
1	<p>Linear programming problem</p> <p>This query targets studies that specifically mention "linear programming problem." It is a broad term that can capture a wide range of research related to linear programming.</p>
2	<p>Resource allocation (land and water)</p> <p>This query focuses on studies that discuss "resource allocation" specifically in the context of "land and water." It narrows down the research to those that deal with agricultural resources.</p>
3	<p>Optimization of land and water allocation</p> <p>This query looks for studies that specifically mention the optimization of land and water allocation. It is more specific than the previous query, targeting research that explicitly aims to optimize these resources.</p>
4	<p>Combinatorial optimization</p> <p>This query targets studies that mention "combinatorial optimization." This term is often used in the context of optimization problems that involve discrete variables, which can be relevant to resource allocation problems.</p>
5	<p>Discrete optimization</p> <p>This query looks for studies that mention "discrete optimization." Similar to combinatorial optimization, this term is relevant to problems where the variables are discrete, which can be applicable to land and water resource allocation.</p>
6	<p>(1 or 2) and {system, framework, tool}</p> <p>This query looks for studies that mention either "linear programming" or "optimal allocation" in conjunction with terms like "system," "framework," or "tool." It aims to find research that discusses specific systems, frameworks, or tools related to linear programming or optimal allocation.</p>
7	<p>(1 or 2) and {model, technique, approach, algorithm}</p> <p>This query searches for studies that include either "linear programming" or "optimal allocation" along with terms like "model," "technique," "approach," or "algorithm." It targets research that discusses specific models, techniques, approaches, or algorithms used in linear programming or optimal allocation.</p>
8	<p>(1 or 2) and {review, analysis, survey}</p> <p>This query seeks studies that mention either "linear programming" or "optimal allocation" along with terms like "review," "analysis," or "survey." It aims to find literature reviews, analyses, or surveys related to linear programming or optimal allocation.</p>
9	<p>(1 or 2) and (3 or 4 or 5)</p> <p>This query combines the terms "linear programming" or "optimal allocation" with any of the terms from queries 3, 4, or 5. It broadens the search to include studies that discuss linear programming or optimal</p>

	allocation in the context of systems, frameworks, tools, models, techniques, approaches, algorithms, reviews, analyses, or surveys.
10	(3 or 4 or 5) and (6 or 7 or 8) This query combines terms from queries 3, 4, or 5 with terms from queries 6, 7, or 8. It looks for studies that discuss systems, frameworks, tools, models, techniques, approaches, algorithms, reviews, analyses, or surveys in the context of linear programming or optimal allocation.

After gathering the initial results, we executed two rounds of filtering using both inclusion and exclusion criteria (Table 2). The first round applied the initial inclusion criteria to narrow down the results, while the second round further refined the selection. Any resources that did not meet the inclusion criteria or met the exclusion criteria were eliminated.

Table 2: The inclusion (relevance) and exclusion (irrelevance) criteria

Inclusion criteria	
1	The title contains relevant terms or suggests relevance.
2	The resource's abstract or keywords suggest relevance.
3	The resource is peer-reviewed.
4	The resource (not just its title and abstract) is in English.
5	The resource provides an analysis, describes a problem, or validates existing solutions to resource allocation (land and water) problems.
Exclusion criteria	
6	The resource does not meet any of the inclusion criteria.
7	The resource focuses on general social or psychological aspects of the problems.
8	The resource has a more complete version published elsewhere (Replacing duplicates with the more detailed versions).

We sorted the studies based on two factors to streamline our initial review process: whether the study is a survey, literature review, or thesis, and the number of citations it has received. This approach helped us identify seminal works and provided a solid foundation for grasping the overall research landscape. We prioritized literature reviews and surveys to gain deeper insights.

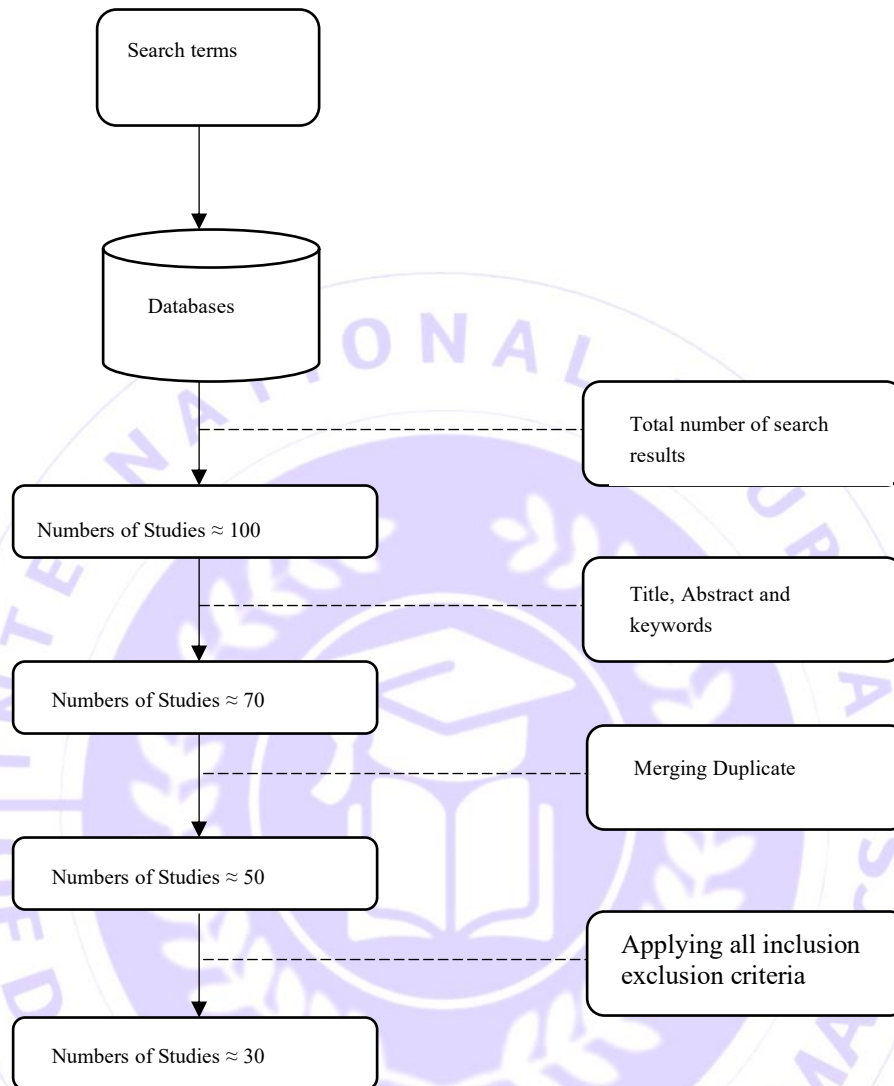


Figure 1: The quantity of resources at various phases of the selection process.

3. Results and Discussion

Qualitative data highlights the significance of Linear Programming (LP) in operations research, initially applied by Waugh (1995) to optimize livestock feed rations. LP aims to maximize or minimize goals like costs and revenues, with the simplex algorithm being a widely used and efficient method. Research by Alotaibi and Nadeem (2021) demonstrates that LP enhances farm productivity and profitability. Mixed-Integer Linear Programming (MILP) effectively optimizes feed mixes, crop rotations, and irrigation scheduling, while Integer Linear Programming (ILP) aids in determining optimal land allocation for crops (Wankhade and Lunge, 2012). LP faces challenges with multi-goal problems, prompting the use of Goal Programming (GP) and related methods to achieve multiple objectives. Combining LP with Weighted Goal Programming (WGP) allows for simultaneous optimization of objectives, as evidenced by Prišenk *et al.* (2014) and Al-Nassr (2019). Additionally, Fuzzy Goal Programming (FGP) addresses uncertainty in farm decision-making. Overall, LP is crucial for solving region-specific agricultural problems, as summarized in Tables 3, 4, and 5, which present research findings, applications, and objectives related to resource allocation in agriculture.

Table 3: Studies on Resource Allocation

ID	Year	Author(s)	Description
P1	2023	Miao et al.	Utilized a portfolio model analysis, leveraging mixed cross-sectional data gathered from rural households spanning a three-year period.
P2	2023	Das et al.	Constructed a linear programming (LP) framework to investigate the most efficient distribution of land and water resources within the Hirakud Canal Command region
P3	2022	Bulukazari et al.	Applied a non-linear programming optimization model together with the AquaCrop model to evaluate the best allocation of water and land resources.
P4	2023	Fasakhodi et al.	Utilized a Multi-Objective Fractional Goal Programming (MOFGP) approach with various linear and fractional programming models to optimize sustainability indicators.
P5	2023	Rabie et al.	Employed an optimal water management model at the farm level, assessing deficit irrigation strategies using a genetic algorithm toolbox in MATLAB to maximize benefits.
P6	2020	Zhai et al.	Conducted a study on decision support systems for agriculture 4.0, analyzing thirteen representative systems for their applications, interoperability, and usability to address challenges in resource allocation and climate change adaptation.
P7	2020	Kakelli and Aju	Proposed an IoT-based Agribot for precision agriculture to improve water management and optimize resource usage in developing nations, showing promising performance across various conditions.
P8	2021	Malhi et al.	Examined how climate change affects food security and agricultural productivity, looking at the reasons behind these changes and their impact on plant growth, pest behavior, and economic aspects.
P9	2021	Kamaludin et al.	Evaluated the allocation of agricultural land for food crops in Indonesia amid the coronavirus pandemic, advocating for advanced technologies and enhanced planning to achieve optimal land use.
P10	2022	Moulogianni	Compared three mathematical programming models (LP, PMP, WGP) for sustainable land management in Central Macedonia, assessing their performance based on economic, social, and environmental indicators.

Table 4: Summary of 10 Studies Utilizing Linear Programming (LP) in Various Applications

Study	Application areas	Problem targeted	Model	Contribution	Outcome
Bhatia, and Rana (2020),	Land allocation and optimization	No optimal land distribution to improve cropping	Simplex method of LP	Developed an optimal land allocation strategy to enhance farm productivity across various crops.	Boost the profits by expanding the total allocated area.
Prachi <i>et al.</i> (2024)	Land, water allocation and optimization	addressed the challenge of optimizing agricultural resource allocation such as land, fertilizers, water, and crops	Linear Programming	Determining the appropriate land area for planting different kinds of crops, and which crop more profitable for each season	This approach underscores the potential of mathematical modeling to boost agricultural productivity within regional constraint
Qi <i>et al.</i> (2025)	Agricultural water and land resource management	Optimizing water and land resource allocation considering crop water demand during different growth stages	Improved Water-Carbon-Economy Coupling Model (IWCECM)	Enhanced understanding of crop growth processes and resource allocation under various scenarios	Significant improvements in carbon sequestration, grain yield, and water resource management
Chamas, <i>et al.</i> (2021)	Sustainable resource optimization in agriculture	Balancing water, energy, food, and carbon resources	Water-Energy-Food-Carbon Nexus Optimization Model	Integrated framework for sustainable development goals	Sustainable resource allocation and management strategies
Kazem <i>et al.</i> (2025)	Agricultural land management, cropping pattern design	Optimizing resource allocation for sustainable cropping patterns	Robust multi-objective MILP model	Integration of GIS, System Dynamics, and optimization techniques for grid-scale land suitability assessment and dynamic water resource modeling	Suggested cropping pattern reduces irrigation by 25% while maintaining food security

Bulukazari <i>et al.</i> (2022)	Optimization of water and land allocation	Improper extraction of water from resources especially in arid and semi-arid regions leads to a decrease in the quality of water and soil resources.	A non-linear programming optimization model (NLPOM)	To enhance water productivity in the agricultural sector, we employed production functions to determine the optimal cultivation area and water consumption for various crops. Our objective was to maximize net income and water use efficiency.	The study revealed that the model successfully simulated crop yield under salinity and water deficit conditions. It also demonstrated its effectiveness in optimizing irrigation water quantity and cultivation area on a regional scale, considering salinity conditions.
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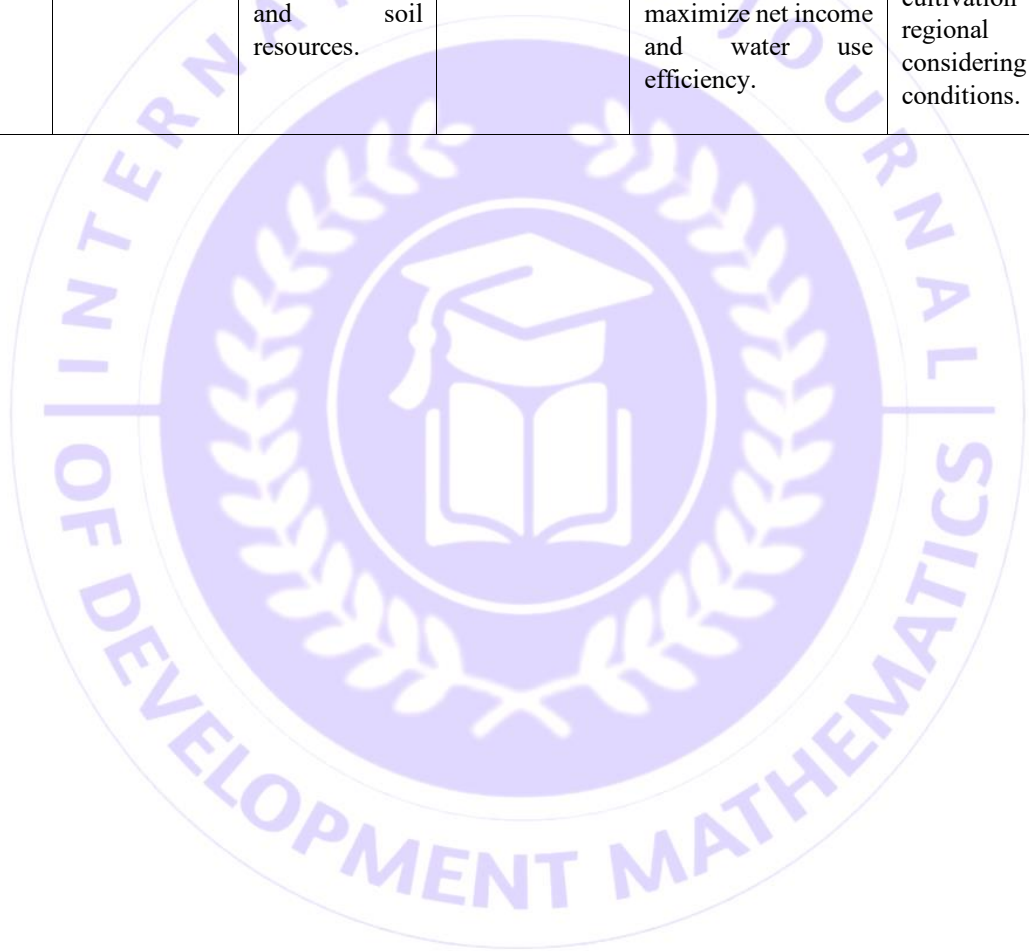


Table 5: Objectives in the LP Models of 6 Studies [\uparrow Maximization, \downarrow Minimization]

Categories	Objectives	Software Used	Authors
Optimum utilization of land of food crops	\uparrow : Agriculture production, Net Profit, Net Present Value (NPV)	LINGO software	Bhatia and Rana (2020)
Economic distribution of crop water per month.	\uparrow : Net profit, Water productivity. \downarrow : Minimize the demand at the head of the channel.	LINDO software	Miao <i>et al.</i> (2023) Mialyk <i>et al.</i> (2024)
Sustainable cropping pattern design	\uparrow : Food security, Resource efficiency, Environmental sustainability	GIS, System Dynamics, Robust multi-objective MILP model	Kazem <i>et al.</i> (2025)
Optimum land utilization of food crops	\uparrow : Agriculture production, Net Profit, Net Present Value (NPV)	Various computational methods	Divya Nimma, Jyoti A. Dhanke, G. S. N. Murthy, Sachin Dadu Khandekar, J. Hymavathi, Pradeep Jangir, Mahesh Singh (2025)
Economic distribution of crop water per month	\uparrow : Net profit, Water productivity	Optimization models	Mo Li, Xu Zhang, Yingshan Chen, Yaowen Xu, Rentao Li, Li Zhao, Qiang Fu (2025)

4. Conclusion

Optimizing land and water resource allocation is a key challenge for farmers and agribusinesses, necessitating continuous efficiency improvements. This research utilized a systematic literature review to explore the role of Linear Programming (LP) in resource allocation. To enhance LP applications in agriculture, it is recommended that advanced LP techniques be adopted, LP tools be integrated with modern agricultural technologies, and training programs be invested in for effective resource management. Collaboration with research institutions and support from policymakers through incentives are crucial for success. Additionally, ongoing research is essential to evaluate the impact of LP applications and develop innovative solutions, ultimately improving efficiency and sustainability in resource management.

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