RICE PRODUCTION GOAL PRIORITIZATION IN NORTH-EAST NIGERIA: THE ANALYTIC HIERARCHY PROCESS (AHP) APPROACH

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ABSTRACT
This study applies the Analytic Hierarchy Process (AHP) to prioritize key goals for rice production in north-east Nigeria, aiming to provide insights into resource allocation for enhanced productivity. The results indicate that the Labour and Seed goal is the highest priority, with a score of 0.4460, reflecting its critical role in optimizing production. The Yield goal follows with a score of 0.3150, signifying its substantial impact on overall output. Conversely, the Budget goal (0.1176) and the Chemical goal (0.0673) are ranked as less critical. A consistency ratio of 0.03973 confirms a reliable level of consistency in the pairwise comparisons, adding robustness to the prioritization results. These findings suggest that stakeholders should focus primarily on improving labour and seed inputs to maximize efficiency in rice production. Emphasis on these resources aligns with previous research underscoring the influence of labour and seed quality on crop productivity. In contrast, budget and chemical inputs are deemed secondary priorities. By concentrating efforts on labour and seed optimization, sustainable and profitable rice farming practices can be promoted, ultimately benefiting regional agricultural outcomes.

Keywords: Rice production; Analytic Hierarchy Process (AHP); Resource allocation; Agricultural productivity.
JEL Classification: D61, D70, Q10

1. INTRODUCTION

Rice production is a vital component of agricultural systems and food security in Nigeria, particularly in the north-eastern region, where it serves as a staple food and a source of livelihood for many households. Despite the significant potential for rice cultivation in this area, farmers face numerous challenges that hinder optimal production. These challenges include inadequate infrastructure, limited access to agricultural inputs, and fluctuating market prices. Consequently, there is an urgent need for a systematic approach to prioritize production goals and allocate resources effectively to enhance rice yield and sustainability in this region (Hassan et al., 2021; Abubakar et al., 2022; Eze et al., 2023; Ibrahim & Musa, 2024).

The Analytic Hierarchy Process (AHP) is a robust decision-making tool that facilitates structured prioritization of goals based on multiple criteria. This method is particularly relevant for addressing the complexities associated with rice production in north-east Nigeria, where various stakeholders must navigate competing interests and limited resources. AHP allows decision-makers to evaluate different goals quantitatively and qualitatively, ensuring that resource allocation aligns with the most critical objectives. Previous studies have highlighted the effectiveness of AHP in agricultural planning and resource allocation, providing a strong justification for its application in this context (Saaty, 2008; Nascimento et al., 2019; Mahdavi et al., 2020).

In the face of increasing population pressures and climate change, the need for a strategic framework to enhance rice production becomes even more pressing. Efficient goal prioritization through AHP can assist policy-makers and stakeholders in identifying the most pressing challenges and opportunities within the rice production sector. By systematically analyzing factors such as land use, water availability, input costs, and market dynamics, AHP can provide valuable insights that drive more informed decision-making processes. This is particularly important in north-east Nigeria, where resource constraints and environmental conditions significantly impact agricultural productivity (Ibekwe et al., 2021; Chukwu et al., 2022; Adetunji et al., 2023).

This study aims to utilize AHP to prioritize production goals in rice cultivation within north-east Nigeria, facilitating effective resource allocation. By engaging stakeholders in the decision-making process and aligning production goals with available resources, this research seeks to contribute to the sustainability and resilience of rice farming in the region. The outcomes of this study are expected to provide a framework for future research and policy initiatives aimed at enhancing agricultural productivity in north-east Nigeria, ultimately contributing to food security and economic stability (Baiyegunhi et al., 2021; Usman et al., 2022; Odo et al., 2023).

This paper begins with an Introduction outlining the research problem, objectives, and relevance of prioritizing rice production goals using AHP. The Methodology details the AHP process and consistency checks. Results present goal rankings and scores, followed by a Discussion interpreting findings. Finally, Conclusion and Recommendations provide actionable insights for stakeholders.

2. LITERATURE REVIEW

2.1 Conceptual Review

The prioritization of goals in rice production is increasingly crucial, especially given the necessity to optimize resource allocation and production strategies. The Analytic Hierarchy Process (AHP) has emerged as a popular decision-making tool to structure and rank multiple objectives in rice production by assigning relative weights to factors such as environmental impact, cost, and yield optimization. Recent studies utilizing AHP focus on assessing sustainability within rice production by weighing ecological impacts alongside traditional goals of maximizing yield and profit. These studies underscore that AHP helps decision-makers effectively integrate complex variables—such as resource scarcity, climate adaptability, and input requirements—into a comprehensive goal hierarchy, enabling precise prioritization of production strategies. For example, studies have highlighted how farmers in different regions utilize AHP to balance crop resilience with high-yield goals under varying environmental conditions (Ahmed et al., 2020; Wang et al., 2021; Zhang et al., 2022; Singh et al., 2023; Chen et al., 2024).

Furthermore, the adoption of AHP for rice production prioritization aligns with broader agricultural advancements aimed at sustainability and efficiency. Various researchers have integrated AHP with additional methods, such as Fuzzy AHP (FAHP), to accommodate uncertainty and subjectivity in farmers' decision-making processes, particularly in scenarios involving resource limitations and fluctuating market demands. These hybrid approaches allow farmers to weigh complex and sometimes conflicting goals, such as balancing fertilizer use with environmental health, to achieve a sustainable production model. Studies demonstrate that FAHP has been instrumental in regions with limited data, aiding farmers to make better-informed decisions through adaptable, weight-based evaluations. The integration of AHP and FAHP in rice production supports a nuanced approach to priority-setting that accounts for sustainability alongside productivity (Guan et al., 2020; Mir & Padma, 2021; Kumar et al., 2022; Lee et al., 2023; Rahman et al., 2024).

2.2 Empirical Literature

The Analytic Hierarchy Process (AHP) is a decision-making methodology used to evaluate and prioritize alternatives based on multiple criteria. It synthesizes subjective expert judgments into a structured framework through pairwise comparisons, providing both qualitative and quantitative insights. AHP is widely applied across fields such as business, environmental management, and agriculture.

Recent studies highlight AHP's versatility in various decision-making scenarios. Saaty (1980) established AHP's foundational role in multi-criteria decision-making. In environmental management, Lee et al. (2021) demonstrated its utility in assessing sustainability practices in agriculture. Wang et al. (2019) integrated AHP with fuzzy logic to address uncertainty in supply chain risk assessments, showing how hybrid methods enhance AHP's effectiveness. Additionally, Zhang et al. (2020) explored combining AHP with machine learning, particularly neural networks, for optimizing agricultural land-use planning, improving decision accuracy with historical data patterns. Furthermore, Cheng and Li (2022) applied AHP to evaluate technological solutions for smart agriculture, demonstrating its value in selecting viable technologies considering multiple factors.

In conclusion, AHP remains a valuable tool in decision-making processes, especially when expert judgement and complex criteria are involved. Its ability to integrate various methodologies, like fuzzy logic and machine learning, continues to expand its applicability in diverse domains.

2.3 The Role of Rice Production in Solving Food Security in Nigeria

Food security is the condition in which all people, at all times, have physical, social, and economic access to sufficient, safe, and nutritious food to meet their dietary needs and food preferences for an active and healthy life (Yusuf *et al,,* 2022) .

Food insecurity in Nigeria is driven by factors such as population growth, climate change, and conflict, which have disrupted agricultural productivity and food distribution systems, leaving significant part of the population without sufficient access to nutritious food. Additionally, the nation's heavy reliance on food imports exacerbates vulnerability to global market shocks, further deepening the crisis (Ahmed *et al,.* 2024).

Rice is a staple food for a significant portion of Nigeria's population, and its production plays a critical role in addressing food security challenges. As a major source of calories and income, increasing rice production has the potential to enhance both food availability and economic stability in the country. The growing demand for rice, fueled by population growth and changing dietary preferences, underscores its importance in the national food security strategy (Oladejo & Sanusi, 2022).

Nigeria's government has implemented policies like the Rice Transformation Agenda, aimed at boosting domestic rice production to reduce import dependency and improve self-sufficiency. Local production contributes to food security by ensuring a steady supply of affordable rice, reducing the vulnerability to global price shocks (Adesina et al., 2020). Furthermore, expanding rice farming can empower smallholder farmers, increasing their incomes and enhancing access to food resources (Ezedinma, 2021).

However, challenges such as inadequate irrigation systems, low-yielding varieties, pest invasion, flooding, climate change, poor rains, input price increase and fall in output price and post-harvest losses persist. Addressing these issues through investments in agricultural technology and infrastructure can significantly improve rice yields (Onwuka et al., 2023; PA, 2015; GD, 2015). Climate-smart practices, including resilient seed varieties and improved water management, are crucial for sustaining production under changing climatic conditions (Okoye et al., 2021; Ogheneruemu & Opeyemi , 2023; Jonathan *et al.,* 2024).By prioritizing rice production and addressing systemic challenges, Nigeria can strengthen its food security and reduce poverty among its farming communities (Oluwole *et al,* 2021).

3. METHODOLOGY

This study uses the Analytic Hierarchy Process (AHP) with Saaty's rating scale to prioritize rice production goals, utilizing data gathered from rice farming experts in Adamawa State. This section outlines the step-by-step methodology for determining weights and prioritizing production variables. AHP's systematic approach ensures a reliable decision-making framework (Vaidya & Kumar, 2003).

3.1 AHP Methodology of Weight Determination

The Analytic Hierarchy Process (AHP) is a structured decision-making methodology that prioritizes alternatives by breaking complex problems into hierarchical levels, comparing criteria pairwise, and deriving weights for each factor. In this research, AHP effectively ranks goals like labour, seeds, and budget for rice production, ensuring consistency through the consistency ratio. Its flexibility in integrating qualitative and quantitative inputs makes it invaluable for resource allocation in agriculture (Taherdoost, 2017; Vaidya & Kumar, 2003; Ishizaka & Labib, 2011).

3.2 Pairwise comparison

A pairwise comparison table is a fundamental component of the Analytic Hierarchy Process (AHP) methodology, used to assess the relative importance of criteria or alternatives. Each pair of criteria is compared using a scale (usually from 1 to 9) that reflects how much one criterion is preferred over another. The table generates a matrix, where each cell represents the comparison result, and consistency checks (via consistency ratio) ensure the reliability of judgement. This method allows decision-makers to structure complex decisions, as seen in applications ranging from resource allocation to project prioritization (Saaty, 1980; Vaidya & Kumar, 2003; Ishizaka & Labib, 2011). Table 1 present saaty rating scale which was used as a basis for comparing rice production variable goals.

Table 1 Pairwise comparison Table

Comparison	Scale	Explanation
Equal Importance	1	activities contribute equally to the objective
Weak or slight	2	
Moderate importance	3	Experience and judgement slightly favour one activity over another
Moderate plus	4	
Strong importance	5	Strong importance Experience and judgement strongly favour one activity over another
Strong plus	6	
Very strong or demonstrated importance	7	An activity is favoured very strongly over another; its dominance demonstrated in practice
Very, very strong	8	
Extreme importance	9	The evidence favouring one activity over another is of the highest possible order of affirmation
Reciprocals of above		If activity i has one of the above non-zero numbers assigned to it when compared with activity j, then j has the reciprocal value when compared with i

Source: Saaty (2008)

The Pairwise comparison Table of rice production variable goals (Yield, budget, chemical, land and seed (las)) which was obtained from rice farming experts using Table 1 is as shown in Table 2

Table 2: Pairwise Comparison Rice Production Variable Goals

Factor	More important criterion	Comparison	Rating
Yield Vs Las	las	moderately important	3
budget Vs Yield	Yield	moderately important	3
Yield Vs Chemical	Yield	strongly more important	5
budget vs Las	Las	strongly more important	5
budget Vs Chemical	Budget	Equally to moderately more important	2
Chemical s Las	Las	Moderately important	3

Source: Authors' initiative

3.3 A pairwise comparison matrix of production goals

A pairwise comparison matrix in AHP organizes comparisons between criteria or alternatives to quantify their relative importance. Using Saaty's scale (1–9), it generates weights through eigenvalue calculations, ensuring consistent and structured decision-making (Saaty, 1980; Vaidya & Kumar, 2003).

A pairwise comparison matrix (PCM) was develop from step 1 as follows:

Let $g_{ij}, i, j = 1,2,3,4$ represents rice production goals

a_{ij} i,j =1,…..4 represent the pairwise comparison rating of two goals

$$PCM = \begin{matrix} & g_1 & g_2 & g_3 & g_4 \\ g_1 \\ g_2 \\ g_3 \\ 4 \end{matrix} \begin{pmatrix} a_{11} & a_{12} & a_{13} & a_{14} \\ a_{21} & a_{22} & a_{23} & a_{24} \\ a_{31} & a_{32} & a_{33} & a_{34} \\ a_{41} & a_{42} & a_{43} & a_{44} \end{pmatrix} \qquad 1$$

Matrix P_1 present pairwise comparison matrix of the rice production goals

$$P_1 = \begin{matrix} A \\ B \\ C \\ D \end{matrix} \overset{\begin{matrix} A & B & C & D \end{matrix}}{\begin{pmatrix} 1 & 3 & 5 & 1/3 \\ 1/3 & 1 & 2 & 1/5 \\ 1/5 & 1/2 & 1 & 1/3 \\ 3 & 5 & 3 & 1 \end{pmatrix}} \qquad 2$$

Where A, B, C and D are yield, budget, chemical and las goal respectively

Step III: Normalize matrix

The normalize matrix P_2 was obtained by dividing each element of the matrix by its column total

Normalize Matrix

$$P_2 = \begin{matrix} A \\ B \\ C \\ D \end{matrix} \overset{\begin{matrix} A & B & C & D \end{matrix}}{\begin{pmatrix} 0.2041 & 0.4167 & 0.6000 & 0.0391 \\ 0.0680 & 0.1389 & 02400 & 0.0234 \\ 0.0408 & 0.0694 & 0.1200 & 0.0391 \\ 0.6122 & 0.6944 & 0.3600 & 0.1172 \end{pmatrix}} \qquad 3$$

3.4 Weights determination

The corresponding weight to each goal was obtained by taking row averages of Matrix P_2

Weights:

A =0.3150, B= 0.1176, C = 0.0673, D = 0.4460

The production goals were ranked based on the obtained weights as shown in Table 3:

Table 3: Rice Production Goals Ranking

Production Goal	Rank
Labour and seed	1
Yield	2
Budget	3
Chemicals	4

Source: Authors' initiative

Step V: Consistency ratio (CR)

The consistency ratio (CR) in the Analytic Hierarchy Process (AHP) measures the reliability of judgement in pairwise comparisons. It compares the consistency index (CI) of the decision matrix to a random consistency index (RI). A CR ≤ 0.1 indicates acceptable consistency, enhancing decision reliability (Saaty, 1980; Ishizaka & Labib, 2011).

Compute Consistency ratio (CR) as

$$\mathrm{CR} = \frac{\mathrm{CI}}{\mathrm{RI}} \qquad 4$$

Where CI = consistency index of matrix P which is given by

$$\mathrm{CI} = \frac{\mathrm{n_{max}} - \mathrm{n}}{\mathrm{n} - 1} \qquad 5$$

$$\mathrm{n_{max}} = \sum \mathrm{Pw} = 4.1180 \qquad 6$$

Hence:

$$\mathrm{CI} = \frac{4.1180 - 4}{4 - 1} = 0.03933 \qquad 7$$

Where n = number of goals considered

RI = Random Index of P given by

$$= \frac{1.98(n-2)}{n} = \frac{1.98(4-2)}{4} = 0.99 \qquad 8$$

$$\mathrm{CR} = \frac{0.03933}{0.99} = 0.03973 \qquad 9$$

4. RESULTS AND DISCUSSION

The results of the Analytic Hierarchy Process (AHP) prioritize key goals for enhancing rice production, beginning with a consistency index of 0.03933, a ratio index of 0.99, and a consistency ratio of 0.03973. This low consistency ratio, well below the threshold of 0.1, indicates a high level of reliability in the pairwise comparisons, lending credibility to the derived prioritizations (Saaty, 2008). Among the prioritized factors, Labour and Seed goals emerged as the most critical, receiving a priority score of 0.4460. This high score highlights the fundamental role of these resources in improving rice productivity, as efficient labor allocation and quality seed usage have been found to boost crop yields and resource efficiency substantially (Adetunji et al., 2023). Following this, the Yield goal scored 0.3150, underlining its direct effect on production outcomes and its role as an essential benchmark for successful agricultural performance.

In contrast, the Budget and Chemical goals, with scores of 0.1176 and 0.0673, respectively, were deemed less essential. Although financial and chemical resources remain significant, their secondary impact relative to labor and seed inputs aligns with prior research emphasizing labor and seed quality as primary factors in sustainable crop management (Eze et al., 2023). These findings suggest that, while the Budget and Chemical goals contribute to rice production, stakeholders should prioritize resource allocation to labour and seeds for more significant productivity improvements (Mahdavi et al., 2020). This emphasis on labor and seed optimization is crucial for achieving sustainable rice production in north-east Nigeria, as prioritizing these factors supports the adoption of effective practices that enhance productivity and profitability.

5. CONCLUSION

The AHP analysis identifies labour and seed inputs as the primary factors in optimizing rice production in north-east Nigeria. Prioritizing these resources, which directly impact yield, is essential for enhancing production efficiency and sustainability. While budget and chemical inputs are important, their influence is secondary. Focusing on labour and seed improvements offers a practical pathway for stakeholders to drive sustainable rice production, boosting productivity and profitability in the region.

6. RECOMMENDATIONS

Based on the research findings, the following recommendations are suggested for farmers:

1. Prioritize Labour and Seed Quality: Allocate more resources to improving labour efficiency and selecting high-quality seeds, as these factors were identified as the highest priorities for enhancing rice production efficiency.

2. Optimize Yield Goals: Focus on practices and technologies that increase rice yield, as this factor has a significant impact on overall productivity and profitability.

3. Reduce Reliance on Chemicals: Given their lower priority, minimize excessive use of chemicals, and instead invest in more sustainable and cost-effective farming practices that align with labour and seed optimization efforts.

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