

Assessing yield gaps in cotton production: Insights from cotton farmers in Adamawa State, Nigeria

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ABSTRACT: This study investigates the yield gap in cotton production in Adamawa State, northeastern Nigeria, focusing on the gap between actual farm yields and potential yields derived from research stations and demonstration plots. The research employs a multi-stage sampling procedure to select cotton farmers across the state's four agricultural zones. Primary data was gathered using structured questionnaires, while secondary data on potential yields from research stations and demonstration plots were also utilized. The study finds significant discrepancies in input use, with the over-application of nitrogen and potassium, and the under-application of phosphorus. The yield gap analysis reveals that the average farm yield is considerably lower than both demonstration plot yields and the potential yield from research stations, with a total yield gap of 56.7%. Multiple regression analysis identifies key factors influencing the yield gap, including seed rate, nitrogen, and education, with the seed rate gap showing the most substantial impact on yield. The findings suggest that addressing input inefficiencies, particularly in seed and nitrogen use, and improving farmer education could significantly enhance cotton productivity in the region.

Keywords: Demonstration plots, farm yield, input gap, potential yield, yield gap.

INTRODUCTION

Adamawa State is located in northeastern Nigeria and has an agrarian economy supported by fertile lands conducive to the cultivation of crops such as rice, cotton, maize, and millet. These crops play a critical role in the livelihoods of residents through their production, processing, and marketing (Usman *et al.*, 2022). Cotton production, introduced in Nigeria in 1910 under the British Cotton Growers Association (BCGA), remains an important agricultural enterprise cultivated as a rain-fed crop across 24 states. Smallholder farmers dominate the sector, relying on labour-intensive and resource-constrained methods, which often result in inefficiencies and low productivity (Abubakar and Buba 2022).

Historically, cotton was a cornerstone of Nigeria's economy, serving as a major source of foreign exchange and the second-largest employer of labour after the

government sector (Yahaya, 2012). At its peak in 2003/2004, cotton production reached 536,400 metric tons (Babangida, 2016). However, the sector has experienced a steep decline due to factors such as pest infestations, price volatility, high production costs, limited access to credit, and outdated farming techniques. The productivity of Nigerian cotton farmers currently averages 330 kg/ha, which is significantly lower than the global average of 731 kg/ha in the USA and 816 kg/ha in Egypt (Babangida, 2016).

Although efforts such as the ₦100 billion Cotton, Textile, and Garment (CTG) revitalization fund have been introduced to address these challenges, their impact has been limited due to persistent issues such as textile smuggling and inadequate support for smallholder farmers (Amolegbe *et al.*, 2015). Furthermore, a significant yield

gap persists between the potential and actual yields of cotton, largely attributed to inefficient resource allocation and delays in field operations.

Despite numerous studies highlighting the challenges faced by cotton farmers in Nigeria, limited research has focused on strategies to bridge the yield gap through efficient resource allocation at the smallholder level. Existing literature often addresses macroeconomic factors or national-level interventions but provides little insight into localized, farmer-specific solutions for enhancing productivity and profitability in cotton farming. This study seeks to fill this gap by investigating the factors contributing to the yield gap in cotton production in Adamawa State, with a focus on smallholder farmers. The study specifically seeks to estimate the input and yield gap of cotton production, identify the factors responsible for the yield gap and identify and describe the constraints faced by cotton farmers in the study area.

METHODOLOGY

The study area

Adamawa State, located in northeastern Nigeria, spans an area of 38,741 km² and has a population of approximately 3.86 million people (NPC, 2006). It is bordered by Taraba, Gombe, and Borno States, and shares an international boundary with Cameroon. The state has four Agricultural Development Project zones and experiences a mean monthly sunshine of 220 hours from January to April, increasing to 225 hours between October and December (Adebayo, 1999). Rainfall is less than 1,000 mm in the central and northern parts, while the northeastern and southern regions receive over 1,000 mm annually. The main crops cultivated are cereals like sorghum, maize, rice, and millet, alongside cash crops such as cotton, groundnut, and sugarcane.

Nature and sources of data

Primary and secondary data were used for this study. Primary data on farmers' production information and constraints were collected with the aid of a structured questionnaire. Secondary data on the potential yield of the research station and demonstration plots were obtained from Adamawa State Agricultural Development Project (AADP). The study pertained to the agricultural year 2024

Sampling technique and sample size

A multi-stage sampling procedure was employed in selecting cotton farmers from the four agricultural zones of Adamawa State:

Zone 1: Madagali, Michika, Mubi North, Mubi South and Maiha Local Government Areas (LGAs).

Zone 2: Hong, Gombi, Song and Girei LGAs.

Zone 3: Fufore, Ganye, Jada, Mayo-Belwa, Toungo, Yola North and Yola South LGAs.

Zone 4: Demsa, Guyuk, Lamurde, Numan, and Shelleng LGAs.

The first stage involved the purposive selection of Agricultural Zone IV from Adamawa State due to the prominence of cotton production in this zone. The second stage involved the purposive selection of all LGAs from Zone IV (Demsa, Guyuk, Lamurde, Shelleng, and Numan) due to the high concentration of cotton producers in these areas. In the third stage, three villages were randomly selected from each LGA, resulting in fifteen villages. The number of cotton producers was obtained from the chairpersons of associations. The final stage involved the random selection of one hundred and twenty respondents from the selected villages. During the selection process, the cotton farmers were selected randomly and proportionately to the population of cotton producers in each village.

Analytical tools

The analytical tools employed included descriptive statistics (frequencies, percentages, yield gap index, and Garrett ranking technique) and inferential statistics (multiple regression).

The **input gap** was computed using the following formulae below:

Input Gap = Recommended Input dose – Actual Input dose used by farmers

$$\text{Per cent Gap} = \frac{\text{Recommended} - \text{Actual}}{\text{Recommended}} \times 100$$

The **yield gap** in cotton production was estimated using the methodology developed by the International Rice Research Institute (IRRI).

$$\text{TYG} = \text{YG I} + \text{YG II}$$

Where: TYG = Total yield gap, YG I = Yield gap I, YG II = Yield gap II

$$\text{YG I} = Y_p - Y_d$$

Where: Y_p = Potential Yield (Per hectare crop yield realized on the research station), Y_d = Potential farm yield of the demonstration plot.

$$\text{YG II} = Y_d - Y_a$$

Where: Y_d = Potential yield at the research station, and Y_a = Actual farm yield realized by the farmers (per hectare yield realized by farmers on their field).

The **index of yield gap (IYG)** is the ratio of the difference between the potential yield (Y_p) and the actual yield (Y_a) to the potential yield (Y_p) expressed in percentage.

$$IYG = (Y_p - Y_a/Y_p) \times 100$$

Where: Y_p = Potential yield, and Y_a = Actual yield

A **multiple regression model** was used to determine the factors responsible for the yield gap in the study area. The model is specified as follows;

$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \beta_5 D_5 + U$$

Where: Y = Yield gap II in kg/ha, X_1 = Seed rate gap in kg/ha, X_2 = Nitrogen gap in kg/ha, X_3 = Phosphorus gap in kg/ha, X_4 = Potassium gap in kg/ha, D_5 = Dummy for Educational Status (1 if farmer is educated and 0 otherwise), and U = Error term.

Garrett ranking technique was used to rank the problems faced by cotton producers. The farmers were asked to rank the given problems according to their magnitude. The order given by the respondents was converted into ranks using the formula below:

$$\text{Per cent position} = \frac{100 (R_{ij} - 0.5)}{N_j}$$

Where: R_{ij} = Rank given for the i^{th} variable by j^{th} respondents, N_j = Number of variables ranked by j^{th} respondents.

The per cent position of each rank was converted into scores by referring to the table provided by Henry Garrett. Then, for each factor (constraint), the scores of individual respondents were added together and divided by the total number of respondents. The mean scores for all the factors or constraints were arranged in order of rank. The factor with the least ranking was taken as the most severe constraint indicated by the respondents.

RESULT AND DISCUSSION

Input gap in cotton production

The results in Table 1 show the level of material input usage and the gap in cotton production in Adamawa State, comparing the recommended input doses with actual usage. For seeds, the recommended dose is 18 kg/ha, while the actual usage is slightly lower at 17.4 kg/ha,

creating a small gap of 0.60 kg/ha, which is 3.33% below the recommended dose. This indicates that farmers are using slightly less seed than recommended. Nitrogen usage exceeds the recommended dose of 60 kg/ha, with farmers applying 63.29 kg/ha, resulting in a negative gap of -3.29 kg/ha (-5.48%), indicating an over-application of nitrogen. This over-application can potentially lead to inefficiencies, increased costs, and environmental consequences. Phosphorus usage shows a more significant gap, with farmers applying only 23.09 kg/ha against the recommended 30 kg/ha, leaving a gap of 6.91 kg/ha (23.03%), suggesting an under-application of this critical nutrient. The under-application of phosphorus could hinder optimal plant growth and yield. Similarly, potassium usage exceeds the recommended 30 kg/ha, with an application rate of 42.98 kg/ha, creating a surplus of 7.02 kg/ha (23.4%), indicating over-application. Overuse of potassium may also result in nutrient imbalances that affect the overall health of the soil and cotton plants. These gaps indicate that while seed and phosphorus usage is slightly below the recommended levels, farmers tend to overuse nitrogen and potassium, which could lead to inefficiencies or environmental impacts. The results suggest a need for more balanced and precise input management to optimize cotton production and reduce input-related inefficiencies, which is consistent with the findings of Zeldu and Sekar (2015).

Yield gap estimate of cotton production in the study area

Table 2 presents the yield gap estimate for cotton production in the study area, comparing actual farm yields with potential yields from research stations and demonstration plots. The research station yield is 2000 kg/ha, serving as the maximum potential yield. The demonstration plot yield is 1650 kg/ha, reflecting more realistic outcomes under improved farming practices. In Yield Gap I, the difference between the research station and demonstration plot yields, is 350 kg/ha, or 17.5%, indicating that even under optimal conditions, a portion of the potential yield is not realized. The average farm yield is significantly lower at 1003.21 kg/ha, creating Yield Gap II of 646.79 kg/ha, which translates to 39.20%. This highlights a substantial shortfall between what is achievable on demonstration plots and what farmers are producing. The total yield gap, combining both gaps, is 996.79 kg/ha, representing 56.70% of the potential yield from research stations. According to Singh *et al.* (2018), substantial yield gaps exist between experimental yields under research conditions and actual yields obtained by farmers, often due to limitations in access to quality inputs, modern technologies, and efficient farming practices. The relative yield, at 64.88%, indicates that farmers are achieving just under two-thirds of their potential yield under

Table 1. Level of material input usage and gap in Adamawa State.

Variable	Recommended dose	Actual input usage	Gap
Seed (kg/ha)	18	17.4	0.60 (3.33)
Nitrogen (kg/ha)	60	63.29	-3.29 (-5.48)
Phosphorus (kg/ha)	30	23.09	6.91 (23.03)
Potassium (kg/ha)	30	42.98	7.02 (23.4)

() percentage gap (Source: Field Survey, 2024).

Table 2. Yield gap estimate of cotton production in the study area.

Description	Value
A. Research Station (kg/ha)	2000
B. Demonstration plot (kg/ha)	1650
C. Yield gap I in kg/ha	350
D. Yield gap I expressed in percentage	17.50
E. Average farm yield	1003.21
F. Yield gap II in kg/ha	646.79
G. Yield gap II expressed in percentage	39.20
H. Total yield gap in kg/ha	996.79
I. Total yield gap expressed in percentage	56.70
G. Relative yield in percentage	64.88

Source: Field Survey, 2024.

ideal conditions. These findings underscore the need for interventions that can bridge the gap between actual farm performance and potential yields, such as improved farming practices, better inputs, and technology adoption, to boost cotton productivity in the region.

Determinants of yield gap in the study area

The regression results (Table 3) provide important insights into the factors affecting the yield gap, with a focus on key input gaps such as seed rate, nitrogen, phosphorus, potassium, and education. The constant ($\beta_0 = 40.99$) is highly significant, indicating that when all explanatory variables are zero, the predicted value of the dependent variable is 40.99kg/ha. This suggests that even without the influence of the independent variables, the yield gap is relatively high, implying that other unobserved factors might also contribute to the result.

The coefficient for the seed rate gap ($\beta_1 = 5.93$) is positive and statistically significant at the 5% level. This indicates that reducing the gap between the actual and optimal seed rates has a substantial and positive impact on the yield gap. For every unit increase in the seed rate gap, the yield gap is expected to increase by 5.93 kg/ha. The significance of this variable highlights the need for farmers to adopt practices that minimize seed rate gaps to achieve better production outcomes. Pettigrew and

Johnson (2005) reported the significance of seed rate in determining the yield gap of cotton.

The nitrogen gap ($\beta_2 = 0.08$) is also positively related to the yield gap, albeit with a smaller magnitude. Although the effect is less pronounced than the seed rate gap, the variable is significant at the 10% level, indicating that reducing the nitrogen gap has a positive effect on the yield gap. Nitrogen is a critical nutrient for crop growth, and studies have consistently shown that nitrogen deficiencies can lead to reduced yields (Pettigrew and Johnson 2005, Takote *et al.*, 2020).

In contrast, the phosphorus rate gap ($\beta_3 = 1.38$) and the potassium rate gap ($\beta_4 = -1.56$) are not statistically significant, indicating that variations in phosphorus and potassium usage do not have a clear effect on yield gap in this model. While these nutrients are essential for plant growth, their insignificance in this particular analysis may be due to other factors, such as soil nutrient availability or interactions with other inputs, which could diminish their individual effects. As a result, farmers may need to focus less on closing phosphorus and potassium gaps and more on seed rate and nitrogen rate gaps. Tamene *et al.* (2016) and Samuel *et al.* (2020) also reported similar findings.

Educational level ($\beta_5 = -4.03$) is negative and statistically significant at the 10% level, suggesting that the yield gap for educated farmers is less than that of uneducated ones. It may be that more educated farmers adopt more experimental farming techniques that translate into higher yields.

Table 3. Factors influencing yield gap in the study area.

Variables	Parameters	Coefficient	t-calculated
Constant	β_0	40.99***	5.64
Seed rate gap (X1)	β_1	5.93**	2.20
Nitrogen gap (X2)	β_2	0.08*	1.79
Phosphorus gap (X3)	β_3	1.38NS	0.44
Potassium gap (X4)	β_4	-1.56NS	0.49
Education (D5)	β_5	-4.03*	1.90
R2		0.53	
F		3.03***	

***Significant at 1%; ** Significant at 5%; * Significant at 10%; NS Not Significant (Source: Field survey, 2024).

Table 4. Distribution of farmers based on production problems in Adamawa State.

Item	Respondents	Garret score	Mean	Ranking
High cost of labour	120	7502	62.52	II
Pest and disease attack	120	7798	64.98	I
Competition for labour	120	5951	49.59	IV
Lack of improved seed varieties	120	5222	43.52	V
Unfavourable prices received for the produce	120	6626	55.22	III
Birds infestation	120	2987	24.89	VI

Source: Field survey, 2024.

The overall model has an R-squared (R^2) value of 0.53, meaning that 53% of the variability in the dependent variable is explained by the independent variables in the model. This is a moderate level of explanatory power, suggesting that the model is a reasonable fit but that other factors not included in the analysis may also influence the yield gap. The F-statistic (3.03) is highly significant, indicating that the model as a whole is statistically valid and the independent variables jointly explain a significant portion of the variation in the dependent variable.

Production constraints in Adamawa State

The results in Table 4 present the distribution of cotton farmers in Adamawa State based on production problems, ranked by their Garret Scores and mean values. The highest-ranked problem is "pest and disease attack," with a Garret Score of 7798 and a mean score of 64.98, indicating that this issue is the most significant challenge affecting cotton production. Similar findings have been reported by Alam *et al.* (2013), who highlighted pest and disease infestations as one of the leading factors affecting cotton yield in Nigeria. The second-ranked problem is the "high cost of labour," with a Garret Score of 7502 and a mean score of 62.52, highlighting the financial burden farmers face in hiring labour for their farms. Unfavourable prices received for the produce rank third with a Garret

Score of 6626 (mean: 55.22), suggesting that low market prices for cotton also pose a substantial challenge. Competition for labour ranks fourth, with a mean score of 49.59, showing that farmers struggle to access enough labour, likely due to competing demands from other sectors. The lack of improved seed varieties ranks fifth, with a Garret Score of 5222 (mean: 43.52), indicating that access to high-quality seeds remains a moderate concern for farmers. According to Olatidoye *et al.* (2018), limited access to high-yielding cotton varieties constrains farmers' productivity in several African countries. Finally, bird infestation ranks lowest, with a Garret Score of 2987 and a mean score of 24.89, suggesting that while still a problem, it is not as critical as other factors.

Conclusion and Recommendations

The results show discrepancies between recommended and actual input usage, with farmers under-applying seed and phosphorus, while over-applying nitrogen and potassium. The yield gap analysis reveals that farmers in the region achieve only 64.88% of their potential yield under optimal conditions, with a total yield gap of 996.79 kg/ha, or 56.7%. Furthermore, the regression analysis identifies key determinants of the yield gap, including seed rate gap, nitrogen rate gap, and education levels, suggesting that addressing these factors could enhance cotton productivity. Production constraints, such as pest

and disease attacks, high labour costs, and low market prices, further exacerbate the challenges faced by cotton farmers in the state. The study recommends the following:

1. Balanced use of agricultural inputs should be promoted by relevant government agencies and development partners, particularly focusing on increasing seed and phosphorus application while reducing nitrogen and potassium overuse.
2. ADPs should provide extension services and training to educate farmers on optimal input management and the adoption of improved farming practices.
3. Farmers' education should be improved through targeted training programs to reduce the yield gap and promote more efficient cotton farming practices.

CONFLICT OF INTEREST

The authors declare that they have no conflict of interest.

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