POLICY BRIEF

IFDC
Developing Agriculture from the Ground Up

FERARI
FERTILIZER RESEARCH & RESPONSIBLE IMPLEMENTATION

POLICY BRIEF 11

Farmers weigh fertilizer value.

FERTILIZER USE EFFICIENCY AND **ECONOMIC VIABILITY** OF FERTILIZER USE BY **FARMERS** IN GHANA

Maize is an important staple food in Ghana. An efficient maize value chain can contribute greatly toward achieving the goals of zero hunger and poverty in the country. Several agricultural policies and interventions therefore target maize. Since 2008, various fertilizer subsidy programs have been used to increase fertilizer use by farmers in the country. The use of mineral fertilizers is justifiable because of their positive effects on crop yield and soil nutrient levels. The COVID-19 pandemic and the ongoing Russia-Ukraine war, however, have disrupted fertilizer markets and caused hikes in fertilizer prices.

A critical consideration in the current environment is whether the use of fertilizers under farmers' conventional practice is efficient and economically viable in Ghana, given the evidence of low profitability of fertilizer use in other African countries.[1] The responsible use of fertilizers, one aspect of the Fertilizer Research and Responsible Implementation (FERARI) program, relates to both its agronomically effective use[2] and its economic viability. This policy brief highlights the economic viability of fertilizer use in Ghana as related to fertilizer use efficiency.

"How can you sell a full bag of maize and not even be able to pay for a bag of fertilizer?"

— MAIZE FARMER IN GHANA'S GUINEA SAVANNAH ZONE

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Visit the FERARI project online at:

https://www.ifdc.org/projects/fertilizer-research-and-responsible-implementation-ferari/

[1] *Adzawla, W., E.D. Setsoafia, E.D. Setsoafia, S. Amoabeng-Nimako, W.K. Atakora, O. Camara, and P.S. Bindraban. 2023 (submitted). "Fertilizer Use Efficiency and Economic Incentive for Fertilizer Use in Maize Production in the Savannah and Transitional Zones of Ghana."*

[2] *Bindraban, P.S., W.K. Atakora, W. Adzawla, K. Anselme, V. Avornyo, M. El Gharous, R.A. Gyamfi, F. Kwarteng, and H. Sakyi. 2023. FERARI Research Demonstrates Addition of Sulphur to NPK Increases Maize Yields in Ghana. IFDC FERARI Policy Brief No. 10.*

Extension officer observing a maize plant.

ANALYZING THE DATA

FERARI has implemented several maize experiments accompanied by farmer field days and socio-economic surveys in the Guinea/Sudan Savannah and Transitional/ Deciduous zones of Ghana. Using a multistage sampling procedure, a farmer recall survey was conducted with 2,673 farmers (1,363 in 2019, 521 in 2020, and 789 in 2021)[3,4] from 33 districts in these zones (Figure 1). Of these farmers, 1,955 (73%) used mineral fertilizers.

From this data, FERARI undertook to analyze whether farmers were economically benefiting from their expenditures on fertilizer versus the crop yields they harvested. The analysis included the estimation of **agronomic efficiency (AE)**, **value cost ratio (VCR)** and **resource use efficiency (RUE)** of fertilizers.

The efficiency of fertilizer use is proxied by AE, or the increase in yield from the applied fertilizers, and VCR, which reveals the economic viability of fertilizer use by farmers. For farmers to break even, the value of the additional maize yield from fertilizer application must be equal to the additional cost for the associated fertilizers used. But to be economically viable, the VCR value must exceed 2 for farmers to compensate for the high risks associated with crop production and other costs implied with fertilizer use, including transportation, labor for application, and harvesting of the higher yield.

To determine whether farmers underutilized or overutilized fertilizers, the RUE was calculated. A farmer overutilizes fertilizer if the RUE is less than 1, underutilizes fertilizer if it is more than 1, and uses it efficiently if it is equal to 1. Overutilization means that the farmer obtained less monetary value from the increase in maize yield from fertilizer use than the cost invested in the use of the fertilizer. The opposite applies to underutilization.

AGRONOMIC EFFICIENCY (AE)

Agronomic efficiency is estimated as the increase in yield from the applied fertilizers:

$$AE = \frac{(Y - Y_0)}{Nut_q}$$

where:

- Y is the yield of a farmer who applied fertilizer.
- Y_0 is the average yield of farmers in the same district who did not apply fertilizer.
- Nut_q is the amount of total nutrients applied through fertilizers.

VALUE-COST RATIO (VCR)

Value-cost ratios reveal the economic viability of fertilizer use by farmers. It is calculated as:

$$\frac{(Y - Y_0)}{F_q} * \frac{P_Y}{P_F}$$

where:

- F_q is the total quantity in kilograms of fertilizer applied per hectare.
- P_Y is the unit price of the crop yield produced.
- P_F is the unit price of fertilizer.

RESOURCE USE EFFICIENCY (RUE)

This is estimated using the cost of fertilizer and the value of the extra yield obtained by the use of of fertilizer:

$$RUE = \frac{MVP}{MFC}$$

where:

- ***MVP*** is "marginal value product", the value of the extra yield obtained by fertilizer use.
- ***MFC*** is "marginal factor cost", the price per kilogram of the fertilizer used.

MVP is calculated as:

$$MVP = (\beta_F * {}^{Y_i}\!/_{X_{fi}}) * P_{Yi}$$

where:

- β_F is the estimated coefficient of X_{fi}, which was determined to be 0.173.
- Y_i is the farmer's yield.
- X_{fi} is the quantity of fertilizer applied.

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[3] *Adzawla, W., W.K. Atakora, I.N. Kissiedu, E. Martey, P.M., Etwire, A. Gouzaye, and P.S. Bindraban. 2021. "Characterization of Farmers and the Effect of Fertilization on Maize Yields in the Guinea Savannah, Sudan Savannah, and Transitional Agroecological Zones of Ghana," EFB Bioeconomy Journal, 1(100019).* https://doi.org/10.1016/j.bioeco.2021.100019

[4] *Adzawla, W., P.S. Bindraban, W.K. Atakora, O. Camara, and A. Gouzaye. 2022. "Economic Viability of Smallholder Agriculture in the Savannah and Transitional Zones of Ghana: Implications of Farm Output Commercialization and Farm Diversification," Sustainability, 14(11548):1-22.* https://doi.org/10.3390/su141811548

MAIZE YIELDS VERSUS FERTILIZER APPLICATION RATES

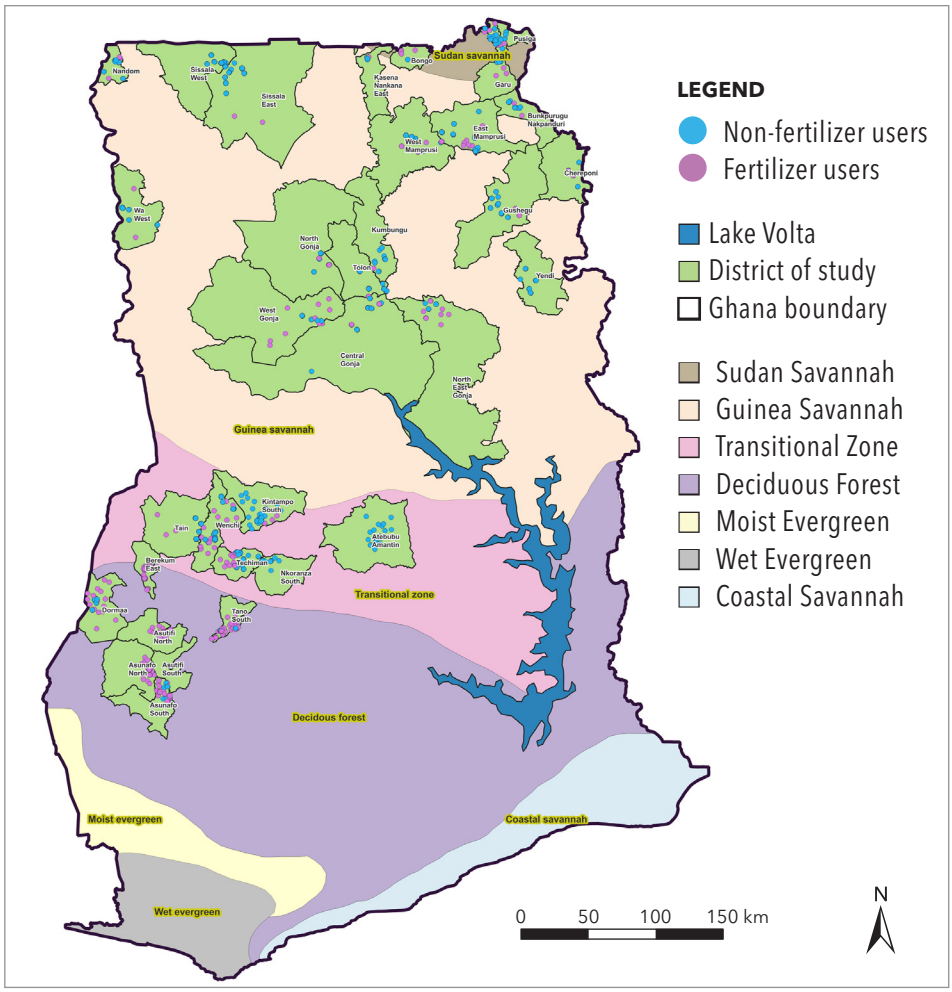
The average maize yield among fertilizer users was slightly higher in 2020 compared to 2019 and 2021, although the fertilizer application rate was lower (Table 1). This could have resulted from better weather conditions and also suggests that maize farmers can increase their yields without increasing fertilizer application rates over the current levels.

For farmers who did not apply fertilizer, the average yield was 1,123.1 kilograms per hectare (kg/ha), 1,447.2 kg/ha, and 1,336.5 kg/ha in 2019, 2020, and 2021, respectively.

The yield increase due to fertilizer application was highest in 2021. The price per kg of maize grain increased from 1.2 Ghana cedis (GHS)/kg in 2019 to 1.7 GHS/kg in 2020 and up to 2.2 GHS/kg in 2021, while the price per kg of fertilizer averaged 2.4 GHS/kg in 2019, 4.1 GHS/kg in 2021, and 4.4 GHS/kg in 2021.

Overall, a farmer pays more for a kg of fertilizer than the price for which they can sell a kg of maize grain. Not surprisingly, one of the farmers interviewed asked, "How can you sell a full bag of maize and not even be able to pay for a bag of fertilizer?" The significant rise in fertilizer prices and lower application rates in 2020 and 2021, compared to 2019, was due to the pandemic-induced low global fertilizer supply and the decrease in the fertilizer subsidy provided by the Government of Ghana.

Figure 1. *Map of Ghana showing the location of sample farmers.*



Market women weighing maize for sale.

Table 1. *Crop yield, fertilizer use, and nutrient use efficiency of maize farmers.*

PARAMETER	AVERAGE		2019		2020		2021	
	MEAN	STD DEV	MEAN	STD DEV	MEAN	STD DEV	MEAN	STD DEV
Yield of fertilizer users (kg/ha)	1,523.3	786.1	1,561.5	478.4	1,805.8	1,128.5	1,599.4	843.0
Yield of non-fertilizer users (kg/ha)	1,123.1	533.7	1447.2	452.9	1,336.5	752.3	1,273.0	640.0
Yield increase (kg/ha)	337.7	614.2	288.9	614.8	353.9	406.5	436.3	734.5
Fertilizer (kg/ha)	166.4	154.5	185.1	148.7	146.2	142.8	147.5	167.3
Nutrient* (kg/ha)	91.5	83.2	105.9	77.8	72.9	74.7	78.8	92.6
Maize price (GHS/kg)	1.5	0.7	1.2	0.4	1.7	0.6	2.2	1.2
Fertilizer cost (GHS/kg)	3.3	1.6	2.4	1.1	4.1	1.1	4.4	1.7

* Total amount of nutrients contained in the fertilizers applied.

FERTILIZER USE EFFICIENCY AMONG FARMERS

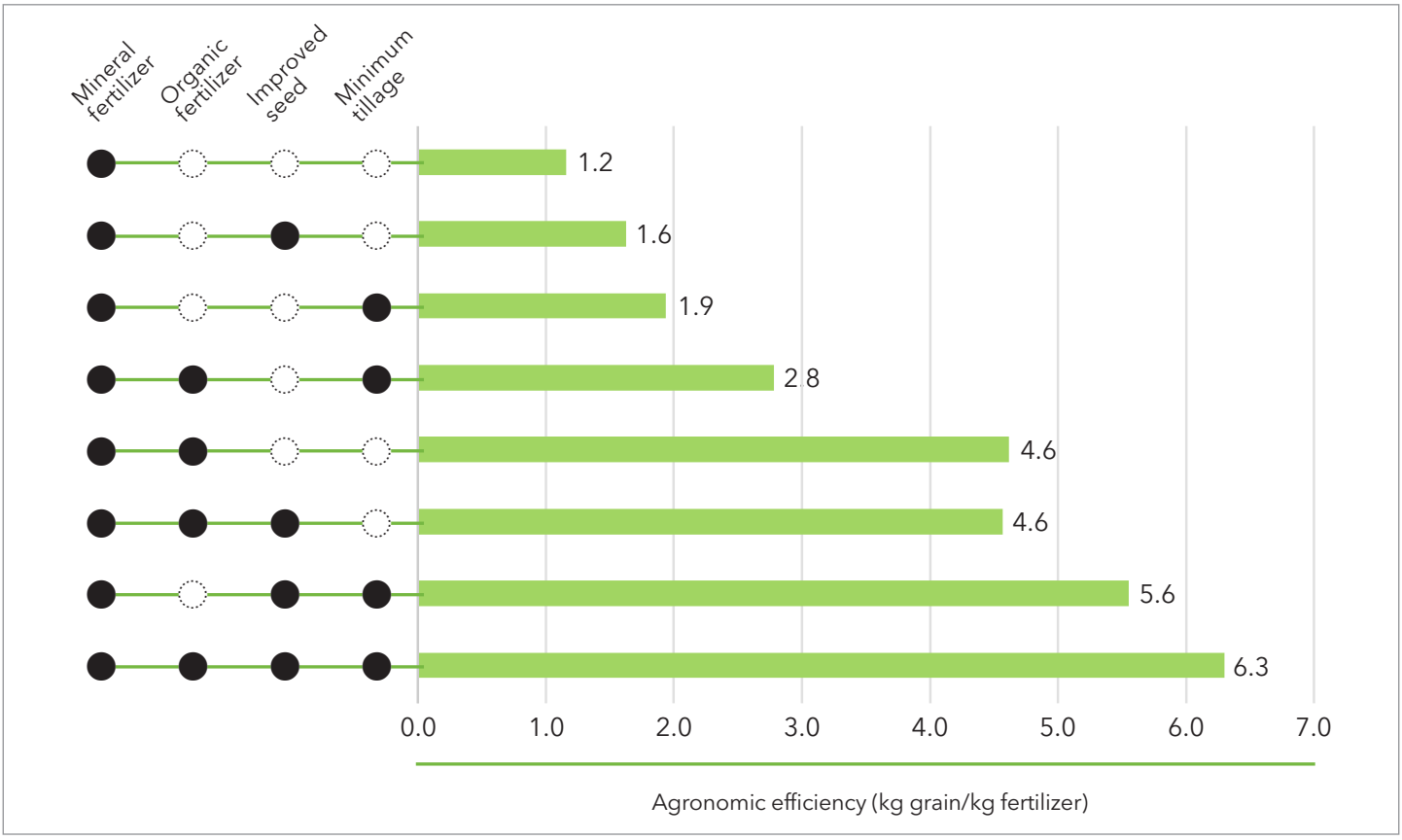
The AE for total nutrients shows that, on average, 2.0 kg of grain was obtained per kg of fertilizer in 2019 and 2021, and 2.9 kg of grain was obtained per kg of fertilizer in 2020. Specifically for nitrogen, the use efficiency averaged 5 kg of grain per kg of fertilizer, while those of phosphorus and potassium averaged 9.1 and 9.9 kg of grain per kg of fertilizer, respectively.

Regression estimates showed that the increase in yield ($Y–Y_o$) of the farmers was positively affected by various fertilizer formulations, especially NPK with sulphur. FERARI field experiments also provide evidence that combining NPK with sulphur leads to higher maize yields.[2]

The AE was better for farmers who were older with fewer years of maize production, were members of a farmer association, had access to credit, produced maize mainly for sale rather than home consumption, had a slightly larger farm size, used fewer laborers, applied fertilizer at the right rate and with the right placement, and used mineral fertilizers with complementary practices such as organic fertilizer, improved seeds, and minimal tillage.

Interestingly, the combination of mineral fertilizers with other practices, primarily the use of organic fertilizer, improved seeds, and minimum tillage, resulted in an AE of 6.3 kg grain per kg of fertilizer, relative to the 1.2 kg grain per kg of fertilizer under sole mineral fertilizer application (Figure 2). The farmers also admitted that they could obtain higher yields from their fertilizer application if they used mineral fertilizers appropriately and effectively controlled weeds on their farms.

Figure 2. *Agronomic efficiency with adoption of integrated soil fertility management (ISFM) practices.*



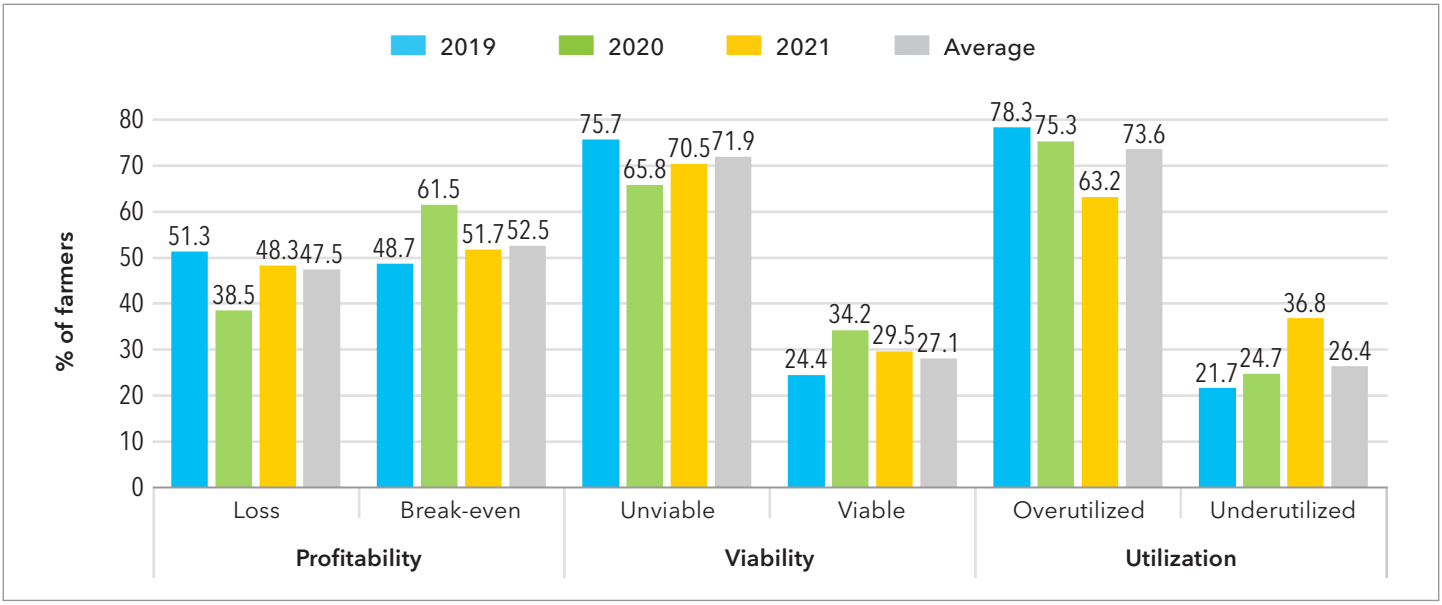
ECONOMIC VIABILITY OF FERTILIZER USE

The lowest VCR of 1.6 was obtained in 2019 due to the small increase in yield from fertilizer use and the high fertilizer application rate. The highest VCR of 2.1 was obtained in 2021, followed by 2.0 in 2020.

Despite the increase in fertilizer prices over the years, the average VCR increased because of the lower application rates, the relatively higher yield gains, and the higher price per kg of maize grain. This has raised concerns because fertilizer cost increases are passed on to the consumer in the prices of food products, affecting the food security of the country.

The use of fertilizers by a farmer is considered to be profitable when the VCR exceeds the break-even point of 1 and not profitable when the VCR is less than 1. Except in 2019, more than half of the farmers at least reached the break-even point with the fertilizers applied (Figure 3).

Figure 3. *Percentage distribution of farmers meeting or exceeding the break-even point (VCR ≥ 1), achieving economically viable fertilizer use (VCR > 2), and attaining fertilizer utilization efficiency.*



Only 24%, 34%, and 30% of the farmers in 2019, 2020, and 2021, respectively, had economically viable fertilizer use, i.e., a VCR exceeding 2. It is thus only economically prudent for less than one-third of the farmers to invest in fertilizer application. Importantly, this implies that the rest of the farmers may not have had an economic loss if they did not apply any fertilizer to their maize crop.

Based on the estimated RUE, over 60% of the farmers overutilized fertilizer; they applied a high rate of fertilizer but obtained low yields. This means that, given the amount of fertilizers used by the farmers, they should be able to achieve much higher yields. Improving the economic viability and utilization efficiency of fertilizers is important to enable farmers to have higher farm incomes to improve their livelihoods and to save enough for reinvestment in farm production in subsequent production seasons.

Although the estimated low average VCR is common in most parts of sub-Saharan Africa,[1] it has raised many concerns about the economic rationale for fertilizer use by farmers. This poses a major threat to sustainable fertilizer use in the region.

Farmers with economically viable fertilizer use produced, on average, 658 kg/ha more grain than those with economically unviable fertilizer use; the difference was highest in 2021 and lowest in 2020 (Table 2). The farmers with economically unviable and economically viable fertilizer use (Table 2) had 521 kg/ha and 1,178 kg/ha higher yields, respectively, than the non-fertilizer users (Table 1). Also, the farmers with economically unviable fertilizer use applied a larger quantity of fertilizers than those with economically viable fertilizer use.

These findings suggest that increasing the quantity of fertilizer on farmers' fields under current farm management practices would not result in significantly higher yields to improve the profitability of the farmers. Averaged over the three years, the application of nitrogen, phosphorus, and potassium at rates of 51 kg/ha, 22 kg/ha, and

Table 2. *Mean statistics of fertilizer nutrient application and yield by economic viability.*

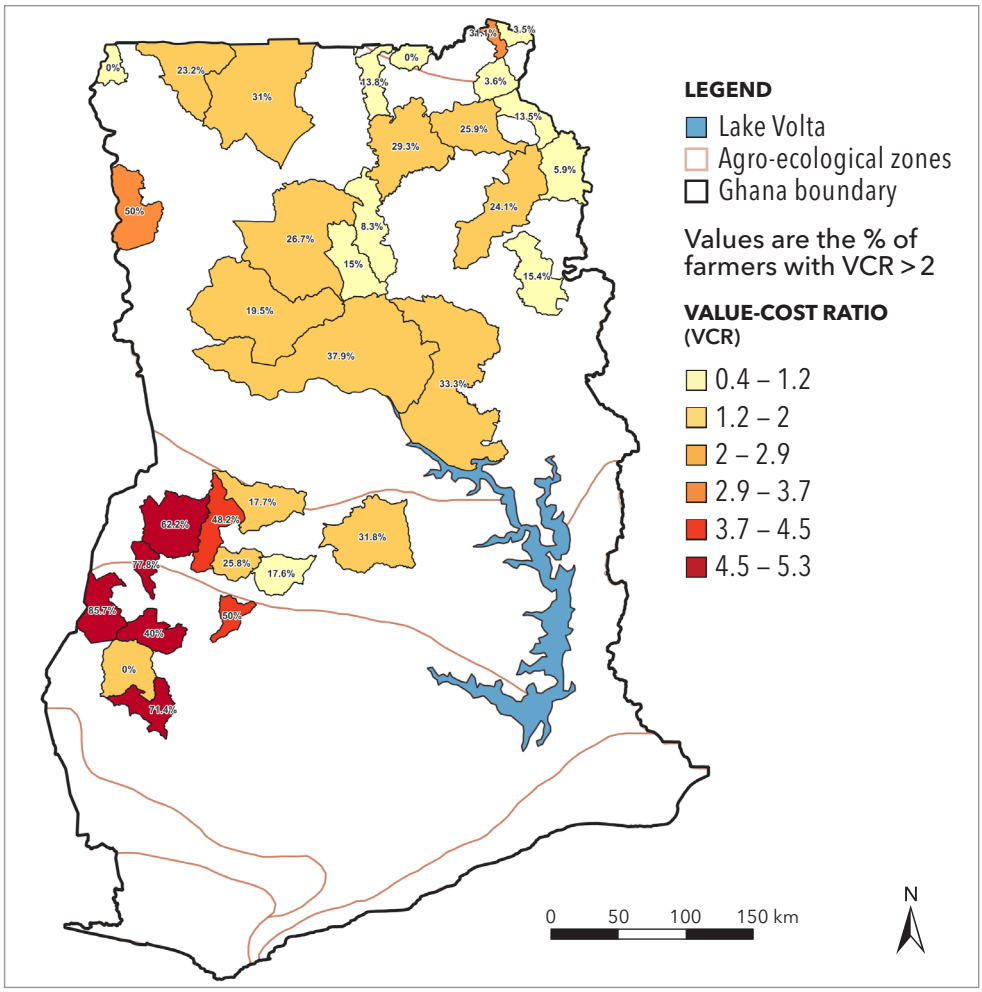
PARAMETER (kg/ha)	AVERAGE		2019		2020		2021	
	UNVIABLE	VIABLE	UNVIABLE	VIABLE	UNVIABLE	VIABLE	UNVIABLE	VIABLE
Yield	1,643.6	2,301.2	1,599.3	2,389.1	1,616.7	1,799.4	1,758.0	2,692.6
Fertilizer	267.0	163.0	271.8	206.9	240.2	79.9	279.9	181.4
Nutrient	142.8	99.5	154.3	118.1	119.3	38.1	139	135.0
Nitrogen	69.7	50.9*	76.1	62.7	54.9	15.4	69.0	64.8
Phosphorus	32.5	22.3*	35.7	25.3	26.4	10.0	31.0	30.7
Potassium	31.3	21.2*	34.8	24.9	24.9	9.7	29.5	27.4
Sulphur	10.7	7.7	9.4	7.4	11.9	2.5	12.2	13.7

* Indicates the average viable application rate of N, P, and K.

21 kg/ha and sulphur at a rate of 7.7 kg/ha could guarantee the economic viability of fertilizer use under current maize yield response to fertilizers.

To improve the economic viability of fertilizer use requires simultaneous improvement in the market conditions by ensuring a higher output price and a lower fertilizer cost and improving the yield gains under fertilizer application. Improving farmers' access to markets, farmers' membership in farmer associations, and farmers' motivation to produce maize largely for sale could also help improve the economic viability of fertilizer use by farmers. Of the 33 study districts, only nine had an average VCR above 2, and in terms of percentages, only six had at least 50% of the farmers with VCR above 2 (Figure 4). Of these nine districts, only Wa West and Bawku Municipal from the Guinea and Sudan Savannah zones, respectively, had economically viable fertilizer use due to the very low fertilizer application rates by the farmers (Figure 4).

Figure 4. *Average VCR by district and distribution of farmers by viability status.*



CONCLUDING POLICY IMPLICATIONS

- Despite the promotion of increasing fertilizer application rates by farmers to increase crop yields, the estimated AE and VCR reveal that it is economically unviable for most farmers to use fertilizers.
- To improve fertilizer use efficiency and economic viability, farmers must reduce their fertilizer application rate and adopt ISFM practices, including the combined use of mineral fertilizers with organic manure, improved seeds, and proper land management (land preparation, weeding, etc.).
- Extension education on ISFM must be prioritized and extension officers given the needed resources (e.g., training on ISFM, financial resources, etc.) to promote the use of ISFM by farmers.
- Given the current maize yield response to the fertilizers on the farmers' fields,N, P_2O_5, and K_2O must be respectively applied at 51-50-25 kg/ha[5] to attain economic viability. This is less than the current recommendation of 100-40-40 and 90-60-60 kg/ha to achieve maximum yield at the Guinea Savannah and Transitional zones, respectively.[6]
- Since the fertilizer subsidy is not an option in Ghana now, other market conditions that affect fertilizer prices, including taxes and exchange rate impacts, must be mitigated, as the increase in the price of fertilizer is likely to be passed on to consumers, which will have major implications on food security in the country.

[5] *NPK (in elemental form) of 51 kg/ha, 22 kg/ha, and 21 kg/ha equals N-P2O5-K2O (commonly referred to as "NPK") fertilizer of 51 kg/ha, 50 kg/ha, and 25 kg/ha.*

[6] *MoFA. "New Fertilizer Blends, The Way for Ghana," https://mofa.gov.gh/site/media-centre/agricultural-articles/324-new-fertilizer-blends-the-way-for-ghana-2*

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