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Evaluation of District-Based Indigenous Farmers' and Researchers' Fertilizer Application for Optimal Maize Production

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Abstract

Most research-based fertilizer inputs proposed for small scale farmers to increase their productivity do not achieve the required results and should consider indigenous practices. This study evaluates the practices of nutrient fertilizer input by farmers and researchers and relates them to their corresponding yields and profit so as to establish the appropriateness of the practices in 13 districts of the Northern regions of Ghana. Soil nutrients assessment of Nitrogen (N), Phosphorus (P) and Potassium (K) contents used to evaluate the soil NPK status was based on previous studies. Data on fertilizer application by farmers and researchers were obtained from the Savanna Agricultural Research Institute (SARI). The amount of N, P and K fertilizer input in 13 Districts and its associated maize grain yields by both farmers (89) and researchers were calculated and compared using two-sample t-test. The t-test results indicated that average amount of fertilizer input by researchers was significantly ($p < 0.05$) higher than the average amount of fertilizer input by the smallholder farmers, but the high fertilizer input did not significantly ($p = 0.74$) increase researchers' maize yields and profits in all 13 study districts grouped together, but there was maize increment in only eight districts. On the average, farmers from five districts applied low fertilizer and recorded low yields. However, when researchers increased quantities of fertilizer applied in these five districts, yield significantly ($p < 0.05$) increased. The outcome showed that smallholder farmers in these five districts could increase maize yields by 36% in the region should they adopt the maize production strategy by the researchers. The study concluded that, for best options, recommended fertilizer doses to enhance maize yields should consider district-specific farmers' practices and soil NPK status. The study could enable better implementation of location-based nutrient recommendation in the Northern Region of Ghana.

Keywords

Fertilizer Application, Smallholder Farmers, Researchers' Practices, Yield Increase, Maize Profitability

1. Introduction

Sustaining soil fertility for crop productivity is a key to ensure food security in every country. To manage poor soils and ensure sustained productivity, smallholder farmers will require adequate and affordable inputs [1]. One such major input required is to apply fertilizers to the soils that have low productivity due to nutrient mining and continuous cropping. Fortunately, several researchers [2] [3] [4] have proposed fertilizer application rates to help farmers boost their production. Nevertheless, some smallholder farmers continue to record low yields upon adoption of such fertilizer dose rate recommendations as compared to their previous practices [5]. This observation makes it necessary to document results from researchers' experiments at different locations and compare with indigenous farmers' approaches in order to properly promote fertilizer rates recommendation. Furthermore, in order to ensure that the appropriate fertilizer recommendation is proposed in a technology, it is essential to study the spatial distribution of the soil nutrients so that the nutrient requirements of the locations could be considered during fertilizer recommendations [6]. Field investigations on farming practices by both farmers and researchers therefore have to be continuously monitored to ascertain their performance. To effectively implement such monitoring systems, it becomes prudent to collect data on locations where researchers conduct their field demonstrations as well as what informs the choice of a technology in a particular locality. This is because soil fertility management practices are means by which soil services are managed in order to increase the quality and durability of such services. Hence, the soil management practices should be an integrated approach that will lead to the development of technologies that produces desired outcome economically and socially [7].

Integrated approach necessitates the need to find ways to identify technologies and to ensure proper monitoring of where, why and how recommended technologies are contributing to increased crop production [8]. Generally, farm locations lack proper location-specific characterization that makes it feasible to recommend technologies at locations having similar soil characteristics [9]. This contributes to wrong adoption of recommended technologies which normally do not achieve required results. Furtherance to wrong technological adoption is the fact that some smallholder farmers record better yields with their farm practice compared to recommended researchers' technologies [5]. This anomaly calls for thorough investigation in order to document such practices to intensify research for better output. The significance and relevance of this study lie in the fact that rare information exists regarding the successful implementation of indigenous practices which could be recommended for other farmers having similar field characteristics. There is a strong perception that researchers' practices of crop cultivation are the best since it has been tested and proven with scientific facts and so farmers are willing to adopt their strategies irrespective of what it offers. However, that perception is flawed when initial background check on what pertains to the smallholder farm has not been investigated.

Farmers may suffer low productivity comparably to previous productivity; however, caution must be taken to find alternative means of increasing their yields without making them worse off by ensuring that location-specific characteristics and farm practices of the locations are being considered. This is because there have been several soil fertility management procedures for yield increment yet smallholder farmers continue to suffer yields decline almost every year. Some smallholder farmers have reported that this decline in crop yields is worse compared to when they were implementing their own fertility management practices. But the good news is that locations where researchers' soil fertility management has been successful, farmers have been able to increase both yields and profit. This study therefore aims to assess soil management practices by smallholder farmers and researchers and compare their crop yields based on their NPK status and profitability for decision making. All other factors responsible for maize production were made constant. The significance of this study is that it will provide new insight into the performance of novel technological recommended researchers' demonstrations aimed at finding solutions to farmers' problems of decline yields. It will also serve as a means of strengthening researcher/farmer collaboration as a way of improving overall yields and profitability at specific locations.

2. Materials and Methods

2.1. The Study Area

The study was conducted in thirteen districts in three regions in the Northern part of Ghana (Savanna, Northern and North East regions) with a total territorial land area of about 70,384 km^2. The regions lie geographically within latitudes N9˚30' and N10˚00' and longitudes W0˚51' and W1˚00' with a mean elevation of 149 m above mean sea level [10]. They are located within the Guinea-Savanna agro-ecological zone [11] which is mainly characterized by dryness and unimodal rainfall patterns. The mean annual rainfall of the region has been reported to be between 750 mm and 1050 mm. Nevertheless, about 80% of the land area is used for agriculture [12]. The average temperature of the region is about 28˚C but could be as high as 40˚C during the dry seasons February/March [13]. The average soil fertility status of some selected chemical indicators are: 0.02% - 0.05% N, 0.6% - 2.0% Organic matter, 2.5% - 10.1 $mg \cdot kg^{-1}$ soil of available P and soil pH of 4.5 - 6.7 [14]. Some major food crops mainly cultivated in these areas include maize, millet, yams and sorghum, and these regions are considered to be part of the bread basket regions in Ghana. Figure 1 presents the map of the study area.

2.2. Data Collection and Analysis

Farm practice data regarding the use of fertilizers from farmers and soil research projects were obtained from the Savanna Agriculture Research Institute (SARI), Tamale in the Northern region of Ghana. Crop yield data on maize (2011, 2012 and 2013) collected from both farmers and researchers were also obtained from SARI and used to assess the differences in crop yield that informed further analysis in this study. Maize crops were solely considered for the study because of the season of data collection whereby maize was being harvested by majority of the farmers and documented; and also as it serves as the major staple crop in Ghana. Field location data points obtained with the GPS provided the coordinates of locations of farmers' fields. Soil samples from five farm locations within each district were used to assess the variation in concentrations of major soil nutrients—N, P and K. The preparation of the soil nutrient status map has been described in [15] and is presented in Figure 2. The data analyses were performed using the ArcGIS 10.7 software and the Statistical Package for Social Sciences (SPSS) 22nd editions.

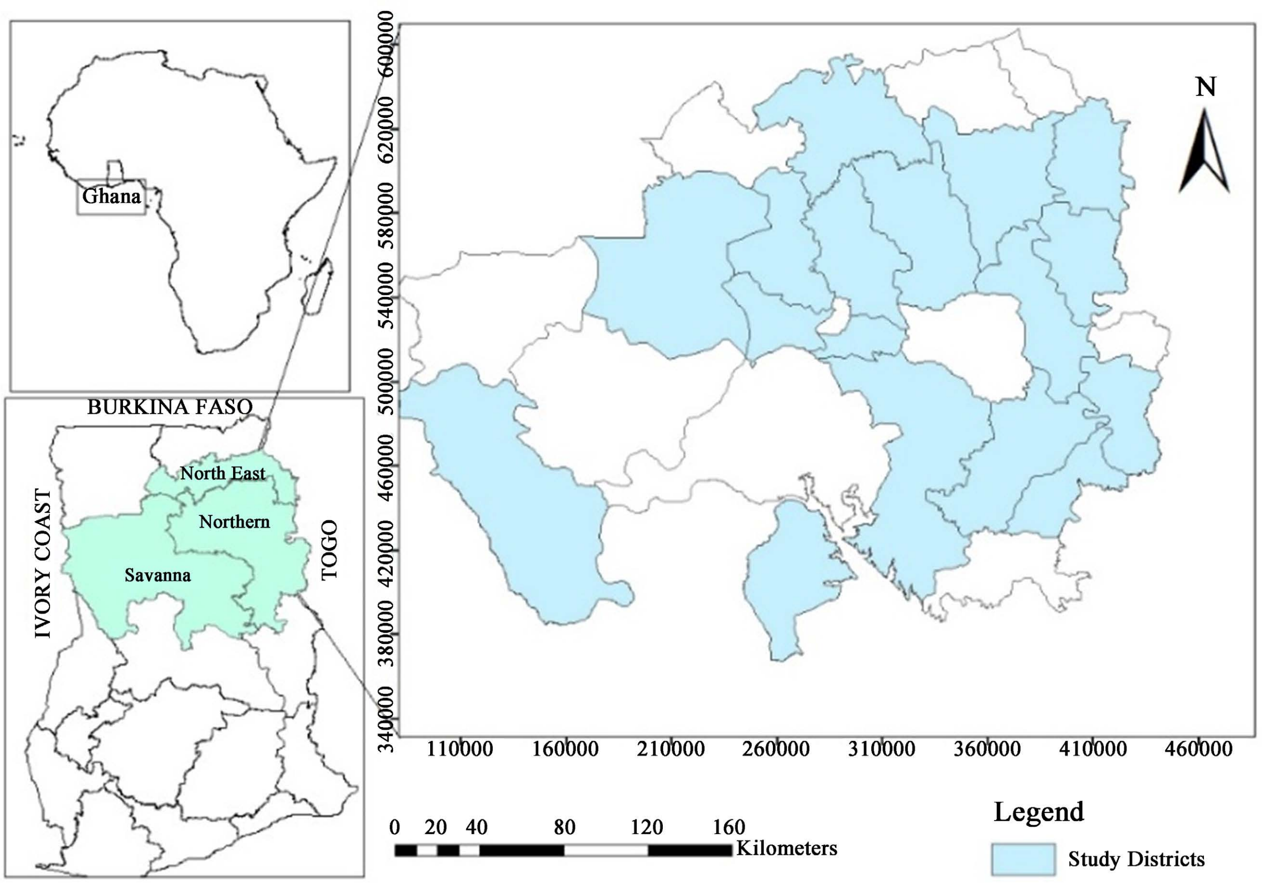

Figure 1. The study area map.

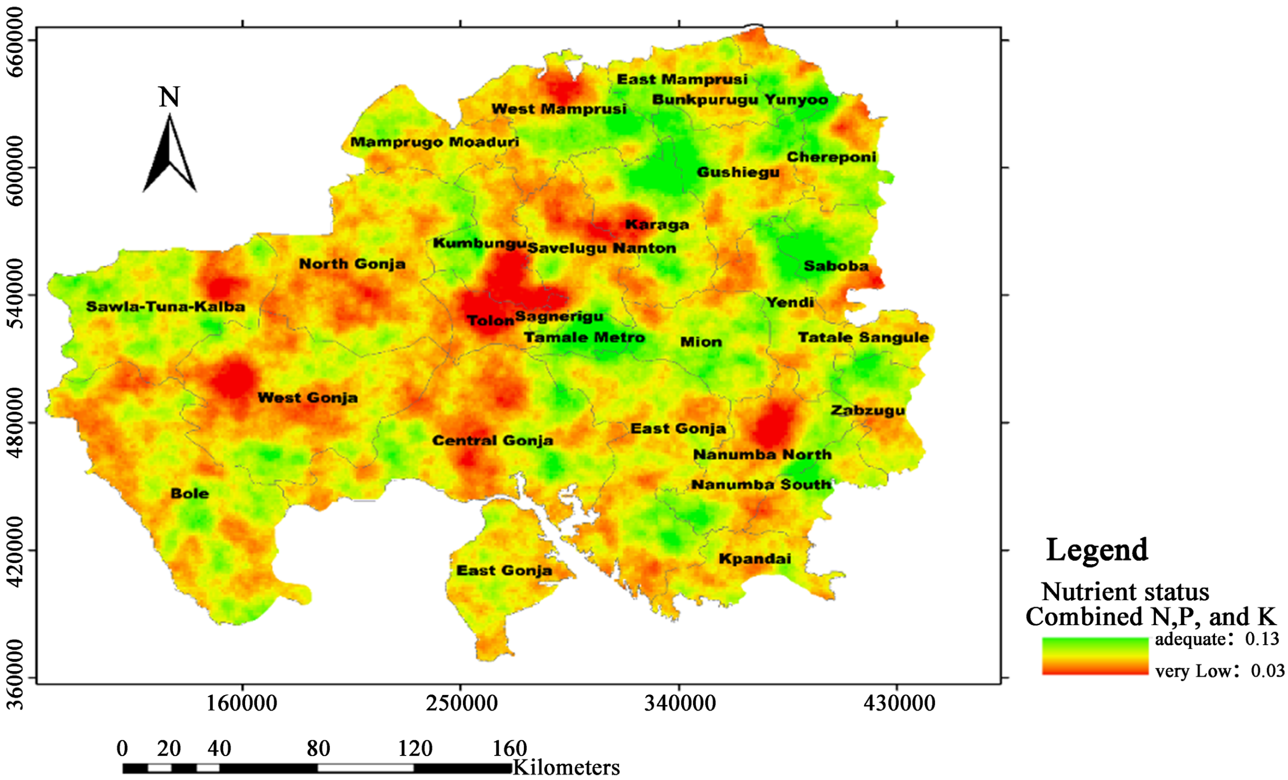

Figure 2. Soil Nitrogen, Phosphorus and Potassium (NPK) status in three Northern regions of Ghana (Savanna, Northern and North East). Source: Antwi (2020) [15].

2.3. Evaluation of the Relationship between Amount of Fertilizer Input by Farmers and Their Corresponding Yields

The relationship that existed between quantities of fertilizer input by farmers and their corresponding yields was evaluated. This relationship was to determine whether the blanket recommendation of 375 kg·ha^{-1} of NPK application had any significant increase on farmers' yields, regardless of the location of the farms in the districts. All other variables that contribute to yield outcomes such as climatic conditions and sowing dates were held constant due to data constraints, and were not included in the data analysis. The hypothesis for this analysis was that, if fertilizer input by farmers was exceeded from the blanket recommended rate, it would have a significant impact on the maize yield if all other conditions were favourable.

2.3.1. Processing of Farmers' Data to Study the Variation within Different N, P and K Nutrient Application

Hundred and fifty (150) maize farmers' data were obtained from SARI and used for this study. After thorough scrutiny of the selected farmers' data, 89 were chosen for the study based on the use of fertilizer under three categories of application of both NPK 15:15:15 and SoA (Sulfate of Ammonia). These categories were: 1) farmers whose fertilizer input on the field was less than the blanket recommendation (*i.e.*, <375 kg·ha^{-1}); 2) farmers who used the blanket recommendation (*i.e.*, 375 kg·ha^{-1}) and 3) farmers whose fertilizer input exceeded the blanket recommendation (*i.e.*, > 375 kg·ha^{-1}). The selected 89 farmers were considered because they had both their amount of fertilizer input and corresponding maize yields available in the database provided by SARI. The data used for this study were subjected to regression and variation analyses to analyse the relationship and variability that existed between and within these three groups, with their corresponding yields using SPSS (22nd edition). The amount of fertilizer input applied is the independent variable and it is a categorical variable, while the dependent variable was the corresponding maize yield.

2.3.2. Homogeneity Test of Variance between Farmers' Fertilizer Input

Test of homogeneity of variance was performed on the three categories of farmers fertilizer application to determine how comparable the quantities of fertilizer inputs were. The homogeneity test assumed that samples used were from populations of equal variances, meaning variability of scores for each of the groups were similar. Therefore, Levene's test of equality was performed at significance level of $p < 0.05$ for equality of variances on the farmers' maize yields as part of the analysis of variance.

2.3.3. Analysis of Variance of Farmers' Fertilizer Input and Corresponding Maize Yield

After the test of homogeneity of variance, a one-way analysis of variance (ANOVA) between and within groups was conducted to explore the varied impact of amount of fertilizer applied on the maize yield outcome. Subsequently, the effect size, which is given as eta squared, and expressed as the amount of associated variation that was accounted for by the effect of fertilizer application on maize yield and error obtained [16] in ANOVA, was determined. The effect size was determined as:

$$eta^2 = \frac{\text{sum of squares between categories}}{\text{Total sum of squares}} \quad (1)\ [16]$$

The effect size which does not over rely on statistical significance to draw conclusions [17] determined whether the obtained means of grain yields within the categories in the analysis of variances were large or small. Cohen (1992), classified effect size of 0.01 as small effect, 0.06 as medium effect and 0.14 as large effect.

2.4. Evaluation of Amount of Fertilizer Input within Farmers' and Researchers' Practices and Recommendation of Location-Specific Practices from Researchers' Demonstrations

Data from field demonstration trials that researchers had made, as well as practices of farmers on their farms with regards to fertilizer application that were collected were categorised for comparison in order to select the best practice for each district under study. Eighty-nine (89) smallholder maize farmers' data were used for this analysis. These farmers' data represented 13 districts in the study area, and consisted of data from two to three years cropping seasons, with at most nine farmers' data from different communities of each district to ensure uniformity in comparison. Thirteen (13) districts were chosen because in the remaining 3 of the districts, data from the researchers' field trials were unavailable. The trials either failed or were not demonstrated at all and so they were omitted. The categorisation consisted of the amount of fertilizer that farmers were using on their farms and the resulting corresponding yield. It also included research trials on Integrated Soil Fertility Management (ISFM) practices targeted at inorganic fertilizer application. The processes through which the categorisation and comparisons were done have been illustrated in the following subsections.

2.4.1. Processing of Fertilizer Input and Maize Yield Data by Smallholder Farmers

The collected data on farmers' quantity of fertilizer application as well as corresponding maize yields were grouped and averaged for each district. The groupings were done in Microsoft Excel by selecting all farmers who had their activities recorded in SARI's database within communities of each district under study. Amount of fertilizer input by the farmers in the communities as well as the corresponding yields were assigned to the district in which it is located and grouped accordingly. The sorting was done to properly identify the year of farming, the various amounts of fertilizer applied on individual farms (at most 9 farms involved for a district) and the associated maize yield for each of the 13 districts. The N, P and K contents within the amount of inorganic fertilizer applied was calculated using the amount of N, P and K contained in 100 kg of NPK 15:15:15 and SoA as a guide to obtain the amount of N, P and K that were used averagely by smallholder farmers in the districts. 100 kg of NPK 15:15:15 contains 15 kg N, 15 kg P_2O_5 and 15 kg K_2O and 100 kg of SoA contains 21 kg N while 100 kg of cattle manure contain 0.7 kg N, 0.5 kg P_2O_5 and 0.6 kg K_2O [18].

2.4.2. Processing of Fertilizer Input and Maize Yield Output in Researchers' Demonstration Plots

The various field trials that had been demonstrated to the farmers by the researchers were also grouped and sorted for each of the 13 districts by linking each maize yield output to its corresponding treatment in the demonstrations. The groupings were categorised for a 3-year period from 2011 to 2013 cropping seasons. From the acquired data, four treatments within four demonstration plots were identified for the 13 districts. The maize yield obtained from each treatment in the demonstration plot was assigned to each district as the resulting yields from the treatment and grouped accordingly.

The treatment which produced high yields from the trial demonstrations in the various districts for at least 2 years within the 3-year period (*i.e.*, after evaluation of treatments and maize yields) was then selected to represent that district as attainable yields so that it could be compared to the farmers' maize yields in the district. The trials from ISFM research demonstrations made use of fertilizer application with improved maize seeds and other amendments such as use of fertisoil and organic manure. The use of these resources was set up in four demonstration plots for the cultivation of maize. In all, there were four maize demonstration plots within four different communities in each district. There were at least four different treatments within each of the demonstration plots. Since the focus of this study was on the application of fertilizer, only the quantities of the fertilizer per hectare of land in the demonstrations were considered and they were; 1) no fertilizer use, 2) 2.5 bags of NPK 15:15:15 + 1.25 bags of SoA, 3) the recommended rate (5 bags of NPK 15:15:15 + 2.5 bags of SoA), 4) 5 bags of NPK 15:15:15 + 3.75 bags of SoA, 5) fertisoil (3 t ha^{-1}) + 6.75 bags of SoA, 6) manure (2.5 ha^{-1}) + 1/2 NPK recommended rate and 7) only NPK recommended rate (5 bags of NPK 15:15:15).

The percentage increase in the crop yields was also calculated to assess how much crop yields would be gained if such specific measures were to be adopted by the smallholder farmers within the districts.

2.4.3. Evaluation of the Profitability of Proposed ISFM Strategy and Farmer Practice

The identified researchers' demonstration trials were assessed in terms of cost of inputs and prices of maize grains to obtain the benefits that could be derived by smallholder farmers should they adopt the strategy. The current prices of fertilizers, maize seeds, and fertisoil were obtained from agro-dealers and confirmed with those of the farmers and researchers. The cost of inputs for each district was then used as cost for inputs for both the farmers and researchers. The existing sale prices for 50 kg bag of maize grains at farm gate were also obtained from farmers through survey interview and used to estimate the price of the maize yield output by farmers and researchers. The cost of input variables per hectare for producing the highest yields obtained from the demonstrations were calculated by adding the prices of each input variable. The price of the grain produced per hectare was also obtained by multiplying the maize grain yields by the price of 50 kg of maize grains. The variable cost of inputs was then deducted from the sale price of maize grains produced to obtain the benefit or contribution. Contribution is the reserve which comprised of fixed cost like labour cost or price of insecticide (which could be unique for both farmers and researchers) and profit. A profit volume ratio (P/V), which is a relationship between contribution or benefit and sales of products [19] was calculated to compare the profitability of farmer and researcher practices. The P/V ratio was calculated as shown in Equation (2):

$$P/V = \frac{\text{Contribution}}{\text{Sale}} \quad (2) \ [19]$$

Microsoft excel software was then used to derive a comparison plot of the benefits from both practices in order to properly advice an intervention.

3. Results and Discussion

3.1. Results

3.1.1. Assessment of N, P and K Nutrient Management and Appropriate Location-Specific Options

Evaluation of fertilizer input by farmers and maize yield in the study area

The rate of fertilizer application by smallholder farmers differed among them and affected their maize grain yields differently. The variations in the use of fertilizer by 89 smallholder farmers from the thirteen districts under the three categories of fertilizer input (<375 kg·ha^{-1}, = 375 kg·ha^{-1}, and >375 kg·ha^{-1}) did not reflect in a direct manner in their maize grain yields.

Levene's test of equality of variances within the maize grain yields obtained by the smallholder farmers showed that, the amount of fertilizer used within the three categories by the farmers did not significantly ($p = 0.90$) cause variations in their maize yields (Table 1). Further analysis revealed that, even though the variances in maize yields were not significant ($p = 0.90$), the differences between the means of maize yields for the categories of fertilizer used were significantly large as given by the calculation of the effect size ($eta^2 = 0.06$) in Equation (1); (*i.e.* mean maize yields between farmers who applied less than 375 kg·ha^{-1} and those who applied 375 kg·ha^{-1} (recommended)) was 344 kg·ha^{-1}, that of farmers who applied 375 kg·ha^{-1} and those who applied more than 375 kg·ha^{-1} was 427 kg·ha^{-1} and the difference between those that applied less than 375 kg·ha^{-1} and those that applied more than 375 kg·ha^{-1} was 771 kg·ha^{-1} (Table 1).

The relationship between different amounts of N fertilizer input and maize grain yield

The mean grain yields of smallholder farmers who applied fertilizer below the average of 375 kg·ha^{-1} (2608 kg·ha^{-1}) did not significantly ($p = 0.90$) vary from the mean grain yields of smallholder farmers who applied above 375 kg·ha^{-1} (3379 kg·ha^{-1}) as shown in Table 1.

Nevertheless, the results on the use of fertilizer based on the three categories

Table 1. Statistical description of yield (kg·ha^{-1}) as given by amount of fertilizer applied (kg·ha^{-1}).

Amount of NPK (15:15:15) and SoA fertilizers applied (kg·ha^{-1})	N	Mean maize yield (kg·ha^{-1})	Std. Error	95% Confidence Interval for Mean		Minimum maize yield	Maximum maize yield
				Lower Bound	Upper Bound		
<375	49	2608	178.11	2249.42	2965.67	1024	6144
375 (Blanket)	23	2952	248.14	2437.18	3466.41	1024	5376
>375	17	3379	288.43	2767.74	3990.66	1152	6144
Total	89	2844	131.91	2581.76	3106.05	1024	6144
Levene's test of variance ($p < 0.05$)						0.90	
eta^2						0.06	

of fertilizer input by smallholder farmers led to different responses of maize yields to NPK application in the study area (Figure 3). This analysis was performed on the individual components of N, P, and K of the NPK fertilizer application to ascertain the effect they have on the maize yields. Only N application influenced the maize yields at the end of the analyses. The relationship between the N input and maize yields was negative for the first coefficient (x^2) and positive for the second coefficient (x) with an r value of 0.70. The established quadratic polynomial function explains how an increase in N application impacts the maize grain yields. In the first instance of coefficient (x), as N amount increased, maize grain yield increased. In the second instance of coefficient of x^2, increase in N application rate above 65 kg·ha^{-1} did not continuously increase the maize grain yields.

Evaluation of fertilizer input and maize yield from farmers' fields and researchers' demonstration plots

The amount of inorganic fertilizer used by about 55% of the farmers in the 13 districts were lower than 375 kg·ha^{-1} across the study region (Table 1). The smallholder farmers relied mostly on quantity of fertilizers available as at the time of application without considering what the national recommendations for maize production are. Basically, the common practice in terms of fertilizer input by the farmers was the blanket recommendation of 5 bags of NPK 15:15:15 and 2.5 bags of Sulfate of Ammonia (SoA) for each hectare of land being cultivated. Nevertheless, some farmers used either less or more than the recommended as dictated by availability of fertilizer to farmers at the time of application (Figure 4). Farmers who had other sources of organic input such as animal manure and crop residues applied them to their fields in addition to the compound fertilizers.

3.1.2. Comparison between Farmer and Researcher Fertilizer Use and Maize Yield in the Study Area

Compilation and evaluation of different treatments conducted by researchers for

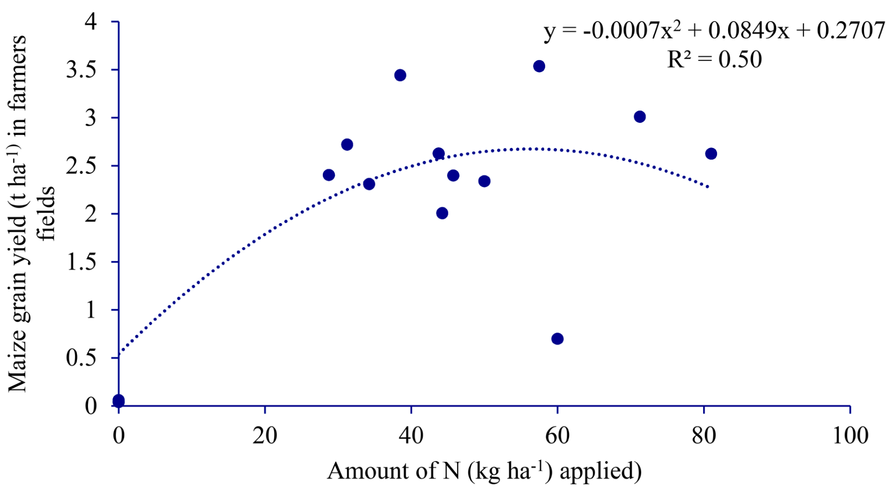

Figure 3. Relationship between N fertilizer application and smallholder farmers' maize grain yields in the study districts of Northern Region of Ghana.

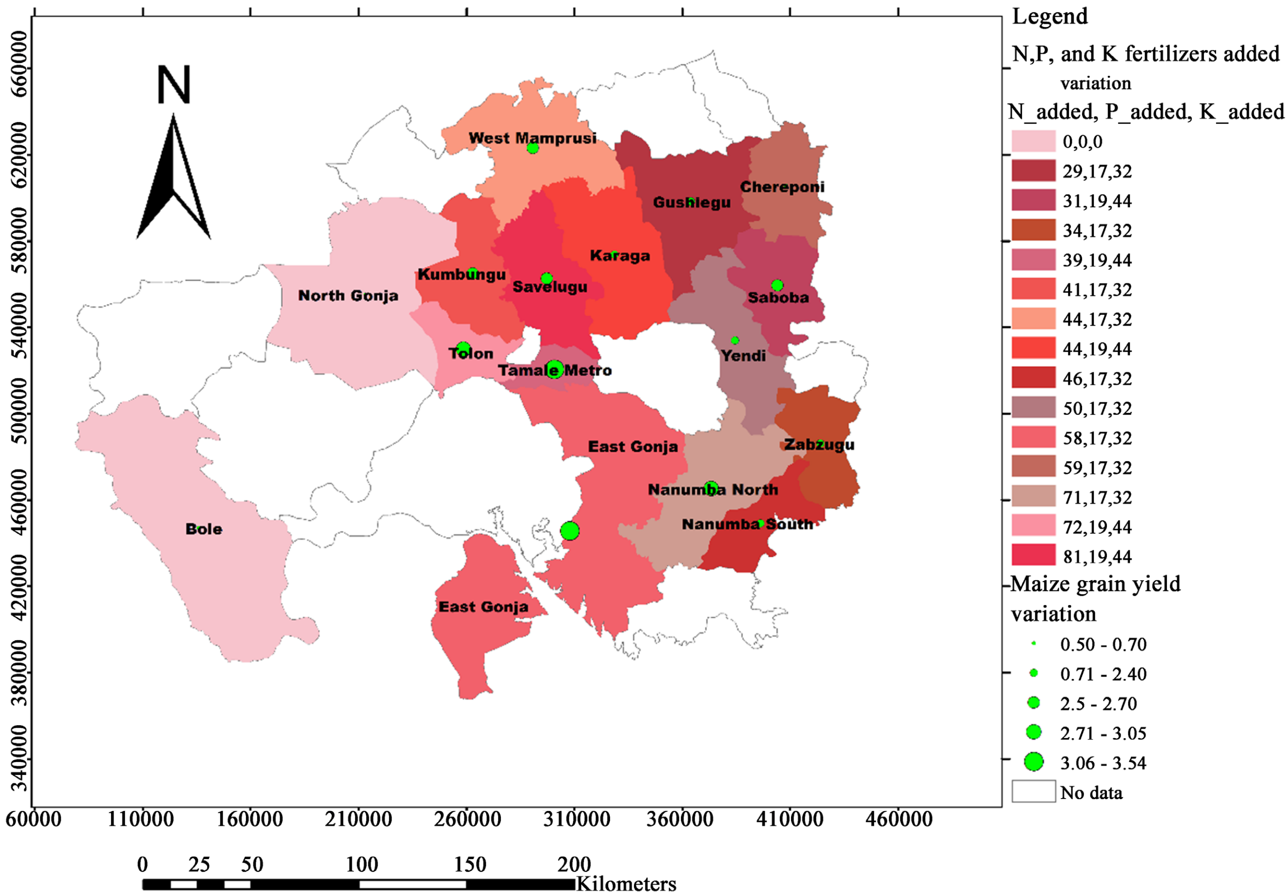

Figure 4. Amount of N, P and K nutrients (kg·ha^{-1}) added by smallholder farmers and the corresponding maize yields in the study districts of the Northern Region.

adoption in the study area revealed that certain treatments produced higher yields consistently in the 13 districts for a period of 3 years; the lowest mean yield was obtained in Karaga district (1719 kg·ha^{-1}) and the highest was obtained in Kumbungu district (4103 kg·ha^{-1}) as shown in Table 2.

The fertilizer input and the mean grain yields from selected (6 - 9) representative smallholder farmers' fields for each of the 13 districts are shown in Table 3.

Comparative results from t-test analysis showed that the average fertilizer used by the researchers was significantly ($p < 0.05$) higher than the average fertilizer input by the smallholder farmers. Regardless of the higher fertilizer input, the mean maize grain yield obtained from the researcher demonstration trials in all the 13 districts was not significantly ($p = 0.74$) higher than the smallholder farmers' grain yields (Table 4).

Recommendation of fertilizer application and maize production option from ISFM demonstration strategies

The trials demonstrated by the researchers increased maize grain yields in five districts whilst smallholder farmers' practice on fertilizer input also produced better yields than the researchers' in eight other districts. In locations where researcher trials produced better yields (*i.e.*, increase of researchers yield over

Table 2. Integrated Soil Fertility Management researcher demonstrations trials producing consistent increase in maize grain yields for a 3-year period.

District	District-specific trial	Maize Grain yield ($kg \cdot ha^{-1}$)			
		2011	2012	2013	Mean
Savelugu	Maize + Manure (2.5 tonnes ha^{-1}) + 1/2 NPK recommended rate	1636	1444	2229	1770
Yendi	Maize + 2 bags NPK 15:15:15 + 1.5 bag SA	2728	2772	N/A*	2750
West Mamprusi	Maize + NPK recommended rate	1263	1587	N/A	1425
Kumbungu	Hybrid (Pannar 53) maize variety + recommended rate	2000	4379	5929	4103
Zabzugu	Maize + Fertisoil 3 t/ha + 2.5 bags/ha SA	3603	2453	5244	3767
Gushegu	Hybrid (Pannar 53) maize variety + recommended rate	2320	3083	N/A	2701
Saboba	Maize + 2 bags NPK 15:15:15 + 1.5 bag SA	2221	1954	3724	2633
Karaga	Maize + 2 bags NPK 15:15:15 + 1.5 bag SA	1314	2124	N/A	1719
Tamale Metro	Hybrid (Pannar 53) maize variety + recommended rate	2017	3902	4181	3367
East Gonja	Omankwa (DTMA maize variety) + recommended fertilizer rate	2453	1497	N/A	1975
Tolon	Maize + 2 bags NPK 15:15:15 + 1 bag SA	1367	2273	3646	2429
Nanumba South	Hybrid (Pannar 53) maize variety + recommended rate	2187	4125	N/A	3156
Nanumba North	Maize + 2 bags NPK 15:15:15 + 1.5 bag SA	1816	2620	N/A	2218

*N/A: data not available.

Table 3. Mean inorganic fertilizer application and corresponding mean maize grain yields for the years 2011, 2012 and 2013 by smallholder farmers in 13 districts of three regions in the northern part of Ghana.

District	($kg \cdot ha^{-1}$)	Fertilizer applied			Soil nutrient status		
	Mean maize grain yield	N	P	K	N (%)	Av. P ($mg \cdot kg^{-1}$)	Ex. K ($cmol_c \cdot kg^{-1}$)
Savelugu	2624	81	19	43	0.04	3.20	0.10
Yendi	2338	77	17	31	0.06	4.18	0.12
West Mamprusi	2627	44	17	31	0.07	5.10	0.10
Kumbugu	2660	64	17	31	0.06	3.44	0.12
Zabzugu	2309	116	39	93	0.07	5.60	0.10
Gushegu	2403	64	17	31	0.07	3.10	0.10
Saboba	2721	31	17	31	0.03	7.20	0.20
Karaga	2005	44	19	44	0.07	2.10	0.30
Tamale Metropolitan	3442	39	19	44	0.09	2.70	0.73
East Gonja	3535	58	17	31	0.06	4.94	0.40
Tolon	3052	72	19	44	0.05	5.50	0.10
Nanumba South	2397	64	17	31	0.06	3.41	0.10
Nanumba North	3010	71	17	31	0.06	3.90	0.10

Table 4. Test of significance of average grain yield on demonstration and farmers' fields in the study area (n = 13).

Sample	Mean fertilizer input (kg·ha^{-1})	Variance	F pr	Mean Grain yield (kg·ha^{-1})	Variance	F pr.
Demonstration plots	370	6811	**0.001**	2620	660	**0.74**
Farmers' fields	244	8537		2700	200	

Table 5. Percentage increase in average maize grain yield of researchers over average farmer's yields in five districts within the study area.

District	Mean Maize Yield (kg·ha^{-1})		% increment
	Farmers	Research	
Zabzugu	2309	3767	63
Gushegu	2403	2701	11
Kumbungu	2660	4103	54
Nanumba South	2397	3156	32
Yendi	2338	2750	18
t-test statistics			
Mean yield	2421	3295	F pr.
Variance	20	390	0.03

NB: Overall yield increment was 36% on the average.

farmers yield), the overall yield increment for the study area was 36%; with the highest increase being 63% for Zabzugu district and the lowest, 11% for Gushegu district (Table 5). These demonstration trials differed from one district to another (Table 2), and hence the demonstration trials that produced increment in grain yields compared to those from other demonstration trials in each of those districts were recommended to be implemented in such districts. Results from t-test that compared the maize grain yields from the demonstration plots and the farmers' fields in the five districts where ISFM strategy caused increase in maize yields showed that their mean yield was significantly higher (p = 0.03) than that of the farmers' (Table 5).

3.1.3. Comparative Profitability Assessment of Farmers' Practice and Proposed ISFM Interventions

The cost involved in the production of maize within farmers' practices and proposed ISFM strategies are presented in Table 6 and Table 7. The results present the cost involved in the purchase of fertilizers and maize seeds; and hence other input cost for the production of maize were regarded as same for both researchers and farmers. The P/V ratios for the five districts were high for both farmers and researchers (*i.e.*, above 0.5). But, the P/V values for Zabzugu and Gushegu districts were higher for the farmers (0.8 and 0.9, respectively) than the researchers (0.7 and 0.8, respectively), and same for farmers and researchers in

Table 6. Profitability of farmers' practices in maize production in five districts of the Northern Region of Ghana where demonstration trials produced higher maize grain yields.

District	Input variable (ha^{-1})	Input variable cost (GH₵·ha^{-1})	Maize yields kg·ha^{-1}	Selling price of maize (GH₵)	Benefit (GH₵)	P/V ratio
Zabzugu	Maize + 2.5 bags NPK 15:15:15 + 2.5 bags SoA	440.00	2337.18	2800.00	2350.00	0.8
Gushegu	Maize + 2.5 bags NPK 15:15:15 + 1.25 bags SoA	330.00	2434.73	2925.00	2600.00	0.9
Kumbugu	Maize + 2.5 bags NPK 15:15:15 + 2.5 bags SoA	440.00	2691.85	3225.00	2775.00	0.9
Nanumba South	Maize + 2.5 bags NPK 15:15:15 + 2.5 bags SoA	440.00	2426.98	2913.00	2475.00	0.8
Yendi	Maize + 3.75 bags NPK 15:15:15 + 2.5 bags SoA	550.00	2366.53	2838.00	2288.00	0.8

Price of maize seeds (per kg) = GH₵ 2.00, price of 1 bag (50 kg) of NPK 15:15:15 fertilizer = GH₵ 89.00, price of 1 bag (50 kg) of SoA = GH₵ 85.00, price of 100 kg bag of maize at farm gate = GH₵ 120.00. All other input variables and practices were regarded as constant and remained same for smallholder farmers and researchers.

Table 7. Profitability of researchers' practices in maize production in five Districts of the Northern Region of Ghana where demonstration trials produced higher maize grain yields.

District	Input variable (ha^{-1})	Input variable cost (GH₵·ha^{-1})	Maize yield kg·ha^{-1}	Selling price of maize (GH₵)	Benefit (GH₵)	P/V ratio
Zabzugu	Maize + Fertisoil 3 t/ha + 6.25 bags SoA	1286.00	3812.30	4575.00	3300.00	0.7
Gushegu	5 bags NPK 15:15:15 + 2.5 bags SoA + Hybrid Pannar 53 maize variety	678.00	2734.15	3250.00	2575.00	0.8
Kumbugu	5 bags NPK 15:15:15 + 2.5 bags SoA + Hybrid Pannar 53 maize variety	678.00	4152.53	5000.00	4475.00	0.9
Nanumba South	5 bags NPK 15:15:15 + 2.5 bag SoA + Hybrid Pannar 53 maize variety	678.00	3194.68	3825.00	3150.00	0.8
Yendi	Maize + 5 bags NPK 15:15:15 + 3.75 bags SoA	769.00	2783.40	3350.00	2575.00	0.8

Price of maize seeds (per kg) = GH₵ 2.00, price of 1 bag of NPK 15:15:15 fertilizer = GH₵ 89.00, price of 1 bag (50 kg) of SoA = GH₵ 85.00, price of 100 kg bag of maize at farm gate = GH₵ 120.00, price of Hybrid Pannar 53 maize seeds (per kg) = GH₵ 8.00, price of 1 tonne of fertisoil = GH₵ 300.00. Source of fertilizer prices and maize prices at farm gate for 2015 (1 GH₵ = 0.03 USD): survey interview with farmers and agro-dealers (2015). Source of seed prices [3]: All other input variables and practices were regarded as constant and remained same for smallholder farmers and researchers.

Kumbugu, Nanumba South and Yendi districts (Table 6 and Table 7). However, the profit margins were higher for researchers in Zabzugu, Kumbugu, Nanumba South and Yendi districts but lower in Gushegu district (Figure 5).

3.2. Discussion

3.2.1. Fertilizer Application Strategies by Smallholder Farmers and Their Corresponding Maize Grain Yields

The production of maize is highly influenced by fertilizer application even though other external input like improved seeds, organic manure and even the use of pesticides is important. Therefore, it was expected from this study that different amounts of fertilizer application will cause different maize yield outputs. However, Levene's test of homogeneity implied that the variances in the

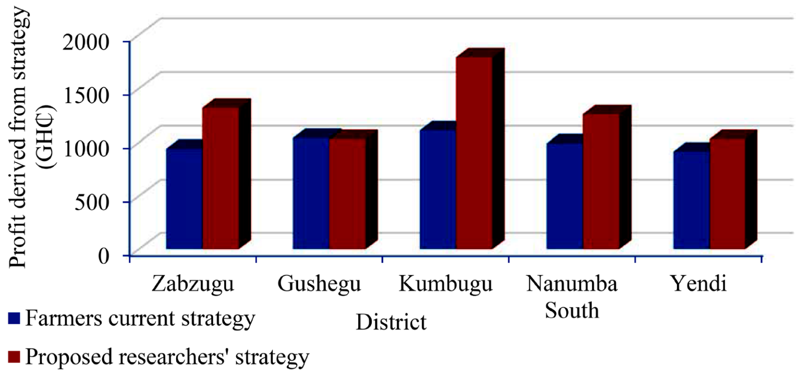

Figure 5. Comparison of profit from farmers' practice and research demonstrations in five districts of the Northern regions of Ghana.

maize yields from the smallholder farmers were similar irrespective of the fertilizer applied (whether below, within or above recommended (375 kg·ha^{-1}) (the recommended amount was obtained from survey data, this study; SARI, 2013)). Even though the test of homogeneity was not statistically significant, the actual differences between the mean maize yields in kg·ha^{-1} (2607.54, 2951.79, and 3379.20) for the three fertilizer categories (<375 kg·ha^{-1}, 375 kg·ha^{-1}, and >375 kg·ha^{-1}, respectively) were averagely large. The differences were explained by the medium effect size of 0.6 obtained for the analysis. The average variation differences imply that the amount of fertilizer input within any of the three fertilizer categories affected the maize yields increment [20]. For a relatively small sample size (89) as used in this study, it is quite difficult to obtain statistical significance difference in maize yields of farmers even if there are obvious distinctions in the fertilizer application [16]. Other factors may also contribute to the seemingly equal variances in the maize yield which necessitated further evaluation in a follow up study.

In Sub-Saharan Africa, fertilizer application on maize fields has been reported to be lower than the crop requirement [21]. Due to the low application, maize yields are also generally low. However, increase in fertilizer application rates and quantities on maize fields have correspondingly increased yields to some extent, yet yields are far below the potential. This has led to the persistent call by researchers to address food security problems by increasing fertilizer inputs to increase maize yields [22]. The N, P and K fertilizers as analysed in this study, however, gave different contributions as to how they cause maize yields to vary. From this study, it was noted that indeed increasing N fertilizer input increased maize grain yields to a peak of about 65 kg·ha^{-1} N. The maize grain yields were not responsive to N input above the peak, which might have been due to some other limiting nutrient factors (Zinc and Boron) prohibiting the maize crops to make use of the added N nutrients [23]. From the sample data on smallholder farmers in the study area, it was observed that farmers who used fertilizer more than the recommended quantity were about 19%, and those that used fertilizer below the recommended were about 55%. The study, therefore confirmed the assertion that fertilizer use on maize fields were low, especially in N nutrients, and that they needed to be increased. However, it must be noted that, higher N fertilizer application does not necessarily increase maize yields due to possible low agronomic use efficiency of higher N applied [24].

Phosphorus and K did not explain much of the variations within the maize grain yields because the quantities of P and K fertilizers applied by smallholder farmers in the study area did not vary much (almost the same quantities of 38 kg P_2O_5 (17 P) and 38 kg K_2O (31 K) per ha; **Table 3** and **Table 4**). There was no considerable range of variations within the P and K applications and hence a predictable relationship could not be properly established between these variables and the maize yields [25].

3.2.2. Comparison between Fertilizer input and Maize Grain Yields in 13 Districts of the Study Area

The test of comparison suggests that, even though researchers were applying high N and relatively the same amount of P and K fertilizer rates in the region, it did not translate into average yield output significantly ($p = 0.74$) higher than the farmers' output in the 13 districts.

Further evaluation of fertilizer input revealed that even though minimum amount of inorganic N (<64 $kg{\cdot}ha^{-1}$) and relatively the same amount of P (17 $kg{\cdot}ha^{-1}$) and K (31 $kg{\cdot}ha^{-1}$) fertilizer input were used in six districts (**Table 3**), there was an increase in maize yield. A study by Whiting, *et al.* [26] reported that minimum amount of fertilizer could increase crop yields. However, it was noted from this study that the minimum addition depended on whether or not that minimum amount (<5 bags of NPK 15:15:15 and 2.5 bags of SoA per ha as applied by the smallholder farmers in those communities) was sufficient in those locations to produce the required maize grain yields. Also, the minimum addition to some extent, depended on availability of cattle manure to some of the smallholders who may apply same on their fields.

Soils in Districts like Karaga and Tamale Metropolitan (**Table 3**) where minimum N fertilizer input yielded high maize yields could be deemed as highly responsive to the N fertilizer inputs [27]. Although low levels of applied fertilizer could lead to nutrient mining and imbalances in the long run [28], maize crops respond highly to the low levels because the small quantity of the applied N could cause high uptake by the maize crops [29], In addition, the relatively high yields obtained from low N fertilizer input could be due to the fact that most farmers around these locations used cattle manure in addition to the fertilizers. Addition of cattle manure and other animal resources, as well as the incorporation of crop residue, could increase maize yields even though minimum inorganic input was used [30] due to the synergistic effect between organic and inorganic materials [18].

Knowledge on nutrient requirement and availability at specific locations is also necessary because five other districts also used low N fertilizer input yet their maize yields remained low (**Table 3**). Such districts lacked required quantities of manure needed for effective maize production. Low use of organic manure in these districts [31] could have contributed to the low maize grain yields. The quantity of fertilizer input and their corresponding maize yields emphasised the fact that fertilizer recommendation must be promoted, especially in Northern Regions of Ghana, since increased N fertilizer application by researchers in the demonstration trials increased maize yields in the five districts. The promotion, however, should be district (location) specific and must reflect the availability and use of other local resources such as animal manure and crop residues [32]. Fertilizer inputs are sometimes scarce and not available to all smallholder farmers [33]. Therefore, to ensure that sufficient inorganic fertilizer quantities reach smallholder farmers for the intended use, it is essential that the nutrient contents of their farms be assessed as shown in this study using generated NPK contents distribution maps (**Figure 2**) as a guide. Moreover, it will provide a better opportunity for smallholder farmers who do not apply fertilizer on their farmlands to get access to the fertilizers and adopt their use [33] according to their nutrient needs.

It is also important to recognise nutrient management practices by indigenous smallholder farmers on their farms [34]. This is because some of their practices yielded better results than those of the researchers (**Table 2** and **Table 3**). What is important, according to Tittonell, *et al.* [27], is to promote the use of inorganic fertilizer in order to make the soils fertile enough to increase yield. The fertilizer use should be promoted especially in locations where the soil produced low maize yields and farmers did not have access to other organic fertilizer materials. In such locations, soils could be deemed less fertile or less responsive to fertilizer input [35] due to other limiting factors and constraints in the soil that impede nutrient availability [36], causing the applied nutrients not to be available to the maize crops; and such situation requires extensive research. Responsive soils show acceptable responses to input fertilizer even when they are minimal [37]. Other factors that might have contributed to the low maize yield output are poor rainfall distribution in the region, whereby some locations might receive less rainfall than others [38], inherent properties of the soil or soil forming processes [39].

3.2.3. Recommendation of ISFM Options in Low Maize Yield Output Districts

Majority of maize fields are found in the savannah areas where the soil has the required physical characteristics to support its production [40] [41]. Generally, what affects the soils production capacity in savannahs is the level of nutrient contents, which when well managed can enhance maize production [42]. Since the mean N, P and K nutrient contents around these locations are below the average requirements for maize production due to continuous removal of the vegetation cover [14], ISFM nutrient management practice that produces higher maize yields is regarded as a better option to meet food security demand [15]. For example, in Yendi district, 2 bags of NPK 15:15:15 and 1.5 bags of SoA used in the demonstration trials produced the highest maize yields and was therefore recommended in the district. The identified ISFM strategies for the five districts represented a location-specific remedy for each of these five districts.

It must however be noted that, although the practice from the researchers' demonstration may give desired and increased maize yield (**Table 5**), they may not be beneficial in terms of increased farmers income (**Figure 5**). The production of maize involves making investment in inputs to maximise yields and increase smallholder income [43]. The P/V ratio obtained for both farmers and researchers practice indicate that indeed the demonstration trials have equal P/V ratios in Kumbungu, Nanumba South and Yendi; and so, since the maize yields of the researchers were higher than those of the farmers in such districts, the researchers' strategies would be deemed better than the practices of the farmers because it would bring about food security as well as sustained income for farmers. The P/V ratios for Zabzugu and Gushegu districts were higher for farmers than the researchers practice and, in this instance, the farmers practices would be deemed as appropriate in order to secure their income and improve their livelihoods other than producing more maize yields and obtaining reduced income. Maize production with higher P/V ratios would be preferred to production with low P/V ratios [19]. However, since profit is one of the main goals in making investment [44], where the profit margin is higher would be preferred, (taking for example, what happened with researchers' profit compared to farmers' profit in Zabzugu district (see **Figure 5**)).

4. Conclusions

Low levels of N, P and K contents in the Northern part of Ghana could be improved with the use of fertilizer to reduce the wide variation in nutrient contents to support maize production. However, the application of the fertilizer amount should be based on the nutrient contents already in the soil and other resources available to smallholder farmers. Evaluation of farmers' and researchers' fertilizer application practices revealed that some practices adopted by indigenous smallholder farmers in some districts resulted in higher maize grain yields compared to those from demonstration trials. These results provide clear signals for in-depth research and collaboration with indigenous farmers for better yield output.

In addition, the study identified, in five districts, researchers' trials that produced increased maize yields that were recommended for adoption in these districts. With the hope to enhance food security in Ghana, smallholder farmers in Zabzugu, Kumbugu, Nanumba South, Yendi and Gushegu could increase maize grain yields by 36% based on adopting the recommended practice by ISFM researchers. However, not all yield increment may be profitable to the smallholder farmer considering the net profit of his/her own practice and that of the proposed strategy as revealed through this study. The study therefore recommends that farmer/researcher collaboration should be strengthened in order to promote farming practices that sustains income and food production at the same time.

Conflicts of Interest

The author declares no conflicts of interest regarding the publication of this paper.

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