EFFECTS OF ADOPTING FERTILIZER MANAGEMENT PRACTICES ON YIELD IN MAIZE-BASED SYSTEMS IN EMBU COUNTY, KENYA: AN INSTRUMENTAL VARIABLE REGRESSION APPROACH

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ABSTRACT

Global food security is increasingly becoming dependent on judicious fertilizer use. However, inefficient use by farmers has hindered yield potential and caused environmental pollution. The principles of "4R Nutrient Stewardship" promote best fertilizer management practices for enhanced economic, social and environmental outcomes. Despite widespread promotion of various fertilizer management practices under the 4R- framework, the empirical evaluation of their effects on yield remains limited. This study therefore employed an Instrumental Variable regression model to evaluate the nuanced effects of fertilizer management practices on yield. Results of the IV regression revealed that adoption of manure plus inorganic fertilizer, split application, soil testing and precision fertilization positively influence maize yield. Furthermore, practices such as intercropping, soil moisture conservation, crop rotation, and agroforestry positively influence yield, whereas minimum tillage has a negative effect. Efforts should be directed towards supporting and expediting the adoption of fertilizer management practices under the 4R- Nutrient Stewardship to increase maize yields among smallholder farmers.

Keywords: Maize, Fertilizer Management Practices, 4Rs, IV regression, Effects

INTRODUCTION

Food insecurity remains a pressing global issue, disproportionately affecting Africa (FAO *et al.*, 2023). In Kenya, it was projected that 4.4 million individuals are at a risk of facing acute food insecurity (IPC, 2022). In a world faced by pervasive hunger and malnutrition, global production of the world`s major grains like maize must double by 2050 in order to feed the growing population (Tian *et al.*, 2021). Maize (Zea mays L.), is a valuable cereal crops in Sub-Saharan Africa contributing significantly to dietary needs and supporting millions of smallholder farmers (FAO, 2021). Despite its indispensable role, maize productivity has not increased in a proportionate manner and significant gaps in yields are still evident.

Fertilizers play an important role in maize production and have been acknowledged for their potential in boosting yields by a substantial margin of between 40 to 60 percent (FAO, 2015). Nevertheless, escalating fertilizer prices have led to suboptimal utilization (Obour *et al.*, 2015). Excessive application, on the other hand, raises environmental concerns (Sapkota *et al.*, 2014). Additionally, farmers lack knowledge on fertilizer use and often apply excess or insufficient fertilizers (Aryal *et al.*, 2018 ; Kishore *et al.*, 2021). Recognizing the above limitations in fertilizer use, the Four Rights (4Rs) (*right rate, right source, right time, right place*) of fertilizer application were formulated through cross-sector collaborative efforts by the International Fertilizer Industry Association (IFA) and the International Plant Nutrition Institute (IPNI) as guidelines for optimal management of fertilizers worldwide (IPNI, 2014). Best fertilizer management practices under this study including soil testing, split application, combining manure with inorganic fertilizers, precision fertilization, and concurrent application of fertilizers and seeds during wet planting are inherently embedded within the 4R Nutrient Stewardship framework. They have been promoted for adoption in different regions. However, empirical evidence showing effects of adoption on maize yield among small-scale maize farmers remains sparse. This study therefore sought to assess effects of fertilizer management practices under the 4Rs on maize yield. Addressing this gap is important to get detailed insights into the best fertilizer types, applications rates, timings, and placement methods for maximum maize yield.

METHODOLOGY

Study area, data sources and sampling procedure

This study was conducted in Embu County, in upper Eastern Kenya. Embu is one of the strategic areas of African Plant Nutrition Institute owing to the strong interaction between water and nitrogen as key factors influencing yield in dryland maize-based crop systems. A household survey was conducted, and data was collected using structured questionnaires anchored on an android aided platform (Survey to go). A multistage stratified sampling technique was employed in selecting sample sub-locations and households. The study excluded higher wet zones, and dry lower zones where maize is not majorly grown. The agro-ecological zones were stratified into three transects (1, 2, and 3) encompassing the sub-locations.

There are about 5200 farmers within these transects (list provided by the Sub- County agriculture officers). This created a definite sampling frame and therefore the study adopted the Taro Yamane (1967) formula below. n=$\frac{N}{1+Ne^2}$ where: n = sample size, N = total population, and e = margin of error. The sample size was computed with a confidence level of 95%. n= $\frac{5200}{1+5200*(0.05)^2}$ = 371 maize farmers. Data cleaning was done thereafter to identify and remove duplicates and address outliers arriving at a final data set of 365 farmers.

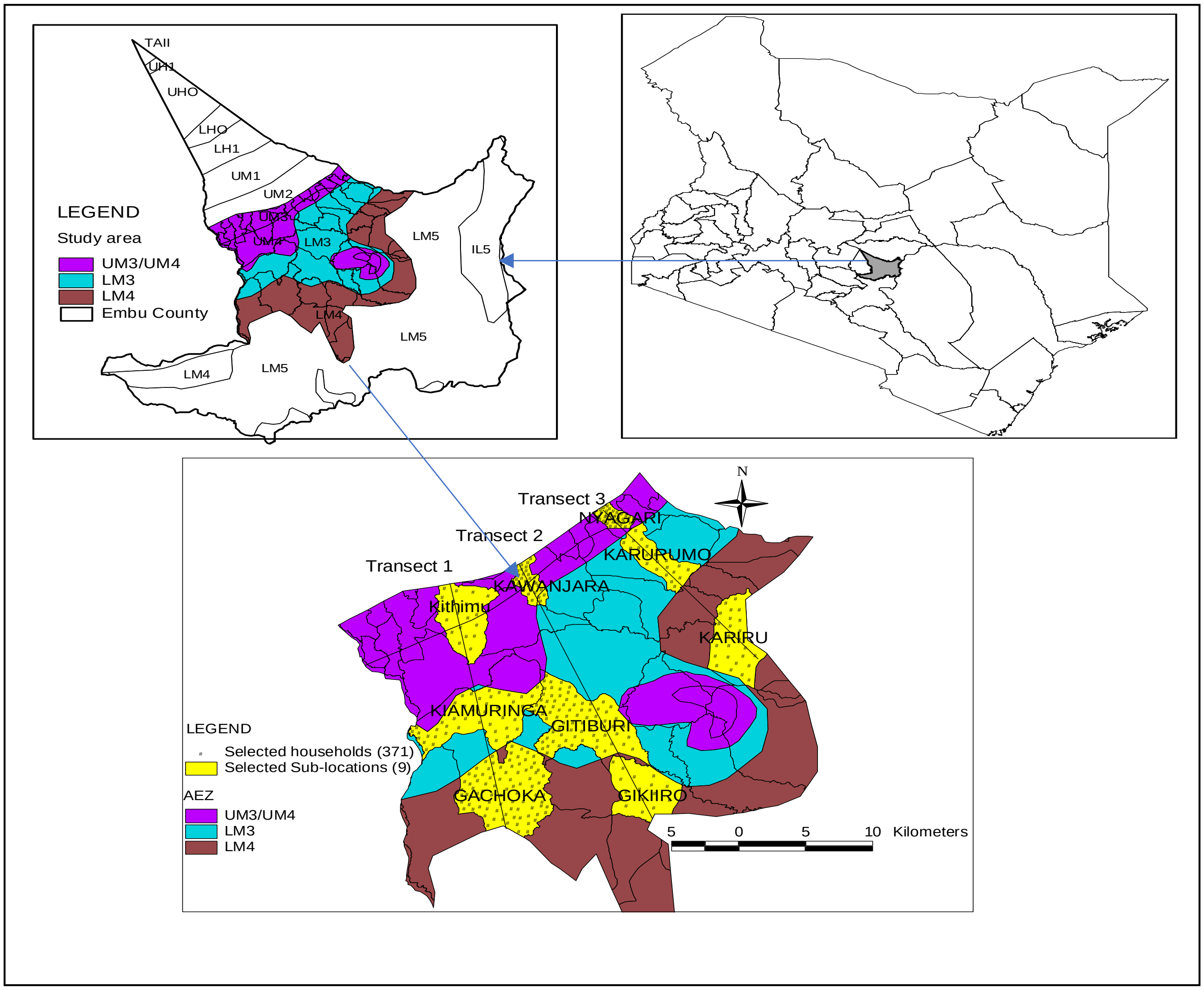

Figure 1. Map showing the study area. Source: Author`s compilation

RESULTS AND DISCUSSION

Effects of adopting fertilizer management practices on maize yield- IV regression

Results of the Instrumental Variable (IV) regression are presented in table 1 revealing the effects of four fertilizer management practices on maize yield. Adoption of manure plus inorganic fertilizer was found to increase maize yield by 306 kilograms/acre. This result highlights the importance of an integrated nutrient management approach, where organic nutrient sources such as manure are combined with inorganic fertilizers. It was further revealed that, compared to non-adopters, farmers adopting precision fertilization experienced significant increases in maize yield, of 294 kilograms per acre. Precision fertilization through side banding application involves placing fertilizer near the root zones ensuring efficient nutrient utilization. Adoption of this practice enhances efficient and targeted nutrient application, ensuring site-specific nutrient supply to maize. The IV regression analysis further revealed that adoption of soil testing had a positive and significant effect on maize yield, increasing yield by 1037 kilograms/ acre. Farmers leveraging soil testing can align their fertilizer applications precisely to meet specific soil deficiencies and requirements.

Table 1. Results of IV regression on effects of fertilizer management practices on yield

Variable	Manure + fertilizer	Precision fertilization	Soil testing	Split application
	Coefficient (Std error)			
Land tenure individual	-6.4029 (63.5392)	-43.3200 (60.4266)	-45.1778 (57.9350)	-42.9425 (60.7676)
Experience	-2.418957 (2.9040)	-2.9043 (2.8824)	-2.4473 (2.7452)	-2.9685 (2.9029)
Intercropping	600.2347 (92.3679) ***	612.856 (91.1396***	532.7773 (105.9075) ***	583.8539 (94.3519) ***
Minimum tillage	-222.1926 (82.6809) ***	-204.9583 (80.7194) **	-68.8440 (108.8409)	-214.660 9 (82.3724) ***
Monoculture	470.1703 (101.7040) ***	502.0999 (97.6594***	453.0867 (105.8808) ***	461.2402 (105.4477) ***
Moisture conservation	-85.85303 (72.4340)	-96.97673 (71.4337)	153.1873 (77.2872) **	-100.9195 (71.8379)
Conventional farming	-81.17338 (81.0702)	-57.7537 (79.0499)	46.8493 (100.5287)	-64.7622 (79.8595)
Crop rotation	691.5752 (83.3769) ***	677.5726 (87.9084) ***	641.7493 (102.1253) ***	670.0214 (90.6610) ***
Agroforestry	439.9163 (69.1065) ***	439.9945 (68.3584) ***	417.3008 (67.9312) ***	443.0685 (68.7047) ***
Farm demonstrations	Instrument **	Instrument 1**	Instrument 1**	Instrument 1**
Soil fertility training	17.0645(78.3552)	Instrument 2**	Instrument 2**	Instrument 2**
Farm experimentation	-4.4157(56.5874)	-8.5776(56.7589)	-31.5137 (60.4823)	-23.43488(59.6578)
Effect on maize yield	305.564 (168.339) *	294.2713 (177.0331) *	1037.811 (706.9282) **	295.1308 (179.2012) *
No. of observations	365	365	365	365
Wald χ2	χ2 (18) 161.33	χ2 (18) = 162.67	χ2 (18) = 171.73	χ2 (18) = 171.73
Prob > χ2	0.0000	0.0000	0.0000	0.0000
R-squared	0.2919	0.31	0.36	0.29

The practice of split application demonstrated a positive effect on maize yield, increasing yields by 295 kilograms per acre. Nutrient distribution at different growth stages maximizes nutrient availability when plants require them most, leading to vigorous growth and increased yield. This study further revealed that, practices such as intercropping, soil moisture conservation, crop rotation, and agroforestry positively influenced yield, whereas minimum tillage had a negative effect.

CONCLUSION AND RECOMMENDATIONS

This study assessed effects of adoption of fertilizer management practices on maize yield. The study used the Instrumental Variable regression model to assess effects of adoption. Average maize yield stood at 1552.05 kg/ha, which is significantly lower than the global average and potential yield. Adoption of practices like manure plus inorganic fertilizer, split application, precision fertilization (side banding) and soil testing positively influence maize yield. Other practices including intercropping, soil moisture conservation, crop rotation, and agroforestry also positively influence yield, while minimum tillage was associated with reduced yields. The findings from this research collectively highlight the important role of different fertilizer management practice under the 4R-Nutrient Stewardship in addressing the existing yield gaps and enhancing maize productivity in Embu County, addressing food insecurity concerns. Efforts should be directed towards supporting and expediating the adoption fertilizer management practices to increase maize yields among smallholder farmers in different regions.

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