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DETERMINANTS OF THE ADOPTION OF INTEGRATED SOIL FERTILITY MANAGEMENT TECHNOLOGIES IN MBALE DIVISION, KENYA

Aura S[1*]

Sylvester Aura

*Corresponding author email: slyaura2002@yahoo.com

[1]Rural Outreach Program (ROP), P.O. Box 29086 – 00625 Nairobi, KENYA

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ABSTRACT

The agro-climatic conditions in western Kenya present the region as a food surplus area yet people are still reliant on food imports, with the region registering high poverty levels. Depletion of soil fertility and the resulting decline in agricultural productivity in Mbale division has led to many attempts to develop and popularize Integrated Soil Fertility Management (ISFM) technologies that could restore soil fertility. These technologies bridge the gap between high external inputs and extreme forms of traditional low external input agriculture. Some of the ISFM components used by farmers are organic and inorganic inputs and improved seeds. However, the adoption of these technologies is low. The study aimed to examine the factors that influence the adoption of ISFM technologies by smallholder farmers in Mbale division, Kenya. The study was conducted in 9 sub-locations in Mbale division. Purposive sampling was used in selecting the 80 farmers to get the data based on a farm-household survey. Self-administered questionnaires were used to collect data on the determinants of the adoption of ISFM technologies from the sampled farmers in the study area. The study sought to answer the research question: What factors influence the uptake of ISFM technologies by farmers in Mbale division? The hypothesis tested was that the adoption of ISFM technologies is not influenced by age, education, extension services, labour, off-farm income and farm size. Data was analyzed using descriptive statistics. Cross tabulation was used for examining the relationship between categorical (nominal or ordinal) variables, and the bivariate correlations procedure was used to compute the pair wise associations between scale or ordinal variables. Probit regression was used to predict the socio-economic factors influencing the adoption of ISFM technologies among smallholder farmers. Results of the study indicated that education of household head, membership in social groups, age of the household head, off-farm income and farm size were the variables that significantly influenced the adoption of ISFM technologies. The findings show that there is need for a more pro-poor focused approach to achieve sustainable soil fertility management among smallholder farmers. The findings will help farmers, extension officers, researchers and donors in identifying region-specific entry points that can help in developing innovative ISFM technologies.

Key words: Soil fertility, adoption, smallholder farmer, integrated soil fertility management

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INTRODUCTION

While agriculture remains the mainstay of economies for many countries in sub-Saharan Africa (SSA), the poverty rate is expected to fall further from 48.5% to 24% by 2030, representing 300 million people, but its share of global poverty balloons to 82% [1]. Poor and declining soil fertility is the biophysical root cause for declining per capita food production in SSA [2]. The agro-climatic conditions in western Kenya present the region as a food surplus area [3]. In reality, the people are still reliant on food imports, whilst national poverty surveys consistently show them to be amongst the poorest in the country [4]. At the root of this problem is low productivity, declining soil fertility coupled with low use of improved inputs such as fertilizer.

One way to address the problem of low agricultural productivity and environmental degradation is through increased adoption of ISFM technologies, particularly fertilizer use –both organic and inorganic, especially in low income countries where fertilizer use is lowest [5]. Inorganic fertilizer use in grain production, for example, can increase output by 40-60% [6]. Application of organic fertilizer on the other hand provides some nutrients besides playing a crucial role in improving soil moisture conservation, especially when combined with conservation tillage practices that protect soil structure, reduce erosion and runoff, and promote soil biological functions important for soil productivity. Nonetheless, a combination of organic and inorganic fertilizer for integrated soil fertility management is the most ideal in increasing yield while maintaining long term soil fertility [6].

Indirectly, use of fertilizers leads to higher economic growth and poverty reduction through increased agricultural productivity and output [7]. This is particularly more evident in sub-Saharan Africa (SSA) countries where agriculture is the primary sector and source of livelihood to the majority of the population [8]. On the environmental front, agricultural intensification – where a farmer gets more output from the same piece of land by using high yielding inputs including fertilizer, reduces forest cover loss and promotes biodiversity [5]. Nevertheless, if not well managed, long-term use of fertilizer – whether organic or inorganic, results in inefficiencies of input use, leading to soil degradation, lower productivity and potential damage to the environment [9].

Despite the benefits, adoption of ISFM technologies in crop production in Kenya remains low. According to the World Bank report, 2006 [8], unless radical interventions occur, projected inorganic fertilizer consumption growth in SSA until 2030 will remain at 1.9% per annum. This is attributed to a range of factors -both economic and non-economic, that hinder adoption of ISFM technologies.

RESEARCH METHODOLOGY

Mbale division in Vihiga County, covers an area of 96 km^2 and falls between Latitude: 0°04' 15"N and Longitude: 34°44' 59" E. Altitude is between 1300 and 1500 m.a.s. and land is dominated by rugged terrain. The area experiences bimodal rainfall which is well distributed throughout the year and ranges from 1800 mm to 2000 mm. The average farm size is 0.72 ha with a population density of over 1100 people per square

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kilometer [10]. Maize (*Zea mays* L.), often intercropped with beans (*Phaseolus* spp.), dominates the cropping pattern. The soils have low fertility with deficiencies of phosphorus (P) and other nutrients. The agricultural practice is continuous cropping with low soil replenishment and a high demand for wood products making agroforestry interventions a possible solution [11]. The major soils are dystric acrisols and humic nitosols. Ecologically, 95% of the total area in Vihiga district falls in the upper midland 1 (UM1) agro-ecological zone (AEZ), whilst 5%, is in the lower midland (LM1) [12].

Research Design and Sampling design

A survey design that entailed interviewing of respondents was used to provide a detailed examination into the subject matter under study. The purpose of this quantitative correlational study was to determine the socioeconomic factors that influence farmers' adoption of the ISFM technologies in Mbale division. It employed a non-experimental design since the subjects were not randomly assigned to the control or experimental group. Key informant interviews were used to collect information from the farmers on the effect of various ISFM practices on the crop productivity and income, as well as the constraints and determinants of the adoption of those practices. Primary sources of data were questionnaires while secondary sources included reports and unpublished data on any projects in the area concerning ISFM.

The predictor variables were: the level of education, labour, extension services, age, gender, off-farm income, farm size and group membership.

The outcome variable was the degree of adoption (farmers' level of use) of ISFM technologies. The study sought to answer the research question: What factors influence the uptake of ISFM technologies by farmers in Mbale division? The hypothesis tested was that the adoption of ISFM technologies is not influenced by age, education, extension services, labour, off-farm income, gender and farm size.

The study employed non-probability sampling in the selection of subjects to be used. A multistage purposive sampling procedure was adopted to select farmers from nine sub-locations that were practicing ISFM. These sub-locations were Muhanda, Chambiti, Mbihi, Vunandi, Kegoye, Kigama, Munoywa, Bugina and Magu. Sample size was determined using Fisher equation. The number of respondents was set at 80, which was a convenient sample of population that practices ISFM. A sample size of 80 was thus selected at a confidence level of 95% and a marginal error of 5%.

The Fischer equation uses the following formula in the calculation of a sample size.

$N = \frac{z^2 pq}{d^2}$............................. [13]

Where ;

N = the desired sample size

Z= the standard normal deviate (1.96 for 95% confidence interval)

p = percentage picking a choice, expressed as a decimal (0.5)

q = (1-p)

d = the level of accuracy desired, or sampling error, (often set at 0.05)

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Data collection
Structured self-administered questionnaires were used. This entailed posing questions systematically along the expected answer to find out what the farmers encounter as they employ various soil enhancing technologies**.** Emphasis was put on what farmers encounter when cultivating their produce and also as they try to orient their agricultural production markets. Information captured using this approach included the type of soil fertility enhancing technologies, size of farm allocated to preferred crops, socio-economic characteristics such as education level of farmers, marital status, family size and gender diversity and factors affecting their adoption of ISFM technologies.

Data analysis:
Quantitative data was processed, coded and analyzed using Statistical Packages for the Social Sciences (S.P.S.S version 20). The results were presented by use of descriptive statistics, namely percentages and frequencies. Probit regression model was used to predict the socio-economic factors influencing the adoption of ISFM technologies among smallholder farmers in the study area.

Ethical consideration:
The study was conducted in accordance with the standard research ethics [12]. Informed consent was sought prior to data collection. Anonymity and confidentiality were also upheld. An appointment for administration of questionnaires to the respondents was prepared with the assistance of the village elders.

RESULTS

Socio-demographic characteristics

The socio-demographic characteristics of the farmers who participated in this study in Mbale Division are represented in Table 1. Most of the respondents were female (68.3%), while most household decisions were made by men (62.8%). A high number of respondents were married (79.6%) and had attained secondary school education (41.7%). Those who had attained at least post secondary education were 10.1%, with only 4.6 % of the respondents being illiterate.

Soil management practices
On the basis of data analyzed to inquire about the soil management practices used in Mbale division, inorganic fertilizers, manure, compost and a combination of the three were the main components used. Results of the surveyed sources of soil nutrients show that organic matter was the most widely applied among households at about 34.7%, while 21.5% used inorganic fertilizers (Table 3). Only 30% of the households applied combinations of inorganic fertilizers, manure and compost. A small proportion of farmers (5.1%) registered zero usage of any of the aforementioned soil management practices. The average rate of manure application was 1.45 tons per hectare (t ha^{-1}) against the recommended rate of 5 t ha^{-1} for most crops. Table 3 further shows that 21.5% of the farmers used inorganic fertilizers. The amount of inorganic fertilizer nutrients applied was relatively low, averaging 14.9 kg ha^{-1}. Farmers in Vihiga district on average

applied inorganic fertilizer rate of 10.7 kg ha^{-1}, which is much lower than the already low Kenyan average of 31 kg ha^{-1} against the recommended rates of 120 kg ha^{-1} [15, 16]. Green manure was not popular in the study area as only 8% of the sample households used it. None of the farmers who adopted green manure used it singly, hence it was not reported in Table 3.

Determinants of the adoption of ISFM practices

A probe into the determinants of the adoption of selected ISFM components revealed that education of household head (Educ) was positively associated with both adoption of inorganic fertilizers ($p < 0.05$) and combination of inorganic with organic resources ($p < 0.1$). Age of the household head was negatively associated with the adoption of inorganic fertilizers. Off-farm income (Officome) as the main source of income was positively correlated with the adoption of inorganic fertilizers ($p < 0.01$) whereas per capita farm size (Fampersn) was negatively associated with the probability of adoption of manure ($p < 0.01$) and ISFM as a whole ($p < 0.05$). The ratio of household members who provide farm labour (Labour) was positively associated with probability of adopting inorganic fertilizers ($p < 0.1$) and manure ($p < 0.05$). Distance to the major market (Distomkt) showed a weak association with the adoption of inorganic fertilizers ($p < 0.1$) and compost ($p < 0.05$). Membership in social groups (Grpmemb) had positive influence on the adoption of inorganic fertilizers ($p < 0.1$) and manure ($p < 0.01$) while access to extension contacts (Extensn) had a positive effect on the adoption of inorganic fertilizer ($p < 0.1$).

DISCUSSION

These results generally show that the educational level of most of the surveyed farmers is sufficient for adoption of good agricultural productivity practices. Increasing literacy helps farmers to acquire and understand information and to calculate appropriate input quantities in a modernizing or rapidly changing environment. Post primary education influences adoption of new innovations because it is associated with ability to synthesize more information on offer and improvement of farm management [14]. Most respondents said they preferred animal manure since it costs less than inorganic fertilizers. This can be attributed to the fact that farmers kept a few livestock due to feed shortage occasioned by land scarcity resulting in the production of low quantities of manure.

A few farmers that used inorganic fertilizers could not afford the recommended rates owing to financial constraints; poor access to credit and high risks associated with agricultural enterprises. This makes integrated application of the ISFM practices rather difficult as inorganic fertilizer is a key ingredient for implementation of ISFM strategy. The dismal adoption of green manure was attributed to inadequate information on its use, especially on incorporation of green manure into the soil, and high labour demand at the time of planting.

Integrated Soil Fertility Management practices are knowledge-intensive and require considerable management input. Formal schooling may enhance or at least signify latent managerial ability and greater cognitive capacity. The implication would seem to be that

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extension systems and agricultural development projects in the region should seek not only to provide technological options to small farmers, but also to attempt to make up for low levels of educational attainment, perhaps through emphasis on management training and skills building.

As decision-makers age, their planning horizons shrink and so the incentives for them to invest in the future productivity of their farms diminish. They become more conservative, risk averse and do not easily learn or adopt the new innovations. Moreover, younger farmers may incur lower switching costs in implementing new practices since they only have limited experience and the learning and adjustment costs involved in adopting ISFM practices may be lower for them. Moreover, since ISFM practices generally require more physical effort, the relatively healthier and stronger younger farmers are more likely to implement them than their older counterparts. This raises an important extension policy issue. Extension systems must differentiate their clientele based on critical demographic characteristics such as age. If younger farmers are more likely to adopt new practices, perhaps extension messages should be focused on certain (younger) age cohorts, especially in the early stages of technology development and dissemination.

Off-farm income from informal and formal non-agricultural employment is important in fostering adoption of the ISFM practices. Cash is essential in the hiring of labour for the construction and maintenance of compost and farmyard manure, as well as for purchase of chemical fertilizer. At existing productivity levels and production scales, the high-population-density smallholder farming system of this part of western Kenya might not be generating sufficient investible surpluses to remain self-sustaining in the absence of non-farm income to invest in sustainable agricultural intensification, including through ISFM [17].

Soil management practices are not strictly scale neutral or, more likely, that the unobserved constraints and shadow prices facing households vary systematically with farm size. Increasing farm size may be proxy for other factors unaccounted for in the present regression model, especially the growing of tea or other cash crops such as vegetables which may be selectively targeted for chemical fertilizer application by these farmers). However, if ISFM practices are scale-dependent economically, even if they are technologically scale-neutral, research and extension practices must take this into account, especially in places such as western Kenya where farm sizes rarely exceed one hectare and now average less than 0.4 ha [18]. The policy lesson for research and extension is that ISFM technology development must emphasize not only sufficient divisibility but also that new methods prove remunerative even at small scales of operation.

Family labour (as proxied by number of adults in the household) assumes great importance given that low incomes constrain financial liquidity for hiring wage labourers, and given possible moral hazard problems associated with non-family labour calling for considerable supervision. These problems raise the real cost of hired workers beyond the observed wage rate. Given that the bulk of labour for most farm operations in this region is provided by the family rather than hired, lack of adequate family labour

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accompanied by inability to hire labour can seriously constraint the adoption of ISFM technologies [19]. The result is consistent with an earlier study in western Kenya, which found that labour constraints had a significant negative effect on the adoption of improved tree fallows, which are labour- intensive like manure use [20, 21].

Gender also plays a crucial role in the adoption of ISFM technologies. Previous research in Africa has documented women's lesser access to critical resources (land, cash and labor), often undermining their ability to mobilize labour, including reciprocal labour which often requires considerable food expenditure needed to carry out labour-intensive ISFM construction and maintenance activities [22]. The small coefficients for manure and fertilizer suggest that controlling for non-farm income and livestock holdings that are strongly correlated with the gender of the household head; gender alone has minimal independent effects on these two ISFM practices. Therefore, it does not appear that gender *per se* heavily affects these particular adoption patterns. Rather, the inherent resource inequities between men and women play a big role. These inequities are caused by cultural conditions in many African societies which traditionally did not grant women secure entitlements to land and other property [23].

For more labour-dependent practices such as compost and farmyard manure application, by contrast, women fare better, perhaps due to superior social capacity to mobilize family or other reciprocal labour. This may mask inherent gender differences in conditional adoption rates. Research and extension organizations will need to compensate for this by making extra efforts to reach women, who are generally disadvantaged by skewed patterns of endowments of critical resources needed to make ISFM practices adoption remunerative.

Group memberships could enable members to be exposed to information on improved technologies. Other studies have similarly reported a positive influence of group membership on the adoption soil management technologies [24], particularly organic fertilizers. Farmers who belonged to a farmers' association were more likely to adopt an agricultural technology [25]. Trust, group activities and past adoption learning effects from other farmers (social learning) significantly influences the adoption behavior [26, 27]. Farmer groups unite individual farmers in order to determine and set production standards and by-laws in ISFM practices. These groups undertake collective off-farm investments such as packaging and storage facilities for harvested produce. They also influence introduction of educational programmes at the lower levels of the education ladder.

Overall, the above results confirm earlier observations that farmers do not adopt a complete package of a technology even when extension attempts to popularize it because of capital scarcity and risk considerations. They instead adopt parts or a component of recommended technology [28]. Thus, different households have different adoption patterns of a given technological package. Some households combined organic and inorganic fertilizers, while others did not.

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CONCLUSION

Results showed that determinants of the adoption of ISFM technologies varied by the practices surveyed. Resource endowment in land, relative cost and access to inputs are some of the factors that influenced the ability of farmers to adopt ISFM technologies. Age and sex of the household head also influenced the intensity of application of organic and inorganic inputs. Per capita farm size reduced the rate of adoption of ISFM practices while access to off-farm income increased the likelihood of the adoption of inorganic fertilizer.

RECOMMENDATIONS

Since the choice of the soil fertility management practice is highly dependent on the capacity of the farmer to afford such investment, emphasis should be put on a pro-poor approach so as to achieve sustainable soil fertility management among smallholder farmers. Agricultural policy can be made more pro-poor if it focuses on programmes that promote the private incentives of sustainable soil fertility management practices. Such incentives include increased budgetary support to agricultural research and development, extension, seasonal agricultural credit and promotion of access to viable soil fertility technologies in the rural areas. These would help reduce the opportunity costs that farmers perceive when adopting various ISFM technologies. Lastly, projects should make available financial resources to support ISFM investments for farmer groups that are well organized and have prospects of success.

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Table 1: Key characteristics of Mbale Division

Annual precipitation (mm)	1900
Altitude (m)	1300-1500
Soils	Dystric acrisols, humic nitosols
Population (2009)	60,000
Population density (persons km^{-2}) (2009)	1100
Area (km^2)	96
Farm size (ha)	0.5

Table 2: Socio-demographic characteristics of the farmers in Mbale Division

Characteristics	% Response
Female (%)	68.3
Mean age	50.1
Mean family size	6.4
Chief provider (%)	
Wife	45.7
Husband	42.4
Decision Making	
Husband	62.8
Wife	8.5
Wife & Husband	26.7
All family members	2
Marital Status (%)	
Married	79.6
Single	4.2
Widow (er)	17.3
Divorced/separated	1.0
Household Head Education Level	
Primary	49.1
Secondary	41.7
Post-secondary	10.1
Illiterate	4.6
Adult education	0.0

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Table 3: Percentage adoption of soil fertility management practices in Mbale Division

Soil management practice	% Response
None	5.1
Inorganic fertilizers only	21.5
Manure only	34.7
Compost only	8.3
Inorganic fertilizer +Manure+Compost	30.4
Total	**100**

Table 4: Results of logit models for the adoption of ISFM practices

Variable	Inorganicfert.	Manure	Compost	ISFM
Percpn	0.291(0.113)***	0.207(0.095)	0.172(0.102)*	0.115(0.101)
Educ	0.569(0.280)**	0.456(0.282)	-0.059(0.283)	0.569(0.309)*
Age	-0.038(0.011)***	-0.009(0.010)	-0.010(0.010)	-0.001(0.010)
Gender	0.597(0.401)	0.211(0.337)	0.004(0.341)	0.172(0.346)
Officome	1.003(0.320)***	0.386(0.263)	0.277(0.275)	0.071(0.274)
Labour	0.086(0.052)*	0.678(0.361)**	0.332(0.341)	0.134(0.146)
Food	-0.887(0.369)**	-0.055(0.347)	-0.056(0.343)	-0.241(0.360)
Fampersn	-0.040(0.285)	-0.663(0.232)***	-0.320(0.265)	-0.740(0.302)**
Distomkt	-0.076(0.044)*	-0.048(0.035)	-0.119(0.057)**	-0.099(0.055)
Grpmemb	0.992(0.549)*	1.480(0.541)***	0.287(0.499)	0.143(0.585)
Extensn	0.538(0.295)*	0.280(0.251	0.039(0.265)	0.097(0.269)
Constant	2.059(1.024)**	0.252(0.949	-0.080(0.898)	-0.878(0.935)
Log-likelihood	-172.21	-203.25	-194.36	-184.084

Note: Values in parenthesis are standard errors * Significant at 0.1, **significant at 0.05, ***significant at 0.01

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