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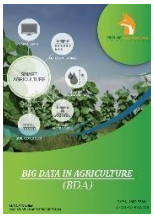

RESEARCH ARTICLE

FACTORS INFLUENCING THE ADOPTION OF INTEGRATED SOIL FERTILITY MANAGEMENT TECHNOLOGIES BY SMALLHOLDER FARMERS IN NAMTUMBO DISTRICT, TANZANIA

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ABSTRACT

Sub-Saharan African smallholder farmers face two challenges: low production and restricted funding for nutrient inputs. By combining the use of enhanced germplasm, prudent fertiliser use, and organic matter management tailored to the local farming conditions, integrated soil fertility management seeks to increase productivity. This study set out to evaluate determinants for the adoption of integrated soil fertility management technologies by smallholder farmers in Namtumbo district, Tanzania. The design of the study was cross-sectional. Using the random sampling technique, 223 respondents were selected. The study utilised IBM SPSS to analyse both descriptive and inferential statistics. The findings show that almost all farmers adopted the ISFM initiative's supported technologies, including better-quality seed strains, legume-maize rotation, and maize-legume intercropping. Findings on the determinants for the adoption ISFM knowledge were depicted by a binary logistic regression model whereby variables included in the model were good (Nagelkerke R2 = 0.81) predictors of determinants for adoption of ISFM technologies by farmers. Soil fertility, climatic conditions, education, participation in groups, access to extension services, cost of input and credit access had substantial ($p< 0.05$) influences on the probability of adoption of ISFM technology by a farmer. The inference of this discovery is that the adoption of ISFM technologies is affected by various factors. In order to guarantee accurate agricultural information on ISFM technologies and boost productivity, the study recommends increasing the number of extension staff and raising awareness among farmers about the importance of using extension staff. Adoption of ISFM procedures is also significantly influenced by the availability of better seed varieties. For this reason, smallholder farmers ought to have easier access to more inexpensive, better seed varieties. Furthermore, there should be a strong emphasis on intercropping maize and legumes as well as rotating legumes with maize.

KEYWORDS

Adoption, Determinants, Smallholder farmer, Soil fertility.

1. INTRODUCTION

In nations with limited resources, traditional farming practices depend largely on extracting minerals from the soil. Because crop cultivation is a key entrance point to breaking the never-ending cycle that underlies impoverishment in rural areas, there is raised understanding of the need to maintain the development of agriculture in these nations. Since fertiliser is an expensive commodity, the Alliance for a Green Revolution in Africa (AGRA) has embraced Integrated Soil Fertility Management (ISFM) as an approach for increasing crop yields by means of dependency upon soil fertility management expertise, with a focus on raised accessibility and utilisation of fertiliser made from minerals (Vanlauwe et al., 2011).

The Africa Soil Health Consortium defines ISFM as "a set of methods for managing soil fertility practices that optimise agronomic use of efficiency of the applied nutrients and improve crop productivity, typically requiring the use of fertiliser and enhanced seeds in conjunction with an understanding of how to adopt these practices to local conditions (Vanlauwe et al., 2010). According to this definition, ISFM involves using high-quality planting materials, applying the right amount of organic and/or inorganic fertiliser, or combining both.

ISFM is a group of soil fertility management practices that, in addition to knowing how to customise these practices to specific conditions, invariably involve the use of fertiliser, organic materials, and improved plant material in order to achieve the highest agronomic use efficiency of the applied nutrients and boost yields of crops (Fairhurst, 2012). Including legumes is essential to putting ISFM into practice (Vanlauwe, 2015; Mhango et al., 2012; Ollenburger, 2012). Generally speaking, ISFM offers one of the intensive, sustainable soil nutrition approaches that farmers have found to be effective (Ollenburger, 2012 and Sommer et al., 2013).

Over the past 30 years, sub-Saharan Africa's per capita food production is thought to have decreased due to a combination of population growth and soil nutrient depletion (IFDC, 2015). Historically, farmers have cleared ground, planted crops, and then moved on to clear extra land. By leaving the depleted land fallow, this technique helped it to restore its fertility. In addition, farmers are now compelled by the unceasing population growth to cultivate crops on the same plot of land, therefore "mining" the soil and removing all of its nutrients. In a region where many countries already import a sizeable amount of food, this extrapolates into a major increase in the requirement for food, fuel, feed, and fibre (IFDC, 2015).

Literature also demonstrates how current ISFM practices are influenced by well-established evidence of the positive effects of typical ISFM

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interventions at plot scale, such as multifaceted legume-cereal shifting (Sanginga et al., 2009), micro-dosing of manure and fertiliser for grain crops in drought-prone areas (Tabo et al., 2007), and the combined use of organic manure and mineral fertilisers, and the joint use of manure and inoganic fertilisers contributes to the current practices in ISFM. The ISFM is also in line with the ideas of sustainable intensification, which is one of the concepts driving efforts to boost smallholder farming systems' production (Pretty et al., 2011; Vanlauwe et al., 2010). Enhanced crop yield, preservation and/or restoration of other ecosystem services, and increased shock resistance are typically components of sustainable intensification. Studies on ISFM also suggest that by diversifying farming systems, basically with legumes, and increasing the availability of organic resources within farms, primarily as crop residues and/or farmyard manures, the technology enhanced an increase in crop productivity and likely enhanced other ecosystem services and adaptability (Vanlauwe et al., 2011).

Tanzanian agriculturalists have been confronting the challenge of access to fertiliser and soil degradation owing to inappropriate land use (Kaliba et al., 2000). It is therefore expected that the adoption of ISFM would benefit the agriculture sector, particularly smallholder farmers. Therefore, the study revisits the problem by examining how small-scale farmers in Tanzania's Namtumbo District have embraced ISFM techniques.

2. Research Methodology

2.1 Study area

The highlands comprise a range of volcanic mountains, partly covered in forest and grassland. The area is Tanzania's main breadbasket. This study was based on the district of Namtumbo in Ruvuma region which is located at 10.46643290S and 36.13009690E. The district was selected because it was involved in ISFM project under AGRA. The region is among Tanzania's main breadbasket.

2.2 Research design and sampling

A cross-sectional research design was applied. Determining the relationship between and among the variables as well as providing a description was both made easier by the design. In social science investigations, this approach has a higher level of accuracy as well as precision (Kothari, 2008). The design saves costs and takes a shorter period to collect data.

In all, 223 farmers participated in this investigation. Every farmer was given an equal likelihood of being chosen through simple random sampling. Additionally, the study purposefully chose its key informants.

2.3 Data collection

Observations, interviews, and documentary reviews were some of the techniques used to gather data. Patton (2002) has noted that using more than one data collection method strengthens and gives credibility to the study. The use of more than one data collection method thus portrays a true picture of the problem under study. Studies that use only one data collection method is vulnerable to errors linked to the particular method used.

2.4 Data analysis

Inferential as well as descriptive statistical techniques were used in the investigation. While means, frequencies, percentages, and cross-tabulations were examined as descriptive statistics, binary logistic regression analysis and the t-test statistic were employed as inferential statistics. IBM SPSS Statistics version 24 was software used for all analysis.

2.4.1 Binary Logistic Regression Model

The likelihood of a binary response based on one or more predictor (or independent) variables (features) is estimated using the binary logistic model. For this study, the following model was used.

$\text{Log}(p/1\text{-}p) = \beta 0 + \beta_1 X_{1i} + \beta_2 X_{2i} + \beta_3 X_{3i} + \beta_4 X_{4i} + \beta_5 X_{5i} + \ldots\ldots\ldots + \beta_{11} X_{11i}$

Where:

Log (p/1-p) = log-odds ratio

p: Probability that farmers adopted ISFM technologies given X (Y 1 = adopted, 0 = not adopted)

Where;

β_0 = Model constant

$\beta_1 - \beta_{11}$ = Parameters for independent variables

X_1 = Soil fertility

X_2 = Technology complexity

X_3 = Climate

X_4 = Education

X_5 = Participation in groups

X_6 = Extension services

X_7 = Cost of input

X_8 = Access to credit

X_9 = Access to output market

X_{10} = Sex

X_{11} = Age

ε = error term

3. Results And Discussion

3.1 Demographic features of respondents

3.1.1 Gender of respondents

Table 1 disclosed that 47.5% of respondents were women and 52.5% of them were men. The results imply that both may utilise agricultural technologies regardless of gender. In contrast to research findings, researchers suggesting that men had better access to technology than women (Okuthe et al., 2013). However, adoption is positively impacted for households headed by males as, in most societies, men are in charge of productive resources like labour, capital, and land: all of which are essential for the adoption of new technology (Abunga et al., 2012). On the other hand, because they have less access to the resources needed for production, families headed by women tend to embrace technology less frequently (Matata et al., 2010).

3.1.2 Age of respondents

Table 1 displays data which indicates that 56.5% of farmers are between the ages of 36 and 50. The farmers were 42 years old on average. This shows that the majority of the small-holder cultivators belonged to the age group that is considered active, which promotes effective engagement in agricultural operations. This result is consistent with research conducted on the Mkindo irrigation scheme's economic impact and viability in Tanzania (Yamindanda, 2013). About 13.6% of the agricultural workforce was in the 18–35 age range, according to the descriptive study. It is the youth group that participates in farming to a lesser extent. This was anticipated as a researcher hypothesised, that young people are more driven to pursue other careers than farming (Bett, 2006). Older adults who were 51–60 years old (22.8%) and above 60 (6.1%) were the age groups most likely to have more agricultural experience and, thus, be more open to implementing ISFM technologies.

3.1.3 Level of education

According to the report, 99.1% of smallholder farmers have completed primary education, and 0.9% has completed secondary education (Table 1). Smallholder farmers may learn, use, and accept new and suitable agricultural technologies from extension officials with the help of this literate level. The results supported the report in 2010, which found that education increases farmers' access to fertiliser information and their understanding of how much to apply (Zhou et al., 2010). Education exposure may raise farmers' technological awareness and, in turn, their ability to implement a particular technology.

3.1.4 Marital status

Table 1 indicates that 84.3% of the participants are married. This suggests that those who responded are individuals who are in charge of meeting their own families' everyday needs. In order to improve food security and household income, they were also dedicated to agricultural output. Furthermore, the percentages among those surveyed who were single, divorced, widowed, and widower were 3.6%, 1.8%, 5.4%, and 4.9%, correspondingly. Given their familial responsibilities, married people may have an impact on economic activity more than single, divorced, widowed, or widower people, respectively. This finding is supported by researchers in 2003 (Kiriti and Tisdell, 2003).

Table 1: Social-economic characteristics of respondents			
Characteristics	**Frequency(N=223)**	**Percentage**	**Mean**
Gender distribution			
Male	117	52.5	
Female	106	47.5	
Age distribution (Years)			
18 -35	31	13.9	
36 -50	126	56.5	46
51 -60	52	23.3	
Above 60	14	6.3	
Education Level			
Primary	221	99.1	
Secondary	2	0.9	
Marital status			
Married	118	84.3	
Single	8	3.6	
Divorced	4	1.8	
Widow	12	5.4	
Widower	11	4.9	

3.2 ISFM Technologies

3.2.1 Sources of Information about ISFM technologies to the farmers

The Tanzanian government uses a variety of policy tools, including agricultural extension and research, to accomplish its agricultural objectives. Table 2 reveals that 99.6% of farmers get information from extension staff. Other sources of information include fellow farmers (33.6%), lead farmers (19.7%) and field demonstrations (14.3%). Agricultural extension services enable farmers to learn about new or better technologies, and extension workers advise farmers to adopt them in order to promote the usage and adoption of agricultural technology, particularly soil fertility technologies. For example, a study in 2004 indicated that the adoption of improved technology was positively impacted by an extension service (Mugisha et al., 2004). According to Altalb et al., 2015), agricultural extension is the cornerstone for transferring agricultural innovations to farmers and convincing them to use those practices.

Table 2: Farmers' information on ISFM technologies (n = 223)		
Variables	**Frequencies N = 223**	**Percentages***
Extension staff	222	99.6
Fellow farmers	75	33.6
Lead farmers	44	19.7
Field demonstrations	32	14.3

*Multiple responses

3.2.2 Adopted Technologies

3.2.2.1 Intercropping

Findings in Table 3 present the rate of ISFM technologies adopted. The findings show that farmers are adopting ISFM technologies at an impressive pace. All farmers adopted maize-legume intercropping. Intercropping is the most commonly used traditional practice among farmers because of its multiple functions. Conservation reduces labour cost and time during weeding as well as maximises the use of the available land for production. To create management plans for maintaining productivity; maize-legume intercropping is advantageous for concurrent income enhancement, crop diversity, and soil preservation (Sharma et al., 2017). Intercropping boosted the soil nutrient availability (Ma et al., 2017). In another study, it was reported that intercropping boosted soil organic matter and total nitrogen concentration (Cong et al., 2015). The biomass production ranged from 2.03 to 4.71 Mg/ha/season and the total N build up from 87 to 180 N/ha in research by six crop associations conducted either as grain legume rotations or intercropping (Gwenambira-Mwika et al., 2021).

3.2.2.2 Crop rotation

Crop rotation reduces the chance of yield losses by disrupting the life cycle of organisms that cause pests and diseases. This makes it crucial for the control of crop pests. Due to the fact that crop rotation requires little capital outlay, Table 3's findings demonstrate all growers have embraced it. Crop rotation also contributes significantly to maintaining soil fertility by minimizing nutrient depletion. Crop rotation plays a crucial role in crop pest management (Bonabana-Wabbi et al., 2016). Crop rotation is also possible for farmers with huge acreages because it is not a costly method, meaning farmers aren't required to spend a lot of money to implement it.

3.2.2.3 Improved seeds

The use of improved seeds helped farmers to increase agricultural production, which contributes to the lower incidence of food insecurity and impoverishment. Findings in Table 3 show that 93.7% of farmers have adopted the use of improved seeds. Uses of enhanced cultivars are linked to increased nutrient input usage efficiency (Vanlauwe et al., 2011).

Table 3: Adoption of various ISFM technologies (n=223)		
ISFM technologies	**Frequency**	**%**
Intercropping	233	100
Crop rotation	233	100
Improved seeds	209	93.7

3.2.3 Duration of farmers using ISFM technologies

According to Table 4, 70.9% of those who responded had been using ISFM technologies for five years, compared to 14.8%, 12.6%, and 1.8% who had been using them for four, three, and two years, respectively. Since the ISFM project has been implemented for 3 years in Namtumbo and farmers are still using the technologies up to now, it shows that they have adopted the technologies introduced.

Table 4: Duration of farmers in using ISFM technologies		
Years	**Frequencies N = 223**	**Percentages (%)**
2	4	1.8
3	28	12.6
4	33	14.8
5	158	70.9

3.2.4 Reasons for practising ISFM technologies

The study also looked into the motivations behind farmers' use of ISFM techniques. Table 5 shows the main drivers of ISFM technology adoption in the research area: cash (99.1%), food (82.5%), pest and disease management (0.4%), and improved soil fertility as reported by all farmers. For these reasons, it is evident that farmers embraced ISFM technologies to boost agricultural output, which helps to lessen poverty and ameliorate food insecurity. These results support those previous research in 2013 and 2001 (Kaya et al., 2013; Irz et al., 2001).

Table 5: Reasons for practicing ISFM technologies		
Variables	**Frequencies N = 223**	**Percentages (%)**
Soil fertility improvement	223	100
Pest and diseases	1	0.4
For food	184	82.5
For cash	221	99.1

3.3 Factors influencing ISFM technology adoption

We employed binary logistic regression to pinpoint the variables that influenced farmers' adoption of ISFM techniques. Table 6 indicates that the model's variables were good predictors (Nagelkerke R2 = 0.81) of the variables influencing farmers' adoption of ISFM technology. The Wald-Chi square test reveals that the likelihood of a farmer adopting ISFM technology was significantly ($p<0.05$) influenced by soil fertility, climate, education, group participation, access to agricultural extension services, input cost, and availability of agricultural credit. Technology complexity, sex, age, availability of agricultural inputs, and output market accessibility were not significant ($p>0.05$).

3.3.1 Education level

Results in Table 6 show that an increase in education level by three years was associated with an increase in the likelihood of adopting ISFM technologies (OR = 0.05, 95% C. I = 0.0 – 0.54), indicating that more educated farmers, consequently, the increase in adoption of ISFM technologies. Recalling the findings in Table 1 shows that 99.1% of respondents had attained primary education; this result is consistent with previous researchers in 2010 who stated that education improves farmers' access to fertiliser information and increases their understanding of the appropriate amount to apply (Zhow et al., 2010). As a result, education is predicted to have a positive impact on fertiliser decisions. Additionally, literacy is crucial for farmers to have access to written materials and become aware of any new knowledge that may be available (Ndiema, 2010).

3.3.2 Extension services

The degree to which ISFM technologies are adopted is determined in larg e part by the frequency of interactions between farmers and extension st aff as well as by the availability of agricultural extension information.
Results in Table 6 indicate that an increase in access to agricultural extension information by two times was associated with the increase in likelihood of adoption of ISFM technologies by nine times (OR = 8.85, 95% C.I = 0.76 – 102.99). This finding is consistent with researchers in 2009, who found that household heads in Ethiopia's semi-arid regions had favourable coefficients for using compost and stubble tillage in combination with agricultural extension inputs, and that access to information on adoption of ISFM technologies was highly significant (Kassie et al., 2009). Agricultural extension plays a comparable role in Ghanaian agricultural conservation methods (Nkegbe and Shankar, 2004). According to the marginal effect, farmers with a higher number of extension contacts were more likely to see an 18.4% increase in ISFM technologies. This makes sense because ISFM technologies require a lot of expertise, and as more technologies are deployed, the more extension workers a farmer interacts with, the better the farm's input management will become.

3.3.3 Participation in groups

Findings in Table 6 show that an increase in participation in social groups by three times was associated with the increase in likelihood of adopting ISFM technologies (OR = 0.05, 95% C.I = 0.0 – 0.61). According to the study, farmers' involvement in groups had a favourable and significant impact on the adoption of ISFM technology ($p<0.05$). The positive coefficient means that the use of ISFM technology grows by 2.99 units for every additional farmer in a group. These findings are consistent with the earlier research conducted in 2009, which found that belonging to a group makes it possible for participants to learn about new technologies, such as inorganic as well as organic fertilisers, both alone and together (Odendo et al., 2009). Additionally, found that, among male, young, and adult-headed households, belonging to a group significantly increased access to the output market by 8.3%, 7.2%, and 10.8% at the disaggregation level compared to the aggregate sample (Mwangi et al., 2015).

3.3.4 Soil fertility

Results in Table 6 demonstrate that soil fertility had a statistically significant ($p<0.05$) favourable impact on farmers' adoption of ISFM technologies (OR = 0.05, 95% C.I = 0.0 – 0.54), indicating that the more the soil fertility the more the increase in adoption of ISFM technologies. Crop rotation is one of the ISFM strategies that farmers use because it helps to preserve soil fertility by reducing the loss of soil nutrients. Crop production benefits from a high rate of crop rotation adoption. Poor adoption has resulted from interventions that do not systematically take into account the variety of soil fertility (Giller et al., 2011). On plots that increase the effectiveness of nutrient utilisation and are thought to be fruitful, farmers are more inclined to implement ISFM technology. Additionally, a group of researchers discovered that in Ethiopia and Tanzania, the use of inorganic fertilizer was favourably and significantly influenced by moderate soil fertility (Kassie et al., 2015).

3.3.5 Climate

Results in Table 6 show that climatic conditions have a negative coefficient and positively significantly ($p<0.05$) associated with the increase in likelihood of reporting adoption of ISFM technologies (OR = 0.08, 95% C.I = 0.01 – 0.93). This finding concurs with a study in 2021, where researchers conducted a similar study in Ghana (Kwadzo and Quayson, 2021). The findings of the current study indicate that the more poor climatic conditions the more the increase in adoption of ISFM technologies. ISFM technologies are more likely to be accepted by smallholder farmers in agroecological zones with impaired agricultural land (Assefa and Hans-Rudol, 2016; Lahmar et al., 2012).

3.3.6 Cost of input

Based on the findings in Table 6, the cost of input was negatively associated with the increase in the likelihood of adopting ISFM technologies (OR = 0.00, 95% C.I = 0.00 – 0.07), indicating that the lower the cost of input the more the increase in acceptance of ISFM technologies. A growing number of farmers are declining to buy inputs as their costs rise (Oluyede et al., 2007; Humphreys et al., 2009). Consequently, farmers have become less willing to adopt improved seed and mineral fertilisers as their prices rise. For example, the price of maize seed, which is a staple crop, and the amount and type of fertiliser subsidies are said to be the primary factors influencing the financial appeal and potential adaptability of the various soil fertility options.

3.3.7 Access to credit

The results presented in Table 6 show that the adoption of ISFM technologies was strongly ($p<0.05$) influenced by the expansion of agricultural financing availability. This suggests that the adoption of ISFM technology will expand in direct proportion to the level of availability of agricultural loans. Credit constraints have been demonstrated to impede the adoption of cash-intensive technology like fertilisers or enhanced varieties (Lambrecht et al., 2014). Therefore, compared to farmers who face financial constraints, those that have access to credit are more likely to embrace ISM technologies.

Table 6: Regression output on the factors influencing ISFM technology adoption						
Variable	B (Coeff)	S.E.	Wald	df	Sig.	Exp(B)
Soil fertility	5.873	2.142	7.243	1	.005	52.272
Technology complexity	-1.152	1.247	.643	1	.402	.364
Climate	-2.734	1.272	4.052	1	.034	.075
Education	3.059	1.351	6.138	1	.014	.042
Social participation	2.988	1.270	5.372	1	.015	.071
Input cost	-6.576	2.154	10.231	1	.001	.001
Sex	-2.123	1.457	2.875	1	.122	.167
Access to credit	2.754	1.422	3.874	1	.042	.079
Age	-2.241	1.224	4.674	1	.097	.045
Access to market	27.431	72.371	.000	1	.987	86.341
Extension services	3.234	1.455	3.075	1	.002	8.562
Constant	-25.741	272.153	.000	1	.942	.000

Nagelkerke R^2 = 0.81 significance at $p<0.05$

4. Conclusion And Recommendations

Crop rotation, intercropping and the use of modified seeds are ISFM technologies that farmers have adopted. Enhancing soil fertility, raising income and enhancing food security are the main drivers behind the use of ISFM technology. Moreover, there are arrays of variables that both favourably and negatively affect the adoption of ISFM technology. The three main factors that determine this are soil fertility input costs and access to extension services. Smallholder farmers should have easier access to better seed types as a result of government and stakeholder assistance in lowering input costs.

Strengthening farmers' understanding of the value of using extension agents would guarantee that they obtain trustworthy agricultural knowledge on ISFM technologies to boost output, which can help to lessen poverty and improve food security. The government should increase the number of extension staff and provide them with essential items so they carry their duties smoothly and reach more farmers.

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