Determinants in the Use of Agro-chemicals in Maize Production: A Case Study of Selected Villages in Iringa District Council, Tanzania

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Abstract

This study examines the factors that influence agro-chemicals used in maize production in Iringa District Council, Tanzania. The study used a concurrent parallel mixed research design to collect quantitative and qualitative data via structured interviews, in-depth interviews and focus group discussions. A binary logistic model was used to assess the quantitative data of factors influencing agro-chemicals used in maize production. Meanwhile, the content analysis technique was used to analyse qualitative data. The findings show that sex, age, credit accessibility, farmers-extension interaction, soil infertility and pest infestation positively and significantly influence smallholder farmers to use agro-chemicals ($p \leq 0.05$). But, the household size and distance from agro-dealers negatively and significantly influenced the use of agro-chemicals in maize production. Unlike the outcome of binary regression analysis, qualitative data discovered that household income highly influences agro-chemical use. On the other hand, qualitative results indicated that interaction between farmer and research was weak and did not influence the use of agro-chemicals. The policy implication is that the government in collaboration with agricultural stakeholders, should address issues limiting farmers to use industrial fertilizers, herbicides and pesticides. Finally, through rural financial institutions, the government should provide credit facilities to farmers to raise their income and increase their uptake of agro-chemicals to increase maize production.

***Keywords*:** determinants of agrochemical use, fertilizers, maize production, Tanzania

1. Introduction

Globally, agriculture remains the backbone of many developing economies, employing a large share of the population and contributing significantly to food security. It accounts for 30%–60% of gross domestic product in about two-thirds of developing countries, employs 40%–90% of the labour force, contributes 25%–95% of foreign exchange earnings, and provides subsistence and income for over half of the population in least developed countries (Mhagama et al., 2023).

In sub-Saharan Africa, agriculture continues to be the cornerstone of economic development, underpinning livelihoods through employment, income generation, and food provision (Abebe et al., 2025; Geleto et al., 2025). However, agricultural productivity in sub-Saharan Africa faces persistent challenges, including declining soil fertility, pest infestations, and limited access to modern agricultural inputs. Since the 2000s, maize production in particular has been constrained by infertile soils and emerging threats from diseases, weeds, and pests. Among these, the fall armyworm (FAW) has been the most destructive, causing substantial yield losses across the region (Devi et al., 2018). Researchers suggest that FAW first entered Africa through cargo containers and aircraft holds before spreading across the continent by wind (De Buck, 2017). Originating in the West African tropics in 2016, it spread rapidly across at least 12 countries, including Togo, Ghana, Zambia, Zimbabwe, South Africa, Malawi, Mozambique, Namibia, Kenya, Rwanda, Uganda, and Tanzania damaging over 300,000 hectares of cropland in that year alone (De Buck, 2017).

In Tanzania, agriculture is central to the economy and livelihoods. It contributes 27%–30% of gross domestic product, 24%–25% of total export earnings, 65% of raw materials to agro-based industries, 70% of employment, and nearly all national food requirements (Mhagama et al., 2023). The sector employs about 67% of the workforce and provides approximately 70% of rural income (Mpogole et al., 2020). Smallholder farmers dominate production, supplying 85 – 90% of the country's food, while large-scale farms contribute only 10%–15% (URT, 2013; Mmbando & Baiyegunhi, 2016; Baijukya et al., 2020). Despite this vital role, agricultural productivity in the country, especially of maize, remains low compared to global averages, largely due to declining soil fertility, pest

infestations, and limited access to agricultural inputs, credit, and markets (FAO, 2016; World Bank, 2019).

One of the most serious challenges constraining maize productivity in Tanzania is the low and inefficient use of agrochemicals such as inorganic fertilizers, herbicides, and pesticides. Previous empirical studies indicate that although agrochemical use has been shown to significantly enhance crop yields in developing countries (Appiah-Kubi, 2019), adoption among smallholder farmers remains limited due to socio-economic, institutional, and ecological barriers (Msuya et al., 2017; Mlyuka et al., 2021). However, there is limited research that has examined how these socio-economic, institutional, and ecological factors jointly influence agrochemical usage in Tanzania's maize systems. Moreover, adoption patterns vary across agro-ecological zones due to contextual differences in resources and institutions. Therefore, this study addresses the question: What are the key socio-economic, institutional, and ecological factors influencing the use of agrochemicals among maize farmers in Tanzania? Specifically, we examine how those factors affect farmers' decisions to use fertilizers, herbicides, and pesticides.

This study contributes to the existing body of knowledge by integrating specific socio-economic, institutional, and ecological determinants of agrochemical usage within a single analytical framework. It provides empirical evidence about how particular determinants interact to influence smallholder farmers' decision making and input-usage in Tanzania. The findings offer valuable insights for policymakers, extension agents, and researchers seeking to promote sustainable maize intensification through improved input access, targeted farmer support systems, and environmentally sound production practices.

2. Theoretical framework

This study is grounded in the Diffusion of Innovations Theory developed by Everett M. Rogers (2003 [1962]). The theory explains how, why, and at what rate new ideas, technologies, or practices spread within a social system over time (Rogers, 2003; Kariuki, 2025). This theory has been widely applied in agricultural and rural development studies to understand farmers' adoption behaviour with respect to improved seeds, fertilizers, pesticides, and other agricultural technologies.

According to Rogers (2003), the diffusion of innovations depends on five key attributes that influence the rate and success of adoption: relative advantage, compatibility, complexity, trialability, and observability. These attributes

determine how potential users perceive an innovation. Farmers, for instance, are more likely to adopt an agrochemical if they consider it beneficial, simple to use and compatible with their existing farming practices (Kariuki, 2025). The theory further identifies four main elements that shape the diffusion process:

- *Innovation*: Refers to an idea, practice, or object perceived as new by individuals or groups. In this study, the innovation is the use of agrochemicals, specifically fertilizers, herbicides, and pesticides to enhance maize productivity.
- *Communication Channels*: These are the means through which information about an innovation is shared. Channels such as agricultural extension services, farmer groups, cooperatives, community meetings, peer interaction, social networks and mass media play a critical role in transmitting knowledge and influencing attitudes toward adoption.
- *Time:* Represents the period of an individual's progress from initial awareness to full adoption of an innovation. The adoption process involves stages of knowledge, persuasion, decision, implementation, and confirmation.
- *Social System*: Denotes the community or group within which diffusion occurs. In this study, the social system comprises smallholder maize farmers, whose norms, cultural practices, and social ties influence collective decision-making and adoption behaviour. As Rogers (2003) emphasises, innovation adoption is inherently a social process in which learning and experience are shared among members of a community.

Rogers (2003) also categorises those who adopt an innovation into five groups based on the speed at which they embrace new practices:

1. *Innovators:* The first to adopt new ideas; they are adventurous and willing to take risks.
2. *Early Adopters:* Opinion leaders who carefully evaluate innovations before adopting and influencing others.
3. *Early Majority*: Individuals who adopt before the average person, after seeing proven benefits.
4. *Late Majority:* These are more sceptical, adopting only after most peers have done so.
5. *Laggards:* The last to adopt, often constrained by traditional beliefs or limited resources.

These categories highlight that adoption is not uniform across individuals; rather, it reflects differences in information access, risk tolerance, and social influence within farming communities.

The Diffusion of Innovations Theory provides a useful framework for understanding the determinants of agrochemical use among maize farmers in Tanzania. Study variables including education, gender, income, access to credit, extension contact, and proximity to agro-dealers align with the theory's emphasis on the role of communication, socio-economic conditions, and social networks in shaping adoption behaviour. Overall, the theory provides a strong foundation for interpreting the study's results, particularly regarding how education, income, credit access, and extension contact shape adoption decisions among smallholder maize farmers.

3. Research methodology

3.1 Study area

This study was conducted in Iringa District Council, Tanzania. This district council lies between latitudes 35°46'30" and 35°57'00" east and longitudes 7°34'30" and 7°24'00" south. The Iringa District Council was purposely selected because it is one of the famous district councils for producing and supplying maize in the Iringa region and for Tanzania at large (Chuhila, 2019). Also, through personal observation and experience, it is known that there is a low level usage of fertilizers and agro-chemicals in the study area.

3.2 Study design

This study employed a concurrent parallel mixed research design. This involves collecting both qualitative and quantitative data simultaneously in a single visit to the research site while giving equal weight to both types of data. Both qualitative and quantitative data were collected concurrently but separately; at the same time, they were analysed independently, and then combined for meaningful interpretation (Creswell & Plano Clark, 2011). Neither the quantitative approach nor the qualitative approach is self-contained; each approach has its weaknesses, which is why the two approaches were used to supplement the weaknesses of the other. It is also less time-consuming. Hence, it was more appropriate for the study. Thus the use of mixed methods improved upon both of the two approaches as their strengths are synergised to enhance reliability and minimise the weaknesses of each approach when pursued independently (Ary et al., 2010; Gay et al., 2012).

3.3 Sampling procedures and sample size determination

The mixed methods design, as described above, uses both quantitative and qualitative data. In this regard, the researchers assumed that there were different perspectives embodied in the population with different understandings of the research problem. This factor gave rise to the further assumption that multiple sampling techniques would be suitable for ensuring sample representation of the study population. Thus the researchers employed both systematic random sampling and purposive sampling methods, as described in the following paragraphs.

First, researchers started by determining the sample size for heads of household farming maize using Kothari's formula (2004) shown below. In Kihorogota village, the researchers obtained the list of heads of household involved in maize production from both existing offices of the villge council. However, in Kising'a village the list of heads of household farming maize was not available. Therefore, it was with the help of the village chairperson and village council members of Kising'a village that the researchers developed the sampling frame of farmers farming maize.

$$\mathrm{N} = \frac{\mathrm{z}^2.\,\mathrm{p}.\,\mathrm{q}.\,\mathrm{N}}{e^2(N-1)+z^2.p.q} = \frac{(1.96)^2\,(0.5)(1-0.5)(752)}{(0.05)^2(752-1)+(1.96)^2(0.05)(1-0.05)} = 254$$

where n = sample size, z = confidence level of 95%, N = size of population (which is 752 for both villages), e = acceptable error (the precision, $\alpha = 0.05$), p = sample proportion of smallholder maize farmers which is set at 0.5 (50%). P was determined during the pilot study. Variable q is the weighting variable; computed as 1 – p (i.e., 1- 0.5 = 0.5).

Secondly, the households included were proportionally selected to ensure equal distributions of the sample of heads of household from each village. The number of households farming maize in Kihorogota was 245, whereas those maize-farming households in Kising'a were 507. Hence, based on the proportional selection, the sampled households farming maize in Kihorogota and Kising'a were 89 and 165, respectively.

Thirdly, systematic random sampling was used to select members of the sample within each village. An alphabetical list was prepared for each village using the names of the heads of household, and these names were serially numbered. A sampling interval was determined using the formula: $\mathrm{K}=\frac{N}{n}$,

where K is the sampling interval, N is the population size of each village, and n is the sample size of a village. Then the starting point was randomly selected. Thus, each of the numbers from 1 to the obtained number of intervals in each village was written on a piece of paper and these were mixed up. One paper was chosen randomly from the mixed pieces of paper to obtain the starting point of selection for that village sample. Ultimately, every n^{th} head of household was selected from the list of the leaders of households farming maize.

Purposive sampling was employed to select eight key informants (Table 1). These key informants were purposively selected from each village based on their knowledge, skills, and experience in maize production.

Table 1: Category and number of key informants

Category of key informant	Number of sampled key informants
Village Chairperson	2
Village Executive Officers	2
Agricultural Extension Officers	2
Experienced and leading farmers	2
Total	**8**

4. Methods of data collection

A validated and pre-tested structured interview schedule was used to collect data through structured conversations with the sampled heads of household farming maize. The interviews comprised closed-ended questions designed to solicit information about factors that determined the use of agro-chemicals. The rationale for using a structured interview is that it is purported to help eliminate respondents' biases because the interviewer and interviewee see each other. In addition, in-depth interviews were conducted among the sixteen key informants using a checklist which included the main themes about the determinants presumed to influence farmers to use agro-chemicals in maize production. All interviews were recorded with the consent of the participants. Moreover, two focus group discussions were conducted with smallholder maize farmers (i.e. one group from each selected village). Participants were selected based on their small holder experiences of farming maize, their age, gender, and whether their yields were low, medium, or high.

Each group was made up of ten participants. With the consent of the participants, the discussions were recorded. A researcher proposed to the group one question after another, and the issue was discussed. Finally, the group would reach consensually their collective response by agreeing on one response. Each focus group discussion lasted between 30 and 45 minutes.

Secondary data were obtained through reviewing both published and unpublished documents including books, journal articles, national and international reports, and government publications. Such documents were obtained from the Mkwawa University College of Education library and specific internet search engines including Google scholar. The collected data were used to triangulate the discussion of quantitative and qualitative results obtained through primary methods.

4.1 Data analysis

The binary logistic model was used to test the quantitative data about the factors that determine the use of agro-chemicals in maize production. The model reads as follows:

$$\log\frac{pi}{1-pi} = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \cdots + \beta_{16} x_{16}$$

where pi is the probability of the ith respondent's perception of using agro-chemicals in maize production, β_0 is constant, β_1 and β_{16} are coefficients of the independent variables, and x_1 to x_{16} are independent variables entered in the binary logistic regression model.

Qualitative data from in-depth interviews and focus groups discussions were analysed through Content Analysis. Audios were transcribed to text and then coded to summarise repeated themes that emerged in the responses to questions. All related themes were summarised by documenting the repetition of certain types of statements from each focus group discussion or in-depth individual interview. Researchers also made some interpretations of the collected responses to add clarity to explanations of the data. Some of the quotes were cited for more clarification. The collected, transcribed and interpreted data were compared and harmonized with quantitative and secondary data collected in this study.

5. Results and discussion

5.1 Descriptive statistics of socio-economic, institutional and ecological variables

Descriptive statistics used for these variables in the binary regression analysis are presented in Table 2. The results of the 254 sampled heads of households, reveal that 68.9% were males and 31.1% were females, indicating that more men were interviewed in this study. This may imply that many households are headed by males in the study area. These results reflect rural African societies' reality where men are culturally empowered to head the households, or to speak on behalf of households in public or to visiting researchers. Also, Table 2 shows that the majority of respondents (85%) were in the working age group (15-64 years), and few (15%) were in the independent age group or the retired age group (65 years and above), indicating that maize cultivation in the study area was mostly practised by the peer group regarded as economically productive.

Also, the majority of respondents (88.2%) had acquired schooling at the primary level and above (Table 2), indicating that most of the sampled maize farmers had some formal education. Previous empirical studies show that formal education has already been recognized as a positive factor in influencng adoption of improved technologies among farmers (Asfaw & Admassie, 2004; Sheikh et al., 2006). Through education and communication, agricultural technologies can change farmers' perceptions, attitudes, and skills, to affect farmers' frame of mind to one which is conducive to adopting new technologies (Agbamu, 2005). Danso-Abbeam et al. (2017) and Gebresilassie & Bekele (2015) posited that formally educated farmers are imbued with essential learning to appraise new technologies and to adopt them more frequently than farmers who have not been formally educated in schools. However, Tesfaye et al. (2016) countered this submission; they found that non-adopters of improved wheat varieties in Ethiopia were considerably more educated than those who were adopters.

The marital profile of the farmers in Table 2 shows that 57.9% of them were married, and 42.1% were single, indicating a slight majority of those interviewed were married. According to Echebiri & Mbanasor (2003), it is a common practice among rural farmers to marry and have many children that are expected to constitute their farm workforce. Also results show that the majority of sampled households (71.3%) contained four members and above, indicating that the sampled farmers had relatively large household sizes. Large households are preferred in African

agricultural societies because again household members serve as the primary source of workforce on smallholder farms.

Moreover, the results of this study show that many sampled farmers (64.6%) have low incomes. But most of the sampled farmers (88.6%) possessed their own farms, with only a few farmers working on rented or borrowed lands for maize cultivation. The results of this study imply that farmland ownership may be helpful to expanding farmers' cultivation of maize. However, although many farmers were in possession of the land under their cultivation, more than half (55.1%) of them owned and cultivated farms of a small size. This result in the study area concurs with the national agricultural policy reports of the United Republic of Tanzania, which claims that smallholders' subsistence farming on modest acreage comprises more than 90% of the nation's farming population (URT, 2013). Similarly, these findings reflect the Food and Agriculture Organisation (FAO, 2016) overall assessment that around 80% of all farms in sub-Saharan Africa are smallholder farms, and that approximately 175 million people are directly employed on these farms.

Most sampled farmers (66.9%) in this study had accumulated maize farming experience over 15 years or more (Table 2). Only 9.1% of them had maize farming experience of less than five years, 15.4% had been farming maize from five to ten years, and 8.7% had framed maize from 11 to 15 years. These findings show that many farmers were quite experienced in maize production. As the saying goes, experience is the best teacher. Indeed, it has been argued that prolonged farming experience is an advantage for an increase in production since it encourages rapid adoption of improved technology (Emodi, 2010). Thus one might conclude that the longer a person stays on a job, the more likely they are in a position to use new technology.

Furthermore, 54.3% and 31.1% of the respondents indicated walking a distance of 21 – 40 kilometres and 41 and above kilometres, respectively, for agro-chemicals. Only 14.6% could get agro-chemicals at a short distance ranging from 0 – 20 kilometres. This result indicates the limited availability of the agro-chemicals in the study areas. Consequently, 90.6% of the sampled farmers reported having no access to agro-chemicals, indicating that they are unavailable in their villages. In 2003, Tanzania acknowledged that, despite the importance of modern inputs (fertilizers, herbicides and pesticides) in improving agricultural productivity, the availability of the same is still limited in the villages (URT, 2013).

Table 2: Socio-economic, institutional and ecological descriptive statistics

Variable		Frequency	Percept
Socio-economic determinants			
Sex:	Female	79	31.1
	Male	175	68.9
Ages:	15 - 64 Years	216	85.0
	65 years and above	38	15.0
Education level:	No formal education	30	11.8
	Primary School and above	224	88.2
Marital Status:	Married	147	57.9
	Single	107	42.1
Household size:	1 - 3 people	73	28.7
	4 - 6 people	160	63.0
	7 - 9 people	19	7.5
	10 people and above	2	0.8
Annual Income:	Less than 2,450,140	164	64.6
	2,450,140 - 9,566,425	88	34.6
	9,566,426 - 29,654,275	2	0.8
Farm ownership:	Not own	29	11.4
	Own	225	88.6
Farm size:	Less than 3 acres	140	55.1
	3 - 5 acres	72	28.3
	6 - 10 acres	36	14.2
	11 - 15 acres	3	1.2
	Above 15 acres	3	1.2
Maize farming experience:	Less than 5 years	23	9.1
	5 - 10 years	39	15.4
	11 - 15 years	22	8.7
	Above 15 years	170	66.9
Distance to the agro-dealers:	0 - 20 km	37	14.6
	21 - 40 km	138	54.3
	41 and above	79	31.1
Institutional determinants			
Agro-chemicals availability:	No	230	90.6
	Yes	24	9.4
Credit accessibility:	No	237	93.3
	Yes	17	6.7
Farmer-extension interaction:	No	51	20.1
	Yes	203	79.9
Farmer-research interaction:	No	253	99.6
	Yes	1	0.4
Agricultural policies:	No	138	54.3
	Yes	116	45.7
Ecological determinants			
Soil infertility:	No	63	24.8
	Yes	191	75.2
Pest infestation:	No	87	34.3
	Yes	167	65.7

Most respondents (79.9%) acknowledged interacting with extension officers (Table 2), implying that farmers have strong linkages with extension officers during the dissemination and utilisation of industrial fertilizers, herbicides and pesticides. This interaction indicates a positive and significant effect on the use of these agro-chemicals. On the other hand, almost all of the interviewed farmers (99.6%) showed no interaction (or linkages) with researchers in the improved maize innovation system. This finding agrees with the National Agricultural Policy of Tanzania which shows that 60-70% of households have no contact with the research system (URT, 2013). Similarly, Charles et al.'s (2022) study on rice innovation system and Maerere et al.'s (2010) study on the banana innovation system revealed the existence of weak linkages between farmers and research systems in Tanzania. This weak link reveals the presence of little participation of farmers in developing and adoting technological innovations. Hence, research programs have not been able to include farmers' needs in their priorities, and the use of technological innovations has been low or weak.

Finally, Table 2 indicates that more than half of the farmers (54.3%) in the study area are unaware of agricultural policies. This fact reveals that developed agrarian policies and programmes are not directly channelled to the intended farmers for use but are kept on shelves whereby policies, plans and strategies remain unimplemented. This is the revelation again that there is still weak linkage between policy makers and farmers in Tanzania. This result is consistent with the findings by Charles et al. (2022) in the improved rice innovation system, which found weak linkages between farmers and policymakers. Finally, the majority of interviewed farmers (75.2%) and (65.7%) indicated the presence of soil infertility and pest infestation, respectively, in the study area (Table 2), implying that soil infertility and pest infestation can influence farmers to use inorganic fertilizers and pesticides to increase maize productivity.

5.2 Determinants in the use of agro-chemicals

Table 3 shows that the values of Chi-square were 90.006, 53.715 and 92.046 for fertilizers, herbicides and pesticides, respectively, with a degree of freedom 17 and $p = 0.000$, implying that the independent variables had significant influences on the dependent variables. The −2 log-likelihoods of fertilizers, herbicides and pesticides were 258.071, 250.988 and 234.442, respectively, implying that adding explanatory variables delineated more of the variance in the outcome. Also, the values of Cox and Snell R for

fertilizers, herbicides and pesticides were 0.298, 0.191 and 0.304, respectively. Similarly, the values of Nagelkerke R Square for fertilizers, herbicides and pesticides were 0.400, 0.273 and 0.420, respectively. These values imply that the 17 factors included in the binary regression analysis describe the influence of agro-chemicals from 19% to 42 and that other factors describe the use of agro-chemicals that could not be captured in these studies. Moreover, the p-value test statistics of Hosmer and Lemeshow's result were insignificant ($p > 0.05$), indicating that the fitting effect between the data and model is good. The rule of thumb for accepting the binary model is that the p-value of Hosmer and Lemeshow must be greater than 0.05 (Pallant, 2011).

Table 3: Test of the binary model

	Omnibus Tests of Model Coefficients			**Model Summary**			**Hosmer and Lemeshow Test**		
Dependent Variable	Chi-square	Df	Sig.	-2 Log likelihood	Cox & Snell R	Nagelkerke R Square	Chi-square	df	p-value
Fertilizers	90.006	17	.000	258.071	.298	.400	2.213	8	.974
Herbicides	53.715	17	.000	250.988	.191	.273	14.268	8	.075
Pesticides	92.046	17	.000	234.442	.304	.420	8.429	8	.393

The results in Table 4 below show a positive and significant relationship between gender and pesticide usage ($p < 0.05$). This suggests that men involved in farming applied more pesticides to control diseases and pests than women. However, this finding is inconsistent with Abunyuwah et al. (2020), who found that female farmers are more likely to apply pesticides than their male counterparts. This difference could be attributed to variations in socio-economic and cultural values of the study areas.

The age of the household head positively and significantly influences the use of herbicides and pesticides at 5% ($p \leq 0.05$) and 1% ($p = 0.01$), respectively (Table 4). This result indicates that an increase in the age of respondents coincides with an increase in the usage of herbicides and pesticides. According to Alexander & Van Mellor (2005) as well, increase in the use of agricultural inputs corresponds to an increase in the age of active farmer cohorts as they gain experience and increase their stock of human capital; however, they discovered that elderly farmers' reliance upon agricultural inputs decreased as they approached retirement. This study's findings are in line with studies that discovered age of a farmer generally corresponds with the likelihood of reliance upon innovations in pesticide products, contrary to

the results of Sánchez-Toledano et al. (2018), Chete (2021), Okwuokenye & Petu-Ibikunle (2021). These latter researchers reported that young farmers were more likely to be receptive to new ideas and production processes than older farmers who appeared to be entrenched in traditional practices. Similarly, Abubakar et al. (2019) argue that older farmers are more conservative, risk-averse, and reluctant to reject traditional ways than younger farmers who are more innovative in their embrace of new technologies. This difference could be due to cultural variations over time and location.

Results in Table 4 below also show that there is a significantly positive relationship between marital status and usage of both herbicides and pesticides ($p \leq 0.1$), implying that married farmers are more likely to use herbicides and pesticides than unmarried smallholder farmers in the region under study. This could be because married people experience some pressure in their responsibility to increase maize production as a reliable food source for their households.

These results also revealed that access to credit positively and significantly affects the use of herbicides and pesticides ($p = 0.01$). Farmers with access to credit appear more likely to use costly herbicide and pesticide inputs. Correlatively, it emerged in the focus group discussions in both villages that services of agricultural financing institutions made a significant impact upon developing the agricultural sector since individual farmers would otherwise be incapable of buying the agricultural inputs. These regional institutions include commercial banks, microfinance institutions acting as financial intermediaries (such as rural/community banks, savings and credit cooperative organizations) and non-banking financial institutions such as the government's National Social Security Fund. Similary, Ogada et al. (2014) and Melesse (2018) reported that households of farmers who have access to formal and informal sources of credit adopted agricultural new technologies significantly more frequently than those heads of household without these fiscal supports. Survey results in Table 2 show that 93.3% of sampled farmers in this study were not accessing credit. The same was reported during the focus grou discussions, where participants pointed out the difficult conditions for obtaining loans from the regional financial institutions. The difficulties they mentioned included high-interest rates and their lack of collateral.

Table 4: Determinants of agro-chemicals usage

Variables	Fertilizer		Herbicides		Pesticides	
	B	Sig.	B	Sig.	B	Sig.
Socio-economic determinants						
Sex (1)	.257	.542	.438	.343	.861	.080***
Age	.571	.268	1.099	.049**	1.471	.010*
Educational level (1)	.538	.336	.982	.146	.638	.308
Marital status (1)	.118	.766	.711	.092***	.804	.071***
Household size	-.322	.303	-.586	.077***	-.774	.025**
Annual income	-.543	.161	-.083	.825	.161	.681
Farm ownership (1)	.664	.231	.518	.431	.162	.799
Farm size	-.093	.680	.019	.929	-.161	.486
Maize farming experience	.122	.499	-.184	.333	-.040	.840
Distance to the agro-dealers	-.326	.186	-.583	.034**	-.518	.066***
Institutional determinants						
Agrochemical availability (1)	.564	.337	.116	.847	-.433	.512
Credit accessibility (1)	.921	.217	1.757	.006*	1.870	.008*
Farmer-extension interaction	.958	.022**	-.165	.684	1.059	.008*
Farmer-research interaction	20.322	1.000	20.985	1.000	21.665	1.000
Agricultural policies (1)	.164	.649	.058	.875	-.606	.117
Ecological determinants						
Soil infertility (1)	2.742	.000*	1.650	.001*	2.633	.000*
Pest-infestation (1)	.524	.139	.770	.046**	1.226	.003*
Constant	-2.481	.100	-.108	.942	-1.650	.284

Key: * = Significant at 0.01 (1%); ** significant at 0.05 (5%) & *** significant at 0.1 (10%)

Among those in this study, their farmer-extension interactions positively and significantly influenced their use of fertilizers and pesticides at 5% level ($p \leq 0.05$) and 1% level ($p \leq 0.01$), respectively. We found that the more a farmer interacted or linked with extension services, the greater the likelihood of their using fertilizers and pesticides. Access to participate in extension programs such as training seminars, demonstrations, farmers' field days and other extension services create the platform for acquiring the relevant information that promotes adoption of fertilizers and pesticides. This finding supports a study conducted in four regions of Ethiopia by Melesse (2018), where it was determined that farmers who had frequent contact with extension agents were more likely to adopt technology than farmers who had a lower degree of regular contact with agricultural extension programs. Similarly, studies in Bangladesh (Hoque et al., 2022; Nazu et al., 2021) found that extension services had a positive and significant influence on the use of agro-chemicals. They further pointed out that farmers' farming knowledge increases through frequent counsel, practical

demonstrations, field visits, and related contact with extension workers who help them to use agro-chemicals more frequently and efficiently.

Moreover, the results in Table 4 indicate that soil infertility positively and highly significantly influences the use of fertilizers, herbicides and pesticides in maize production ($p \leq 0.01$). Similarly, one experienced and leading farmer who participated in the study's interviews brought attention to this problem by saying:

> In previous years, the land was fertile, and the climate supported high maize production in our village. Farmers got high yields from a small piece of land without inorganic fertilizers. But for the past 4 to 5 years, for smallholder farmers to get high yields are obliged to use inorganic fertilizers because most of the entire land of the village has become infertile. No uses of fertilizers, no longer high yields.

Also, participants in the FGD revealed that due to climatic change and decline in soil fertility, it has become important for them to use inorganic fertilizers to get enough produce. These findings correspond with those of Nonga et al. (2011) in Manyara, Tanzania, which demonstrated that farmers with low soil fertility used fertilizers to increase their farm produce. He noted that 78% of his respondents used inorganic fertilizers as a measure to counter poor soil fertility. Also, Demi & Sicchia (2021) in Ghana reported that many farmers use inorganic fertilizers to encounter soil infertility.

Furthermore, pest-infestation positively and significantly affects the use of herbicides and pesticides at a 5% level ($p \leq 0.05$) and 1% level ($p \leq 0.01$), respectively. As noted earlier, these findings indicate that the increase of diseases, weeds and pests on farms necessity farmers to apply herbicides and pesticides. Put differently; these results infer that farmers could not use herbicides and pesticides in the absence of diseases, weeds and pests on the farms. It is argued by this study that controlling and preventing the spread of maize diseases, pests, and weeds are essential in producing high-quality agricultural goods and generating high yields. Therefore, it is possible to avoid yield losses caused by infections, pests and weeds by controlling them punctually using agro-chemicals. These findings are supported by Abunyuwah et al. (2020) in Ghana, who found that half of the sampled farmers applied pesticides whenever they detected pest infestation threat on their crops and as a preventive and curative measure based on symptomatic observation of pest or disease infestation. Similarly, Abiola &

Olowoyo (2021) in South Western Nigeria found that an increase in pests infestation significantly ($p < 0.01$) increases the pesticide usage in maize production. The influence of pest infestation on the use of pesticides has also been supported by Jeyanthi & Kombairaju (2005), who noted that farmers in India used pesticides frequently since pest infestation was relatively high in vegetable crops.

However, the reasoning of the few other farmers who could not use pesticides to control diseases, weeds and pests was clarified in the focus group discussions conducted in both study villages, where participants expressed that some farmers who encounter pest infestation do not use pesticides to control them. Also, as it was noted, farmers with low income or a complete lack of income did not report using herbicides and pesticides; instead they rely upon local or traditional methods for pest control. For example, in Kising'a village, low-income farmers used ashes to control pests; this, however, is ineffective as a pesticide.

What emerged out of focus group discussions in the study villages was that farmers engaged in maize production with a high income were more likely to use agro-chemicals than farmers with low incomes. The village chairperson in Kihorogota village corroborated these group discussion comments by indicating how limited income denied some farmers the use of agro-chemicals. The chairperson stated that:

> Farmers with low incomes opted to use hand hoes for weeding their maize plants instead of applying herbicides. For example, I am a widow here, I wish I could use herbicides for weeding to save time. But I cannot use herbicides because I do not have money . . . for those with a high income; we always see them using herbicides for weeding. If it was not my poverty, I could buy agro-chemicals to save time by using just a single day spraying herbicides on the whole farm.

Further, qualitative information indicated that the research system has low level of interaction with farmers with no influence on t he use of inorganic fertilizers, herbicides and pesticides in maize production. The Village Executive Officers in Kising'a village had this to say:

> Most of the time researchers come to our village but they never train farmers about the use of agro-chemicals in maize

> production. They always end up asking questions of their interest and leave farmers without any help with the use of agro-chemicals. Researchers have been using farmers to fulfilling their interests and leave them with no knowledge about the use of agro-chemicals in maize production. I would like to tell you that the decision to use agro-chemicals comes from farmers' self-motivation and not the influence of external actors like researchers.

Another experienced and leading farmer in Kising'a village said during an interview:

> I am a native of this village, and since childhood, I have never seen anyone coming here to train us about agro-chemicals. We always learn from each other to find the best way to use agro-chemicals on our farms. We have seen some researchers from [Tanzania Agricultural and Research] Institutes, for example, the Sokoine University of Agriculture and from University of Dar es Salaam who come to interview us like you and later on they disappear forever; hence, there is not any advantage we gain from them.

The weaknesses of interactions between farmers and researchers have revealed an asymmetry in the knowledge and information gained when discussing improved rice varieties and innovations in farming systems. Similarly, Sospeter & Maselle (2024) found that the multi-stakeholder interactions and networks in the grape growing innovation system in Dodoma City were weak, resulting in a considerable deficit for farmers in new information about these innovations. These findings are contrary to those by Charles (2025) who revealed that smallholder farmers' interactions with research organizations and extension services varied considerably from moderate to strong. Strong interactions between farmers and agricultural innovation system actors were found to significantly enhance the knowledge and information sharing which in turn accelerated the intensity of adoption of innovations (Charles, 2025). Thus, when farmers engaged actively with research institutions, extension agents, district officers, local community groups and other key stakeholders, they were more likely to learn about new innovations and technologies, to understand their benefits, and to adopt them rapidly.

On the other hand, surprisingly, the results in Table 4 reveal that household size negatively and significantly influenced the use of herbicides and pesticides at 10% level ($p \leq 0.1$) and 5% level ($p \leq 0.05$), respectively, indicating that as the household

size increases the use of herbicides and pesticides to control diseases, weeds and pest decreases. This was apparent despite the likelihood of the result reflected in the same table that married farmers' propensity to adopt new technology in maize farming than unmarried smallholders. These findings contradict the previous findings by Teferi et al. (2015); Mwangi & Kariuki (2015); Abubakar et al. (2019); Chete (2021) and Okwuokenye & Petu-Ibikunle (2021) which indicate that farmers with larger households are more likely to uptake modern agricultural inputs to increase productivity, especially if it is labour-intensive because they can leverage labour from household members at a low or no cost. According to Abunyuwah et al. (2020), households with more family members serve as labour for spraying and other farm activities. They predict that due to the availability of labour, homes with big family sizes will be more inclined to adopt innovative agricultural production strategies than those with smaller family sizes.

Further, distance from the farmer's village location to the agro-dealers' shops negatively and significantly influenced the use of herbicides and pesticides at 5% level ($p \leq 0.05$) and 10% level ($p \leq 0.1$), respectively. This finding implies that long distances limited farmers' access to and use of herbicides and pesticides. This finding is consistent with the conclusion drawn by Abiola & Olowoyo (2021), who reported that the presence of agro-chemical retail shops nearby the farmers positively (0.2634) and significantly ($p < 0.05$) influenced the pesticide usage in South Western Nigeria. Implied then is that a unit increase in agro-chemical shops' presence increases pesticide usage by 0.2634 units.

6. Conclusions and recommendations

This study supports the conclusion that the use of agro-chemicals among smallholder maize farmers is primarily shaped by socio-economic, institutional, and ecological determinants that either enable or constrain individual farmers' decisions. Ecologically, declining soil fertility and increasing pest and weed infestation strongly compel farmers to apply fertilizers, herbicides, and pesticides to sustain maize production. Institutionally, interactions with extension officers significantly increase the likelihood of using fertilizers and pesticides, while weak linkage between farmer and research system limit farmers' access to practical knowledge on agro-chemical use. Access to credit also plays a key role in promoting herbicide and pesticide use, yet most farmers cannot access the loand from finantial institutions due to strict loan requirements. Socio-economically, gender, age, marital status, household size, income levels, and distance to agro-dealers shape the extent to which farmers can use agro-chemicals, with low-income farmers and those living far from input

suppliers being particularly disadvantaged. Overall, agro-chemical use is driven by farmers' need to respond to worsening ecological conditions while navigating financial, institutional, and demographic constraints.

The policy implications of this study indicate the need to strengthen the key factors that significantly influence agro-chemical use among smallholder farmers, particularly extension services, credit access, soil fertility management, pest and weed control, and proximity to input markets. Strengthening interactions between farmers and extension officers is critical, as regular contact with extension officers was shown to significantly increase the use of fertilizers and pesticides. Enhancing access to affordable credit is equally important because farmers with credit were more likely to use herbicides and pesticides, while the majority lacked access due to high interest rates and collateral requirements. Improving the proximity of agro-dealer shops is necessary since long distances reduced herbicide and pesticide use. Lastly, targeted interventions are needed to support low-income farmers whose limited financial capacity restricts their ability to purchase agro-chemicals, as revealed by qualitative findings.

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