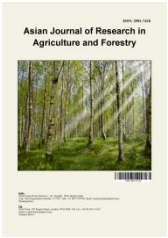

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Impacts Assessment of Farmers' Knowledge in Using Pesticides on Agricultural Productivity in Bugesera District, Rwanda

Védaste Mugemanyi [a*], Pancras Ndokoye [b] and Francois Régis Niyomugaba [a]

[a] University of Lay Adventists of Kigali (UNILAK), Faculty of Environmental and Development Studies, Option of Environmental Economics and Natural Resources Management Kigali, Rwanda.
[b] University of Technology and Arts of Byumba (UTAB), Faculty of Agriculture and Environmental Management and Renewable Energy, Gicumbi District, Rwanda.

Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Nowadays, the use of pesticides in modern agriculture has increased due to the heightened strain from insects and weeds on animal and crop health. This study aimed to assess the impacts of farmers' knowledge in using pesticides on agricultural productivity in the Bugesera district, the Eastern Province of Rwanda. Data were collected from the fifteen sectors of the study area using

**Corresponding author: E-mail: vemugema@gmail.com;*

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questionnaires, with 399 respondents selected through random and purposive sampling techniques. SPSS software was used for data analysis, which was summarized using contingency tables and graphs. Correlation analysis was done to assess the link between farmers' knowledge of pesticide use and agricultural productivity in across sub-locations.

The study revealed that the level of pesticide use in the Bugesera district was very low, at just 17%, and only 22% of farmers had good level of knowledge about pesticide use. Vegetables were the first crops sprayed by farmers, accounting for 82% of the total crop types to which pesticides were applied in the Bugesera district. Moreover, vegetable yields increased from 9t/ha to 9.475 t/ha following pesticide application. The study found a significant positive correlation between farmers' knowledge of pesticide use and agricultural productivity at the 0.01 level ($r=0.509$, $p<0.01$).

Enhanced farmers' knowledge of pesticide use and the proper application of pesticides can reduce yield loss and boost agricultural productivity. It is recommended that the Bugesera district can provide the incentive scheme to the innovative farmers and encourage them to serve as role models for others.

This would promote the adoption of appropriate pesticide use practices and adherence to sound agricultural principles in chemical pesticide application.

Keywords: Pesticides; farmer knowledge; productivity; produce quality; pests; good agricultural practice.

1. INTRODUCTION

Pesticides are widely used in present-day agriculture and constitute a practical and cost-effective method for improving crop produce quantity and quality, hence maintaining food security for the world's ever-growing population [1]. Pesticides have become an integral part of modern farming, and play a major role in increasing agricultural productivity [2]. Every year, around 2 million tons of insecticides are applied worldwide, with China being the leading contributor, followed by the United States and Argentina, which is quickly expanding [3]. Pesticides serve a crucial role in agricultural productivity, however their use has the potential to harm the environment, consumers, and farmer's health [4]. If improperly used, pesticides can lead to secondary pest outbreaks. The effects of synthetic pesticide poisoning cases in humans worldwide are quite tremendous. Around 385 million cases of unintentional acute pesticide poisoning of farmers and agricultural workers are found every year, and in around 11,000 cases this poisoning is lethal [5]. Lack of knowledge about the harmful effects of pesticide exposure allegedly, has an impact on low rates of adopting preventive measures when using pesticides. Different studies on the knowledge and application of safe pesticide usage have been performed by many researchers in recent years [6]. Inappropriate knowledge of the risks associated with pesticides leads farmers in Iran to handle and apply pesticides improperly [7-10]. Previous studies have also found that most farmers consider fellow farmers as their main source of information on pesticide usage [11].

Rwanda is promoting agricultural inputs such as insecticides to increase agricultural output for both home and export purpose. Pesticides are also critical for the control of invasive species and noxious weeds [12]. Pest pressure is one of the greatest challenges to crop output in Rwanda, and improving pest control is one strategy to boost food supply. The usage of synthetic pesticides appears to be at both extremes in Rwanda. Some growers do not use pesticides to protect their crops, whereas a tiny percentage of cash crop growers mainly rely on synthetic pesticides. In Rwanda, some farmers applied prohibited pesticides such as endosulfan and benomyl, and 11% used fungicides such as benomyl, mancozeb, and metalaxyl-M to control fall army worm, despite the fact that fall armyworm is not a fungus, as stated by Jean et al [13]. The different instructions on pesticide labels are written in foreign languages which become the challenge to the farmers. Pesticide residues are not a worry in agricultural products sold in local markets but are a concern in export items. Nevertheless, residues on produce caused by farmers' lack of awareness about pesticide use are one of the most serious food safety problems [14]. Studies conducted on the knowledge and usage of pesticides in several developing countries have shown that farmers' practices are often unsafe and can result in the problems [15]. Some studies indicated that farmers have knowledge which comes from

various sources of information related to the use of pesticides associated with various stakeholders including agricultural extension officers, the private sector, farmer groups, and kiosks or pesticide practitioners. However, this knowledge is not sufficient to motivate farmers to change their behavior when practicing good agriculture practices for safe pesticide usage. The assessment of farmers' pesticide knowledge on agricultural productivity is very important in applying good agricultural practices specifically pesticide usage.

2. MATERIALS AND METHODS

2.1 The Study Area

This study was conducted in the Bugesera district which is located in the Eastern Province of Rwanda at Latitude. -2.2346° or 2° 14' 4" south; Longitude. 30.1483° or 30° 8' 54" east; at elevation of 1,438 meters. According to NISR [16] the total land area for Bugesera is 120,400 hectares, where the agriculture uses about 72,300 hectares. The use of chemical fertilisers is at low rate (21.5%) as higher as the use of irrigation technology (3%). These two practices are very important for increasing land productivity.

2.2 Data Collection

In this study, a descriptive survey approach was also used since it was found to be flexible enough to allow consideration of many facets of an issue under study. The study's population was 47208 farmers registered in the Smart Nkunganire System in Bugesera District for season A 2023. The researcher selected respondents purposefully according to cooperative membership and they were coming from different sectors of Bugesera district. The researcher used the total number of farmers which is 47208 from (SNS, 2023A) in formula to calculate the sample size. Therefore, Yamane formula was used to calculate sample size n=N/(1+N(e)2) [17], Where n is the sample size, N is the population size, and e is the level of precision. To minimize the risk that the sample size represented the true population the margin error was fixed at 5%. $n = \frac{47208}{1+47208(0.05)^2} = 399$.

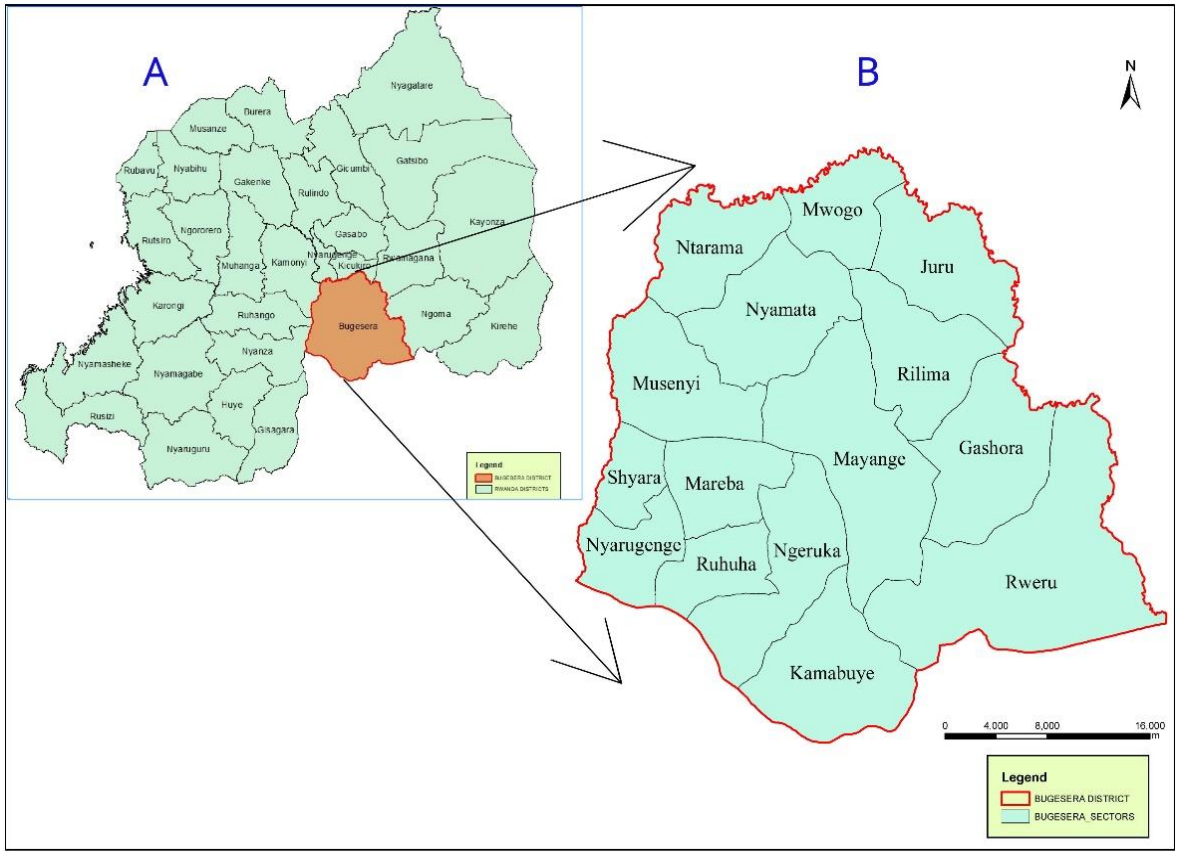

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Fig. 1. Map indicates the location of Bugesera district in Rwanda

Table 1. Sample size showing the number of respondents in each sector

No	Sector Name	Total Farmers	Sample Size
1	Gashora	2002	17
2	Juru	2571	22
3	Kamabuye	3580	30
4	Mareba	3924	33
5	Mayange	2737	23
6	Musenyi	3850	33
7	Mwogo	2201	19
8	Ngeruka	4093	35
9	Ntarama	2137	18
10	Nyamata	2778	23
11	Nyarugenge	1285	11
12	Rilima	1040	9
13	Ruhuha	8925	75
14	Rweru	2950	25
15	Shyara	3135	26
Total Population		**47208**	**399**

The questionnaire for this study was divided into two main parts. The first part contained demographic information while the second one focused on analysis of framers' knowledge in using pesticide and agricultural productivity in Bugesera, where the variables of the study were highlighted. A questionnaire was administered to the respondents , a pre-test of the questionnaire was done before embarking on the actual survey to test its validity and suitability for the study. The questionnaire was addressing the knowledge which farmers have about using pesticides, pests and agricultural productivity.

3. RESULTS AND DISCUSSION

3.1 Characteristics of Farmers

Table 2 shows that 58 % of the respondents were women while 42 % were men. The findings indicate that the information collected was representative for all men and women, therefore everyone has given a chance to air his or her views about using pesticides in agriculture. This means that the probability that a pesticides user is female is closely equal to the probability that such a user is male.

Approximately 16% of the respondents had no schooling; 64% had primary level of education while 14% of respondents had secondary level and the least (6%) had University level of education. As it is indicated on Table 3, it can be said that most of respondents had primary education. Then the literacy can be linked with the level of knowledge in using pesticides in controlling the pests and diseases in their fields, this can be one of the reasons to misuse of pesticides. The illiterate group (16%) had very little skills and knowledge of applying pesticides in the fields. The lower the educational level the lesser one could read and understood instruction on pesticide labels [18].

Table 2. Respondents per sex

		Frequency	Percent
Valid	Male	168	42.0
	Female	231	58.0
	Total	399	100.0

Source: Primary data, 2023

Table 3. Education level of respondents

		Frequency	Percent
Education	No schooling	64	16.0
	Primary	255	64.0
	Secondary	56	14.0
	University	24	6.0
	Total	**399**	**100.0**

Source: Primary data, 2023

3.2 Farmers' Knowledge and Experience in Using Pesticides

Based on Table 4, the study showed that 83 % of the respondents had not used pesticides for controlling pests and diseases but 17 % of farmers had used pesticides in their daily farm activities, the rate of using pesticides in Bugesera district was very low. The main causes of this low rate in using pesticides are ignorance of farmers, pesticides that are either not affordable or not accessible in many parts of district and low knowledge about using pesticides and its importance in increasing agriculture productivity, those findings have the similarity with result of National institute of statistics in Rwanda [16] where in seasonal agricultural survey of 2021 reported that 22.4 % of farmers applied pesticides in season A against 17.9 % of farmers in season B. In addition to that MINAGRI report of Ministry of Agriculture and Animal Resources [19] indicated that the national average of pesticide use is less than 1kg/ha, with the majority of pesticides being fungicides so this can have negative effect on agricultural production so it is very critical that farmers need to have good level of knowledge about using pesticides in effective and efficiency manner in order to increase the agricultural productivity.

All respondents strongly disagreed and disagreed with three statements related to personal protective equipment and using pesticides, as presented in Table 5 all those statements had very weak mean of 1.82 and homogeneity standard deviation. From the observation, researcher found that in Bugesera district farmers have poor level of knowledge in using pesticides and protecting themselves, when they are using chemicals in fields. The farmers did not use full personal protective equipment because the PPE is considered to disturb them when they are working and they are not free to move, which makes difficult for them to breath as reported by Mohammad et al. [20] in their study of pesticide poisoning and the use of personal protective equipment (PPE) in Indonesian farmers. The unwillingness of farmers to not pursue preventive behavior may be due in part to the highly inconvenient of PPE or high cost of PPE for small scale farmers in the study area as confirmed by previous research [21].

Table 4. The respondents who have used chemical pesticides in their farms

Have you ever used chemical pesticides?	Frequency	Percent
No	332	83.0
Yes	67	17.0
Total	**399**	**100.0**

Table 5. Responses of farmers on using pesticide and personal protective equipments

	N	Mean	Std. Deviation
The same pesticide can not be used to control pests and diseases in the same field	67	2.2239	1.49566
Misuse of pesticides affect negatively crops	67	1.8209	1.20511
Personal protective equipments are very important for pesticide users	67	2.2090	1.60998
Valid N (listwise)	67		

Table 6. The real time to spray a chemical pesticide to the crops

Which is the best time to apply a chemical pesticide to the crops?	Frequency	Percent
Morning	56	83
Afternoon	7	11
Evening	4	6
Total	**67**	**100.0**

Source: Primary Data, 2023

Table 6, indicated that the majority respondents around 83% applied chemical pesticides in the morning, while 11% used pesticides afternoon since 6% of respondents used pesticides at the evenings. Spraying in the morning is crucial for serval reasons, including the fact that plants absorb pesticides more effectively and the air is stiller than it is at other times of the day and pesticides to work effectively and for personal safety, still air is essential. Wind disperses spray aimed towards shrubs, endangering people and animals who are in its path. Morning and evening are the best times to apply pesticides.

By considering Table 7 the factors that influence farmers to take decision for spraying are different but this table showed that out of 67 respondents 30 % were aware that they should consider the economic injury level, where farmers should take decision based on the cost used to control pests and diseases while 10% were based on type of pests and diseases for spraying the chemicals, 48% of respondents referring to their farm experience for pesticide application and 12% know that they should apply chemicals based on economic threshold. Therefore, results indicated Table 7 revealed that the most farmers applied chemicals when the cost of application is justified by the outputs, it why good level of knowledge about pests, diseases and pesticides application is very important for increasing the produce in terms of quality and quantity.

Considering the findings of the present study on farmers' knowledge about the colors mark of pesticides, in Table 8 the out of 67 respondents 52 % were aware that the color which indicates more dangerous pesticides is red since the 30% of respondents said that yellow color indicates the high degree of poisonous of pesticides, while 12% said that blue color mark on pesticides shows how the pesticide is dangerous , and 6% of respondents replied that green color is mostly indicates the dangerous chemical pesticides. Whereas (8%) said blue color code, (11%) yellow color code, and (5%) green color code. The current study's findings demonstrate that the majority of farmers who used pesticides to manage pests and diseases are aware of the description that signifies the most toxic insecticides

3.3 Agricultural Productivity Resulted from Pesticides Application

Good agricultural practices regarding pesticide application is essential element for increasing crop yield, it must be done principally to prevent or reduce agricultural losses due to pests and diseases, and this may lead to food availability at reasonable price, all year round. In response to high pest and disease pressure, farmers use several control measures to reduce yield loss including the application of pesticides.

The assessment of agricultural productivity due to pesticides use requires getting the information of how farmers are knowledgeable and their daily practices regarding to pesticide reported by Okonya et al. [22].

Table 7. Reasons for adherence to recommended pesticide dosages in Bugesera District

What have you based on for using pesticide?	Frequency	Percent
On economic injury level	20	30
On type of pests and diseases	7	10
On my own farm experience	32	48
On economic Threshold	8	12
Total	**67**	**100.0**

Table 8. The color marks the most dangerous pesticide

Which color marks the most dangerous pesticide?	Frequency	Percent
Red color	35	52
Yellow Color	20	30
Blue Color	8	12
Green Color	4	6
Total	**67**	**100.0**

Source: Primary Data, 2023

Table 9. Types of crops which have been applied to chemical pesticides

To which crop have you applied to chemical pesticides?	Frequency	Percent
Vegetables	55	82
Maize	8	12
Rice	4	6
Total	**67**	**100.0**

Source: Primary data, 2023

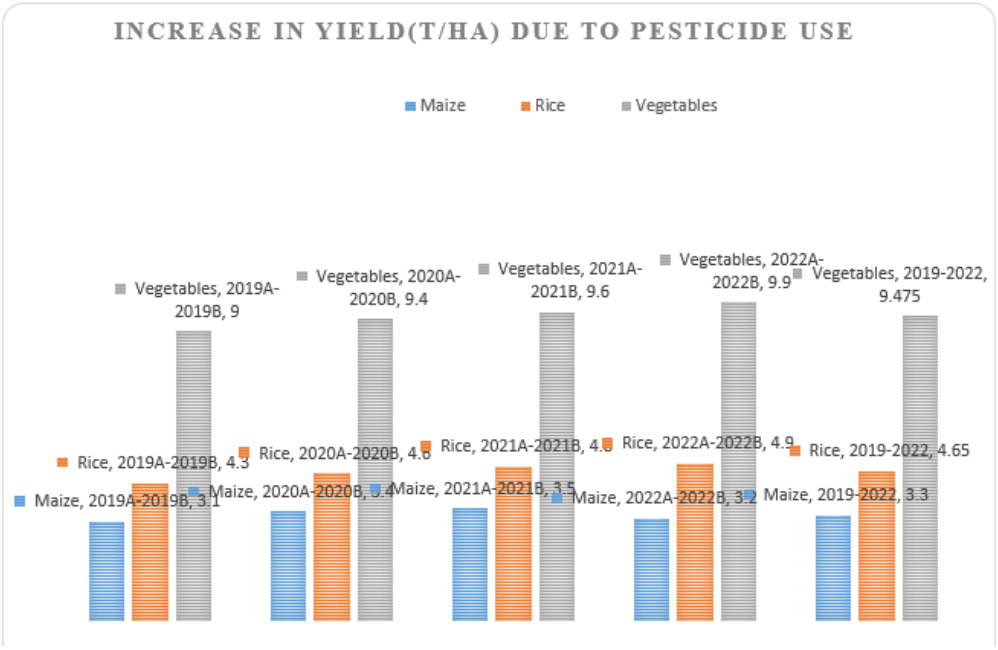

Fig. 2. Increasing crop yield in Bugesera District from 2019-2022

Table 9 indicated that 82% of respondents applied chemical pesticides to vegetable crops,12% of respondents applied the pesticides to the maize since 6% used pesticides for controlling pests and diseases on rice crop. The findings showed that majority of farmers who used pesticides they applied it to vegetable crops. The vegetables are grown in each season of three months and were more susceptible to diseases and pests while other two remained crops were planted one time in each cropping season. This indicated why most farmers applied pesticides in vegetable fields and why they need more knowledge in using pesticides for better increase agricultural productivity in Bugesera district

3.4 Increased Crop Yields Due to Pesticide Application

The Fig. 2 showed the increasing of maize, vegetables and rice crop yield for the respondents who have used the chemical pesticides for controlling pests and diseases in their fields, the increase in production on the above figure started from season A 2019 to season B 2022. For those who have applied the agro chemical pesticides, their yield has increased in the following sequence maize crop yield was 3.1 t/ha to 3.3t/ha, while for the rice yield has increased from 4.3t/ha to 4.65t/ha, while the yield for vegetables has increased from 9t/ha to 9.475 t/ha. Based on the study findings, the vegetable crops were the most responding to pesticides application because most pests and diseases damage this crop compared to others in this study. Farmers testified that their level agricultural production has increased after pesticides application. Their difference in yield can be caused by many factors including the level of knowledge about using pesticide. However the yield can be decreased due to natural disasters such drought, flood, storms and snow in Bugesera district. This result is in line with the findings of study on agriculture development, pesticide application and its impact

Table 10. Relationship between farmers' knowledge in using pesticides and agricultural productivity in Bugesera District

			Farmers 'Knowledge in Using Pesticides
Farmers' knowledge in using pesticides	Pearson Correlation	1	.509
	Sig. (2-tailed)		.000
	N	67	67
Agricultural productivity	Pearson Correlation	. 509	1
	Sig. (2-tailed)	.000	
	N	67	67

Table 11. Farmer household's earned incomes due to pesticides use

Responses	Frequency	Percent
Before using pesticide		
Strongly agree	3	4
Agree	2	3
Neutral	0	0
Strongly disagree	30	45
Disagree	32	48
Total	**67**	**100.0**
After using pesticide		
Strongly agree	36	54
Agree	25	37
Neutral	1	1
Strongly disagree	2	3
Disagree	3	4
Total	**67**	**100.0**

Source: Primary Data, 2023

on the environment by Tudi et al. [12], where they reported that without the use of pesticides, there would be a 78% loss of fruit production, a 54% loss of vegetable production, and a 32% loss of cereal production. Thus, pesticides play a critical role in reducing diseases and increasing crop yields worldwide. It has been noted that loss of crops due to weeds are much more and followed by loss due to pests and insects accounting for the total loss of nearly 50% of crop yield revenues.

3.5 The Relationship between Farmers' Knowledge in Using Pesticides and Agricultural Productivity

Farmers' Knowledge in using pesticides is understanding or awareness of information related to pesticides use. This knowledge refers to the information, facts, skills and wisdom acquired through learning in agriculture sector. Farmers gain knowledge through experiments, observation, and discovery with research. Hence, farmers' knowledge in using pesticides comes into practice in their farming activities and it guides to certain goal of increasing agricultural productivity. In increasing crop yield in terms of quantity and quality famers need to combine knowledge and skills in using pesticides, so there should be relationship between the famers' knowledge in using pesticides and their agricultural produce. The results from this study suggested that, the pesticide application in appropriate way helps in minimizing pest, disease, and weed burdens.

As it is shown by the Table 10 there is a high positive correlation between framer's knowledge in using pesticides and the agricultural productivity, the farmers who have high level of knowledge about using pesticides are more likely to increase their agricultural produce both

quantity or quality. Referring to the above Fig. 2 showed how yield increased among farmers who applied chemical pesticides. The knowledge and practices allow farmers to follow the instructions and taking the right decision in right time. The respondents who used the pesticides in proper way and applying good agricultural practices have benefited from them, the study showed the high positive correlation at the 0.01 level ($r=0.509$, $p<0.01$). This result means that the lower level of farmers' knowledge about using pesticides, the lower level of agricultural produce in terms of quality and quantity. The farmers with a high level of knowledge in using pesticides harvest more and good yield. The knowledge in using pesticides allows farmers to use chemical pesticides in effective and efficiency way so that they can improve their crop yield and livelihood.

The results presented in the Table 11 specified that 45% of all questioned respondents strongly agreed that they did not earn more money incomes before they use pesticides in agricultural activities while 48% of respondents agreed that did not earn enough incomes before using pesticides. After using pesticides 54% of all questioned respondents strongly agreed they earned money incomes from pesticides use while 37% of respondents agreed that farmers earn incomes from pesticide application and 3% of respondents strongly disagreed with the assertion saying that they earned incomes after using pesticides. Some farmers did not generate incomes from pesticide application because they were not able to use required knowledge in using agro chemicals which in turns impacted them to earn the incomes due to lower farming productions they harvested. Therefore, it seems that the majority of all questioned respondents agreed and strongly agreed with the assertion because pesticide application increases farm products and makes farmers get incomes through selling their harvests to market for revenues. Those incomes came from the productions they got due to adopting pesticide application.

4. CONCLUSION

This study was intended to assess the impacts of farmers' knowledge in using pesticides on agricultural productivity in Eastern province. It was conducted in Bugesera district for the period which started from 2019 to 2022. The study found that a great number of farmers do not use pesticides in their field, in order to protect the crops from pests and diseases damage. The famers have low level of knowledge in using pesticide, which negatively affect the pesticides use in effective and efficiency manner and importance of the pesticide and agricultural productivity. There should be a sequence of training events with participatory approaches to enhance and enrich farmers' knowledge and skills, to change farmers' attitudes, and to encourage them to put their knowledge into practice for increasing agricultural productivity. The researcher suggested the further investigation of impact of using pesticides on environment

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of manuscripts.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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