Aflatoxin Awareness and Food Security among Smallholder Farmers in Tanzania

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ABSTRACT

Aflatoxin highly affects food security and income among smallholder farmers. Consumption of aflatoxin contaminated grains or meat, milk and eggs from animals fed with contaminated food causes serious health problems to humans. The aim of this study was to uncover the effects of aflatoxin awareness on food security among smallholder farmers in Tanzania. Awareness theory reviewed rendered the study to use fuzzy cognitive map, with a mixture of observed and unobserved variables. A mixture of latent and observed variables made structural equation modeling an appropriate model for the analysis. Methodological triangulation approach with both quantitative and qualitative analysis was applied, since the study inquired opinions from farmers. Stratified sampling technique was used to get two agroecological regions of Shinyanga and Morogoro, due to their climatic differences. Each region was represented by one district represented by one division. From the division, two wards were selected and from each ward, two villages were selected. In each village, two hamlets were selected, making a total of 8 villages and 16 Hamlets. The sample size of 384 farmers, calculated using Cochran for unknown population, was unequally distributed in each hamlet. The survey revealed that for many farmers, it was the first time to hear about aflatoxin. After a visual illustration, farmers realized that aflatoxin was not uncommon to them. Unlike economic effects, very few farmers knew the health effects of aflatoxin. Some farmers used contaminated stock for consumption, animal feed or making alcohol. Nevertheless, a large number of these farmers did not know what caused aflatoxin during plant growth. They were highly knowledgeable on the causes of aflatoxin during storage. The findings show that aflatoxin awareness has a positive and significant influence on crop quality, hence food security. As was the opinion from many farmers, the Ministry of Agriculture, in collaboration with other development stakeholders, should give high priority to aflatoxin awareness campaigns.

1 INTRODUCTION

1.1 Background to the Problem

Aflatoxins are mycotoxins in human foods and animal feedstuffs (Coppock and Christian, 2007), which threaten food security (Mahato et al., 2019; Grace et al., 2015), as contaminated food turns to be unsafe (Napoli, Muro and Mazziotta, 2011). These naturally occurring compounds from *Aspergillus flavus* and *Aspergillus parasiticus* (Tirmenstein and Mangipudy, 2014), which mostly affect cereals (Lombard, 2014; Udomkun et al., 2018), can be found in oils seeds, spices and tree nuts, as well as in milk (Heshmati, Nejad and Ghyasvand, 2020; Mahato et al., 2019), eggs, and meat from animals fed contaminated feed (Tirmenstein and Mangipudy, 2014). Sineque, Anjos, and Macuamule (2019), suggested dietary diversification to reduce consumption of aflatoxin contamination prone crops as one way to improve health.

Africa suffers, on average, grain economic losses of more than US$ 750 million annually, due to aflatoxin contamination (Kana *et al.*, 2013). For instance, most studies in Africa have consistently revealed higher levels of aflatoxin contamination in maize, above the European regulatory level (Meijer *et al.*, 2021). More than US$ 670 million of export is lost every year due to aflatoxin. Without aflatoxin regulations, contaminated foods which do not meet export standards are sold in the domestic market or used for household consumption, increasing the health risks in local communities (PACA, 2020). The World Health Organisation (WHO) suggests an integrated approach towards controlling aflatoxin. Such practices as removing the sources of contamination, promoting better agricultural and storage techniques, ensuring adequate resources for testing and early diagnosis, enforcing strict food safety standards, informing and educating consumers and smallholder farmers, promoting better livestock feeding and management and creating general awareness about personal protection, are suggested for national authorities to control aflatoxin (WHO, 2018).

Table 1 shows the results from research on the prevalence of aflatoxin in Tanzania for the case of groundnuts and maize. The study used a sample size of 20 farmers, who provided samples for the aflatoxin test in each district. The results show severe prevalence of aflatoxin in groundnuts. In every district, the test had shown aflatoxin concentration above the European Union maximum limit and the East African maximum limit. For the case of maize, at least some districts had all samples with concentration below the European Union and East African maximum limits. These are the standards which are internationally accepted for exports.

Table 1: Prevalence of Aflatoxin in Selected Districts in Tanzania

(a) Groundnuts				(b) Maize			
District	Positive Samples	Exceeds EU limit of 4 µg/kg (%)	Exceeds EAC limit of 10 µg/kg (%)	District	Positive Samples	Exceeds EU limit of 4 µg/kg (%)	Exceeds EAC limit of 10 µg/kg (%)
Babati	20(100)	10(50)	3(15)	Babati	14(70)	4(20)	4(20)
Bukombe	19(95)	6(30)	4(20)	Hanang	5(25)	0(0)	0(0)
Chamwino	20(100)	4(20)	1(5)	Ifakara	14(70)	7(35)	6(30)
Iringa Rural	18(90)	10(50)	6(30)	Kilosa	16(80)	11(55)	11(55)
Kahama	20(100)	5(25)	3(15)	Kiteto	13(65)	1(5)	1(5)
Masasi	18(90)	7(35)	5(25)	Makambako	9(45)	0(0)	0(0)
Nanyumbu	19(95)	5(25)	4(20)	Mbinga	2(10)	0(0)	0(0)
Nzega	20(100)	6(30)	4(20)	Nkasi	7(35)	0(0)	0(0)
Urambo	19(95)	2(10)	1(5)	Songea	6(30)	0(0)	0(0)
				Sumbawanga	13(65)	0(0)	0(0)

Source: Boni *et al.* (2021)

The Partnership for Aflatoxin Control in Africa (PACA) supported initiatives and the Tanzania Initiative for Preventing Aflatoxin Contamination (TANIPAC), target reducing aflatoxin impacts. The government, through different institutions under responsible ministries, is working hard to curb food aflatoxin contamination. For instance, the Tanzania Bureau of Standards (TBS) (PACA, 2020), has already set maximum limits of 5 ppb for aflatoxin B1 and 10 ppb for total aflatoxins in foods for human consumption.

1.2 Statement of the Problem

There are many government initiatives concerning aflatoxin contamination control. However, aflatoxin contamination is still a problem among smallholder farmers in Tanzania. The current study intended to analyse the effects of aflatoxin awareness on food security among smallholder farmers in Tanzania.

1.3 Research Objectives

1.3.1 General Objective

The main objective of this study was to analyse the effects of aflatoxin awareness on food security among smallholder farmers in Tanzania.

1.3.2 Specific Objective

Specifically, the study intended:

- To find out if aflatoxin knowledge was common among smallholder farmers.
- To evaluate measures taken by farmers in fighting against aflatoxin.
- To analyse the effects of aflatoxin measures on food security.

1.4 Research Questions

- Is aflatoxin knowledge common among smallholder farmers?

- What measures do smallholder farmers take to fight against aflatoxin?
- How effective are these measures on food security?

1.5 Significance of the Study

The current study, by assessing food security influence of aflatoxin awareness among smallholder farmers, is in line with government food policies. There are key institutions involved in the delivery of food safety control services in Tanzania. The Ministry of Agriculture and the Ministry of Livestock and Fisheries implement and coordinate food safety activities, in accordance with the National Agricultural Policy of 2013. The Ministry of Industry, Trade and Investment is responsible for implementation of food safety control activities, in accordance with the Agricultural Marketing Policy of 2008 and the Tanzania Standards Act of 2009. Tanzania Bureau of Standards (TBS) is mandated to set food safety standards in accordance with the Tanzania Standards Act (2009), under the ministry responsible for trade. The Ministry of Health, Community Development, Gender, the Elderly and Children, administers food safety services, in accordance with the Tanzania Food, Drugs and Cosmetics Act of 2003. The Tanzania Food and Drugs Authority (TFDA) uses TBS formulated food standards to register food for local manufacture or importation and regularly inspects, tests and certifies all foods sold for export (PACA, 2020).

Nevertheless, there is a lack of literature concerning the effects of aflatoxin awareness on food security. The current study bridged the gap by analysing the effects of aflatoxin awareness on food security in Tanzania. Consequently, the study expanded on the knowledge frontier.

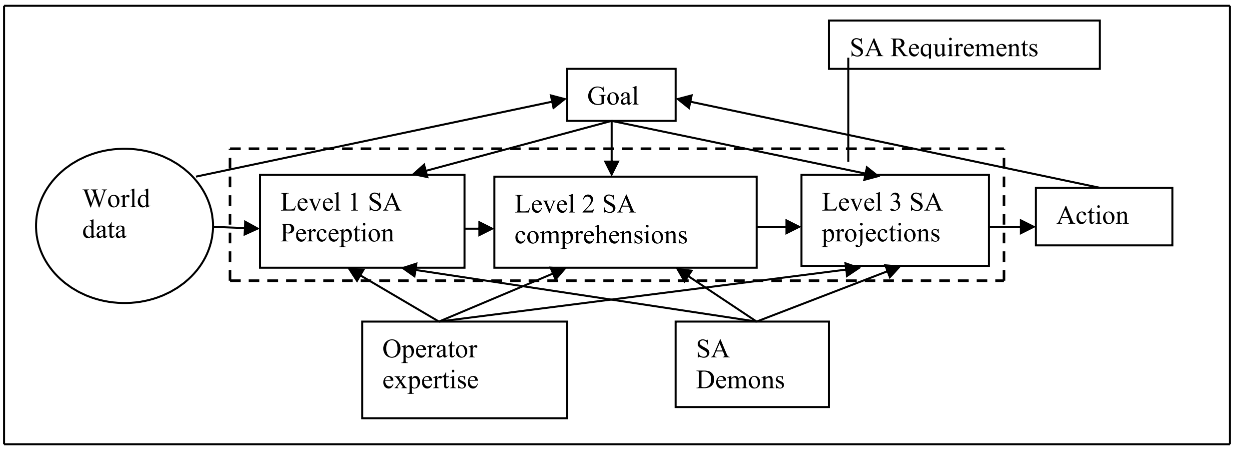
2 LITERATURE REVIEW

2.1 Theoretical Literature Review

The adaptation of technology to ensure the safety of food availability is linked to the Techno-Ecology Theory. According to Scanlan (2003), the Techno-Ecology Theory explains the importance of adapting agricultural methods to produce enough food. Green revolution and new technology to the least developed countries were the idea behind the theory. Fertilizer use and the intensification of agriculture are associated with human adaptation. The Techno-Ecology Theory is appropriate for this study as it requires technology application to deal with aflatoxin. However, it is not possible to adapt anti-aflatoxin technology without being knowledgeable about aflatoxin. Being knowledgeable about a certain situation requires application of the situation awareness theory.

The Situation Awareness Theory is commonly applied among safety analysts. Inaccurate situation awareness may be the proximal cause for operator error (Sætrevik and Hystad, 2017). According to Busby and Witucki-Brown (2011), situation awareness is simply knowing what is going on. However, as noted by Endsley (1995), situation awareness goes beyond perceiving information about the environment. It includes comprehending the meaning of that information in an integrated form, comparing it with operator goals, and providing projected future states of the environment that are valuable for decision making. The Situation Awareness Theory fits the current study as it focuses on how knowledge influences decision making.

Figure 1: High-Level SA-FCM Model



Source: Jones et al., (2009)

Jones, Connors, and Endsley (2009), provided a situation awareness (SA), model showing three levels with fuzzy cognitive map (FCM). SA–FCM model utilizes both top-down (goal driven) and bottom-up (data driven) approaches. Top-down approach begins at the goal node influencing operator's perception from world available data.

The operator's goal influences how much is comprehended (quantity), and what data items are comprehended (quality), describing the nature of comprehensions. Nevertheless, operator's goal has the same influence on the projection node. The aggregate SA from these nodes affects the action of the operator, which then influences the next goal of the operator. The operator's expertise and the amount of SA Demons are nodes that can degrade or enhance the operator's SA. For example, a novice operator may have trouble achieving the same level of high SA as an experienced operator, given the same conditions. Additionally, an increased amount of SA Demons limits the SA of the operator, whereas a low amount of SA Demons does not have significant impact on the operator's SA. The bottom-up approach begins at the data node (world data). Available data determines the goal, which then influences each level of SA. Similar to the top-down approach, the operator's SA is affected by the operator's expertise and the amount of SA Demons. The resulting action is impacted by the operator's SA, which then influences the goal.

Fuzzy cognitive map has been applied in fields like health (Dabbagh and Yousefi, 2019), and road accidents (Yang *et al.*, 2020). But, it is the modeling which is useful in decision support systems and machine learning in variety of real life problems (Motlagh *et al.*, 2015). In the current study, the approach is appropriate as it is about awareness of aflatoxin among smallholder farmers and the measures taken to rescue the situation.

2.2 Empirical Evidence

Aflatoxin awareness is highly researched. Gichohi-Wainaina, Kumwenda, Zulu, Munthali, and Okori (2021), found knowledge disparity among farmers between economic loss and occurrences of aflatoxin, pre-harvest and post-harvest. Their findings show that farmers were more knowledgeable on the economic impact than occurrences of aflatoxin in both pre- and post-harvest periods. In Nigeria, (Johnson *et al.*, 2018), knowledge disparity resulted from aflasafe usage promotion. In areas where aflasafe usage was highly promoted, 100 percent of farmers involved in the survey were aware of aflatoxin. While farmers in areas where aflasafe usage was less promoted, less than 100 percent of farmers were aware of aflatoxin.

Although, aflatoxin awareness was high in the Eastern Democratic Republic of the Congo (Udomkun *et al.*, 2018), researchers have generally revealed higher levels of aflatoxin ignorance in their sample sizes. The documented percentages of respondents not aware of aflatoxin include 97 percent in Tanzania (Magembe *et al.*, 2016), more than 50 percent in Uganda (Nakavuma *et al.*, 2020), 98 percent in Nigeria (Adekoya *et al.*, 2017), in Rwanda 59.7 percent did not know aflatoxin and 99 percent did not know the health effects on humans (Niyibituronsa *et al.*, 2020), only 8 percent of Ghanaians were aware of aflatoxin in 1983 (Udomkun *et al.*, 2017), and in Malawi, over 50 percent did not know the health consequences of aflatoxin (Gichohi-Wainaina *et al.*, 2021). These evidences call for increased awareness campaigns, because (Misihairabgwi *et al.*, 2019), lower levels of public awareness put the population at health risk from exposure to contaminated food.

Variants in aflatoxin ignorance have been noted from the nature of crops infected, stages of contamination and health impacts. For studies carried out in different regions of Tanzania, in Dar es Salaam, 96.7 percent of respondents were unaware of contamination in spices during storage and their health effects (Fundikira *et al.*, 2021), in Kilosa, 97 percent did not know about aflatoxin infection in stored maize and groundnuts (Magembe *et al.*, 2016), and in Babati, 62 percent were aware of aflatoxin, but 98 percent of those respondents did not know that consuming contaminated food posed health risks (Nyangi *et al.*, 2016). Outside Tanzania, studies have shown almost similar awareness trends as those evidenced in Tanzania. For instance, in Kenya, 72 percent of respondents that never heard about aflatoxin, did not know that it can be transferred to milk (Mtimet *et al.*, 2015). In Nigeria, 98 percent of respondents were not aware of mycotoxin contamination in fermented food (Adekoya *et al.*, 2017), in South Africa only 7 percent of smallholder farmers knew about mycotoxin contamination, and some used contaminated food for human consumption (Misihairabgwi *et al.*, 2019), and in Ghana, 63 percent of traders perceived no health effects on consumption of contaminated maize due to high temperature in maize meal preparation (Joseph *et al.*, 2015).

Aflatoxin awareness has been found to vary with socioeconomic characteristics. For example, a study in Tanzania revealed that higher levels of education were associated with higher levels of awareness (Ayo *et al.*, 2018). In Kenya, women were more cautious than men about feeding contaminated maize to their cattle (Kiama *et al.*, 2016). In another survey carried out in Kenya, slightly more men (67.2 percent), than women (48.5 percent), have heard about aflatoxin contamination (Anyango *et al.*, 2018). In Eastern Democratic Republic of the Congo, income was associated with aflatoxin awareness (Udomkun *et al.*, 2018).

Awareness of aflatoxin is very low among all stakeholders, namely farmers, traders and consumers. Suleiman, Rosentrater, and Chove, (2017), revealed a huge aflatoxin knowledge gap among farmers, traders and consumers in Kilosa, Chamwino and Babati agro ecological regions of Tanzania. Over 80 percent of farmers, nearly two-thirds of traders and most consumers were unaware of aflatoxin. It is an improvement, however, if compared to Ethiopia, (Ephrem *et al.*, 2014), where 98.7 percent of farmers, 96.7 percent of traders, and 70 percent of consumers were not aware of aflatoxin contamination and its consequences. Aflatoxin awareness campaigns among stakeholders, especially smallholder farmers (Massomo, 2020), is important for aflatoxin management. As acknowledged in Udomkun *et al.*(2017), effectiveness of measures depend on awareness levels.

2.3 Research Gap

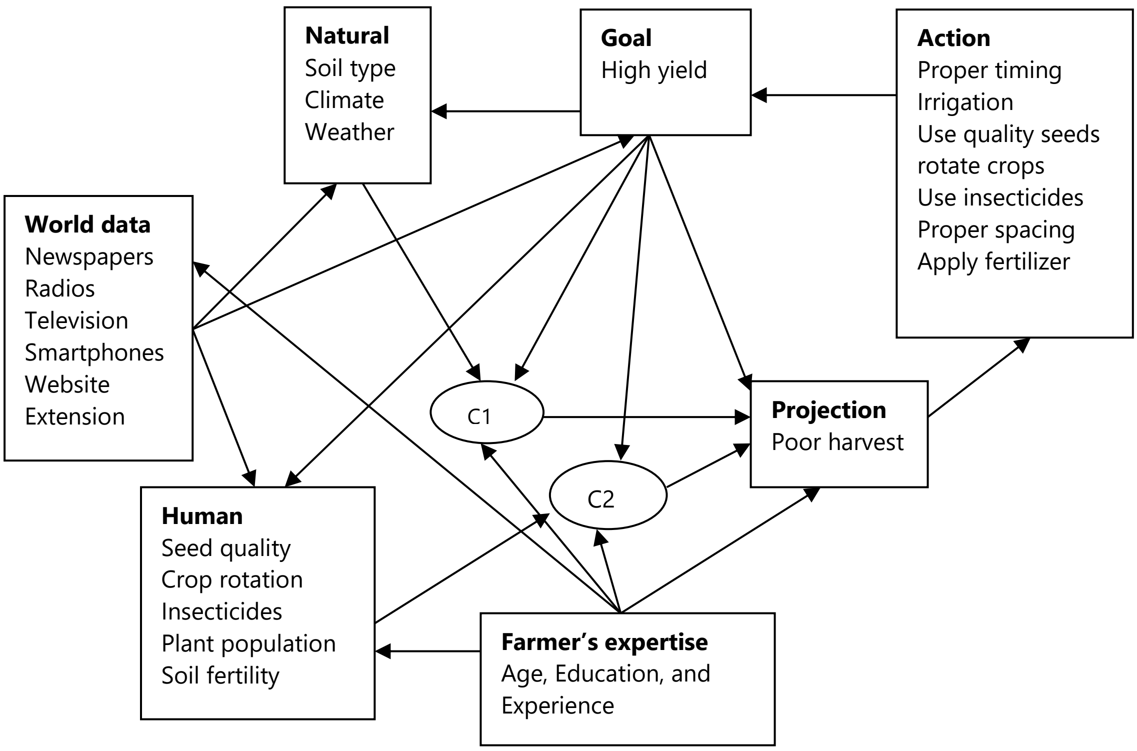
Food security influence of aflatoxin is highly acknowledged (Kana et al., 2013; Ahmed Assaye, Gemeda, and Weledemayat, 2016; Joseph, Lena, Chian, and Anthony, 2015; Waliyar et al., 2016; Worku, Abera, Kalsa, Subramanyam, and Habtu, 2019). Nearly all studies (Suleiman, Rosentrater, and Chove, 2017; Johnson et al., 2018), have used descriptive analysis to show the extent of aflatoxin awareness among stakeholders, namely farmers, traders and consumers, but not how awareness improved food security. The current study bridged the gap by analysing the effects of aflatoxin awareness on food security using fuzzy cognitive map (FCM).

3 RESEARCH METHODOLOGIES

3.1 Conceptual Framework

From Figure 2, farmers receive information from world available data either through different news media or extension officers. This information, natural and human, is perceived and comprehended in Cs. The comprehension leads to projection of whether poor or good harvest, which shapes farmers' decisions on agricultural practices. The action is targeted towards achieving farmers' goal of high yield.

Figure 2: Fuzzy Cognitive Map Before Harvest

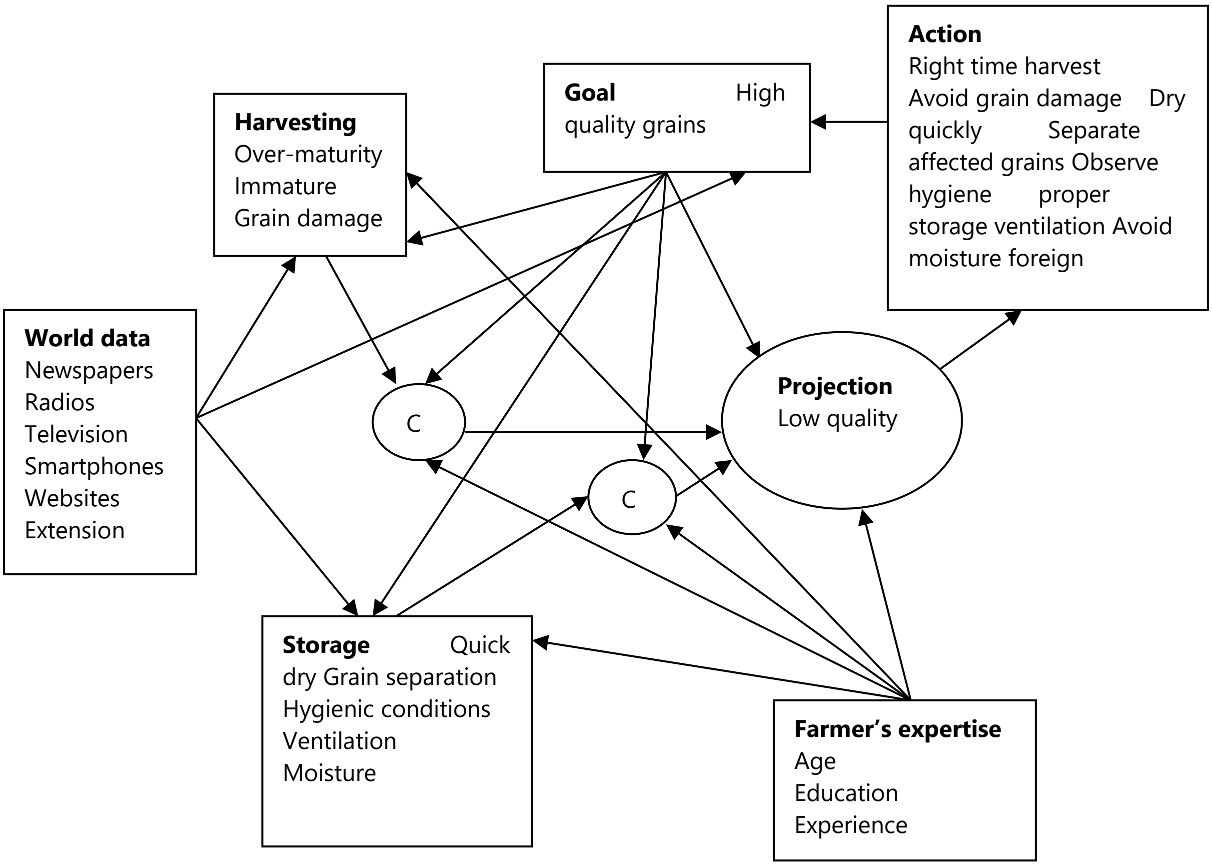


Source: Author's conceptualization

As it is in Figure 1, the farmer can use information to set the goal which then determines the three levels of situation awareness, namely, perception, comprehension and projection, leading to action. The success of each level is hypothesized to be a function of farmer's expertise.

Figure 3 shows the same flow as before harvest, where the farmer depends on the information available from the world, perceives each piece of the information available, comprehends all the perceived information and then projects, thereby leading to action to achieve the set goals.

Figure 3: Fuzzy Cognitive Map During and After Harvest



Source: Author's Conceptualization

The actions depend on the farmer's expertise, yielding good harvest practices, drying and proper storage. The farmer's goal can also influence perception, comprehension and projection, thereby shaping the action. However, quality measure was through observation with grains free from black or green spots of fungus (Sumner and Lee, 2017), considered as high quality grains.

3.2 Model

Structural Equation Modeling (SEM) (McCoach, Black and O'Connell, 2007), accommodates modeling structures based on latent and observed variables, found in both pre- and post-harvest models. Below, is SEM as described in Bollen and Noble, (2011).

$$\eta_i = \alpha_\eta + \mathrm{B}\eta_i + \Gamma\xi_i + \zeta_i \tag{1}$$

Where, η_i is a vector of latent endogenous variables for i^{th} unit, α_η is a vector of intercepts for the equations, B is the matrix of coefficients giving the expected effects of the latent endogenous variables (η) on each other, ξ_i is the vector of latent exogenous variables, Γ is the coefficient matrix giving the expected effects of the latent exogenous variables (ξ) on the latent endogenous variables (η), and ζ_i is the vector of disturbances. The i subscript indexes the i^{th} case in the sample. We also assume that $E(\zeta_i)=0$, $COV(\xi_i^{/}, \zeta_i)=0$, and $(\mathrm{I}-\mathrm{B})$ is invertible. Two covariance matrices are part of the latent variable model: $\sum\xi\xi$ is the covariance matrix of the exogenous latent variables (ξ), and $\sum\zeta\zeta$ is the covariance matrix of the equation disturbances (ζ). The mean of ξ is μ_ξ.

As Bollen and Noble (2011) stress, measurement model links the latent to observed responses or indicators. They portray two equations in the measurement model as given below.

$$y_i = \alpha_y + \Lambda_y \eta_i + \varepsilon_i \quad (2)$$

$$x_i = \alpha_x + \Lambda_x \xi_i + \delta_i \quad (3)$$

Where y_i and x_i are vectors of observed indicators of η_i and ξ_i respectively, Λ_y and Λ_x are matrices of factor loadings or regression coefficients giving the impact of the latent η_i and ξ_i on y_i and x_i respectively, ε_i and δ_i are unique factors of y_i, and x_i. Unique factors are assumed to have zero expected values, covariance matrices of $\sum\varepsilon\varepsilon$ and $\sum\delta\delta$ respectively, and uncorrelated with each other as well as with ζ_i and ξ_i.

3.3 Research Approach and Design

The study used a mixed research approach, which provides more complete understanding of a research problem than either a quantitative or qualitative approach (Schoonenboom and Johnson, 2017). The approach can deal with diversity and complexity of research problems (Hesse-Biber, 2015). The mixed research approach calls for a mixed methods design, namely, convergent parallel, explanatory sequential and exploratory sequential mixed methods (Creswell, 2014). A convergent parallel mixed method was appropriate due to simultaneous collection of quantitative and qualitative data. Demir and Pismek (2018); Tomasi et al. (2018); Razali, Aziz, Rasli, Zulkefly, and Salim (2019), are some of the studies which applied convergent parallel mixed methods.

From the options provided in Table 2, the current study applied a QUAN + qual option, a simultaneous triangulation (Murray, 1999) with qualitative and quantitative methods used concurrently. However, the study used the quantitative sample to obtain qualitative information concerned with farmers' opinions. A mixture of descriptive and explanatory research approaches was used because some results were explained using descriptive statistics, while regression analysis used the explanatory approach.

Table 2: Limitations and Resolutions for Each Methodological Triangulation

APPROACH	TYPE	PURPOSE	LIMITATIONS	RESOLUTION
QUAL + quan	Simultaneous	Enrich description of sample	Qualitative sample	Utilize normative data for comparison of results
QUAL → quan	Sequential	Test emerging Ho; determine distribution of phenomena in population	Qualitative sample	Draw adequate random sample from same population
QUAN + qual	Simultaneous	To describe part of phenomena that cannot be quantified	Quantitative sample	Select appropriate theoretical sample from random sample
QUAN → qual	Sequential	To examine unexpected results	Quantitative sample	Select appropriate theoretical sample from random sample

Source: Morse (1991)

A 5 percent level of significance was used in inferential for consistence with 95 percent confidence interval. A coefficient that passed 10 percent significance level cannot pass the 95 percent confidence interval criterion because it crosses zero just like any other insignificant coefficient. At 5 percent, p values criterion does not contradict the 95 percent confidence interval in results interpretation. Nevertheless, some estimates in the model, namely variances, do not show Z-score or p values, but have the 95 percent confidence intervals.

3.4 Data Collection, Sampling Techniques and Sample Size

This study followed a cross-sectional survey research design capable of obtaining information from large samples (Carpenter *et al.*, 2005). To get information for both pre and post-harvest periods, the study collected data on all stages from farm preparation to food storage. Semi-structured questionnaires were administered in eight villages in the sample.

The study employed a five-stage sampling design, where two regions were purposively selected. Two districts were also purposively selected within those regions. From each district, one division was selected and from one division two wards were also purposively selected. In each ward, two villages, which gave a total of 16 hamlets selected. From these hamlets, farming households were also randomly selected to get a representative sample. Since the population size was unknown, the Cochran Sample Calculation Formula was applied.

$$d = z\sqrt{\frac{\hat{p}(1-\hat{p})}{n}} \Rightarrow n = \frac{z^2(\hat{p})(1-\hat{p})}{d^2} \quad (4)$$

The sample size was determined by confidence level giving Z-score, the success rate, *p* and the critical difference, *d*. The study preferred a confidence level of 95 percent, giving a Z-value of 1.96. The success rate ($\hat{p}$) is always 0.5, but a critical difference (*d*) of 0.05 was decided. With those parameters, approximately 385 smallholder farmers with 192 from Kishapu and 193 from Mvomero were expected in the analysis.

Table 3: Data Collection Arrangement

District	Division	Wards	Villages	Hamlets	Respondents	Percent
Kishapu	Kishapu	Kishapu	Isoso	Karume	27	7.03
				Zaire	20	5.21
			Mhunze	Mwasele	12	3.13
				Mnadani	59	15.36
		Mwakipoya	Mwakipoya	Mwakija Mashariki	23	5.99
				Badi Juu	21	5.47
			Iboja	Iboja	32	8.33
				Korogwe	12	3.13
Mvomero	Mvomero	Mvomero	Mvomero	Kijoja	43	11.20
				Kipogoro	25	6.51
			Mgudeni	Shule Kibaoni	16	4.17
				Vikwang'wa	16	4.17
		Dakawa	Sokoine	Sokoine Shule	19	4.95
				Kanisani	18	4.69
			Wami Dakawa	Magengeni	22	5.73
				Msikitini	19	4.95
Total					384	100.00

Source: Field Data

However, due to errors of omission, the study surveyed only 384 respondents, less than planned. Nevertheless, the respondents were 206 and 178 from Shinyanga and Morogoro Regions, respectively. Table 3 provides detailed information concerning the data collection arrangement. For simplicity, the study used higher strata to make illustrations and in other scenarios, strata have not been applied. Instead, the overall number of the survey was used.

4 PRELIMINARY FINDINGS

4.1 Aflatoxin Awareness Levels and Sources of Awareness

From the survey, a large number of farmers were unaware of aflatoxin, which contends with a large number of literatures concerning aflatoxin awareness like Udomkun et al., (2017), who said that in 1983 only 8 percent of Ghanaians knew about aflatoxin. In the current study, only 53 out of 384 farmers, equivalent to 13.80 percent, were informed about aflatoxin.

Aflatoxin information sources differed among farmers. For farmers who learned about aflatoxin from one source, radio was frequently mentioned compared to other sources, both in Morogoro and Shinyanga. Even those who learned from multiple sources, radio was in almost all combinations but one. Radio was therefore the main source of aflatoxin information. A farmer can easily own a radio and afford its operation costs. Nevertheless, radio listenership cannot negate other activities.

Table 4: Percentage of Farmers Who Have Heard About Aflatoxin

	Morogoro		Shinyanga	
	Respondents	Percent	Respondents	Percent
Yes	33	18.54	20	9.71
No	145	81.46	186	90.29
Total	178	100.00	206	100.00

Source: Field Data

Extension officers were mentioned as the second source after radio and were closely followed by television. Newspapers were only mentioned once in Shinyanga and twice in Morogoro, but in combination with other media. Because many people do not have a culture of reading, newspapers may not be very effective media. It is also possible that aflatoxin issues are rarely published.

Table 5: Aflatoxin Information Sources among Farmers

Information Source	**Morogoro**		**Shinyanga**	
	Frequency	Percent	Frequency	Percent
Radio, Television, Extension Officer and News paper	0	0.00	1	0.49
Extension Officer	6	3.37	2	0.97
None	145	81.46	186	90.29
Radio	12	6.74	7	3.40
Radio and Extension Officer	2	1.12	0	0.00
Radio and Television	0	0.00	5	2.43
Radio, Television and Extension Officer	2	1.12	0	0.00
Radio, Television and News paper	2	1.12	0	0.00
Radio, Television and smartphone	4	2.25	0	0.00
Television	3	1.69	4	1.94
Television and Extension Officer	1	0.56	0	0.00
Total	178	100.00	206	100.00

Source: Field Data

Farmers in Morogoro had access to more information media than in Shinyanga. In Morogoro, even smart phones have been mentioned as a media for aflatoxin information. Smart phones can be more effective because people walk with them everywhere. Since almost every farmer owns a phone, whether smart or featured phone, it is easy to disseminate information, especially through short messages (SMS), which do not require internet connectivity. Although more information can be accessed through the internet, the costs of connectivity can hinder information access. A farmer must have a smart phone to access documents from the internet and since it is only a small portion of farmers who own smart phones, using the internet alone is ineffective.

When they were presented with a sample of affected maize grains and/or ground nuts, farmers confirmed to know aflatoxin. Many farmers knew the economic effects like in Gichohi-Wainaina, Kumwenda, Zulu, Munthali, and Okori (2021). However, health effects tend to be too technical for ordinary farmers. Nyangi et al.(2016) found that 98 percent of respondents did not perceive health risks in consuming food contaminated with aflatoxin.

4.2 Awareness on the Effects and Causes of Aflatoxin

Many farmers, as in Table 6, agreed that aflatoxin reduces harvest and that affected crops fetch relatively lower prices compared to unaffected crops. This is an economic impact of aflatoxin. Unlike economic effects of aflatoxin, the health effects of aflatoxin were not common among smallholder farmers.

Table 6: Percentage of Farmers with Aflatoxin Effects Information

Ward/ Effect	Reduce Price	Reduce Harvest	Stunted Growth	Liver Cancer	Death
Dakawa	91.03	89.74	21.79	17.95	16.67
Kishapu	91.53	92.37	8.47	4.24	2.54
Mvomero	94.00	92.00	23.00	16.00	18.00
Mwakipoya	89.77	89.77	9.09	4.55	2.27

Source: Field Data

A large number of farmers did not know the health effects of aflatoxin contamination. That is why many farmers suggested that the government, through the Ministry of Agriculture, should educate farmers on aflatoxin issues to lessen its health consequences.

Table 7: Percentage of Farmers Aware of Aflatoxin Causes

(a) Farm Preparation Stage					
Ward	Soil type	Climate	Drought	Soil Fertility	Monoculture
Dakawa	7.69	12.82	16.67	15.38	35.90
Kishapu	0.00	2.54	0.85	0.85	3.39
Mvomero	11.00	12.00	17.00	20.00	57.00
Mwakipoya	1.14	5.68	3.41	5.68	21.59

(b) Planting and growing

Ward	Quality Seeds	Plant Population	Insects
Dakawa	20.51	35.90	44.87
Kishapu	2.54	5.93	3.39
Mvomero	22.00	56.00	70.00
Mwakipoya	27.27	30.68	31.82

(c) Harvesting Period

Ward	Immaturity	Over maturity	Damage
Dakawa	64.10	56.41	39.74
Kishapu	4.24	0.85	5.93
Mvomero	88.00	74.00	63.00
Mwakipoya	18.18	10.23	15.91

(d) During Storage

Ward	Fast Drying	Separation	Custody Cleanness	Air Circulation	Moisture Foreign
Dakawa	93.59	89.74	82.05	89.74	97.44
Kishapu	94.07	88.98	92.37	100.00	99.15
Mvomero	98.00	99.00	100.00	100.00	100.00
Mwakipoya	82.95	85.23	96.59	98.86	98.86

Source: Field Data

Many farmers knew that mono-cropping could lead to aflatoxin. But very few farmers knew that soil type could cause aflatoxin, as it required ownership of more than one plot with various soil types to examine. Contrary to Kishapu and Mwakipoya, Dakawa and Mvomero Wards portrayed higher percentages of farmers informed about aflatoxin causes during harvest. Humidity differences determined the maize drying approach. In Kishapu, most farmers left maize to dry in the farm, while in Mvomero maize is harvested earlier to dry at home. During storage, nearly all farmers knew the causes of aflatoxin.

4.3 Farming Practices

Very few farmers used the irrigation method, for economic reasons. Some farmers used resistant crops to cope with drought, while others relied on timing. Soil fertility improvement was avoided by other farmers due to land ownership challenges. The landlord may have taken the land before full realization of fertilizer benefits. A considerable number of farmers rotated crops and very few used mixed farming. Many farmers applied high quality seeds, which fuelled proper spacing as a way of reducing seed costs. The use of insecticides was uncommon for many farmers. In Kishapu District, farmers were given insecticides as loans to facilitate cotton production. Without these loans, the use of insecticides would have been much lower, as it was in Mvomero and Dakawa Wards. This is reflected in other farming activities that required cash.

Table 8: Actions to Prevent Aflatoxin Contamination (Percentage)

Ward	Irrigation	Resistant Crops	Timing	Fertilizer	Crop Rotation	Mixed Cropping	Quality Seeds	Spacing
Dakawa	2.56	0.00	97.44	6.41	47.44	0.00	30.77	85.90
Kishapu	0.85	7.63	91.53	13.56	39.83	4.24	61.86	80.51
Mvomero	2.00	0.00	98.00	4.00	64.00	0.00	23.00	95.00
Mwakipoya	4.55	0.00	75.00	19.32	52.27	0.00	76.14	77.27
Ward	**Insecticides**	**Damaged Crops**	**Timely Harvest**	**Exposure to Sun**	**Sun and Fire**	**Custody Cleanness**	**Good Ventilation**	**No Moisture Foreign**
Dakawa	17.95	60.26	84.62	85.90	0.00	98.72	100.00	100.00
Kishapu	39.83	22.03	55.93	56.78	0.00	100.00	100.00	100.00
Mvomero	15.00	39.00	86.00	86.00	1.00	99.00	100.00	100.00
Mwakipoya	43.18	45.45	61.36	62.50	0.00	96.59	100.00	100.00

Source: Field Data

Many farmers harvested crops in a timely manner, which made exposure to the sun a common drying method. Some farmers, in Kishapu and Mwakipoya, left maize to dry in the field because of lower humidity. In Sokoine Village, farmers harvested earlier to avoid conflict with pastoralists. Earlier maize harvests allow animals to graze on maize stalls. Farmers stored maize grains in special sacks, which ensured proper grain storage. Every farmer stored food in clean and dry places, with enough air circulation to protect grain from moisture foreign.

4.4 Harvested Maize in the Study Area

A large number of farmers in every ward declared presence of contaminated maize in their previous harvest season. Some experienced economically insignificant contamination, while others experienced a large quantity of contaminated maize. But, even for those with low contamination, it was still a huge loss given the quantity of maize harvested. That is why some farmers decided to mix affected maize with clean maize to make food available, albeit of low quality. On average, farmers lost about 0.5 bags of maize due to aflatoxin contamination.

Table 9: Harvested Maize (In Bags)

(a) Affected Maize	Mean	Minimum	Maximum	Observation
Dakawa	.5297	.001	5	62
Kishapu	.4856	.01	3	57
Mvomero	.4592	.03	3	73
Mwakipoya	.5580	.03	10	71
(b) Average Harvest for Farmers Who Detected Aflatoxin Contamination				
Dakawa	10.16	.45	46	62
Kishapu	9.249	1	50	57
Mvomero	16.66	1.5	92	73
Mwakipoya	9.966	1	50	71
(c) Average Harvest for Farmers Who Didn't Detect Aflatoxin Contamination				

Dakawa	4.941	.45	26	16
Kishapu	4.124	.15	20	61
Mvomero	13.26	1	109	27
Mwakipoya	5.235	1	14	17
(d) Overall, Maize Yield in the Study Area				
Dakawa	4.343	.3333	20	78
Kishapu	2.150	.25	25	118
Mvomero	5.827	.6667	13.63	100
Mwakipoya	1.716	.1	7	88

Source: Field Data

On average, farmers who detected aflatoxin contamination, harvested more maize than farmers who did not detect aflatoxin. Farmers in panel (c) have lower average maize harvest compared to their panel (b) counterparts. For instance, a farmer who did not detect aflatoxin in Mvomero harvested 13.26 bags of maize. Though this quantity was significantly greater than in Kishapu District in panel (b), it was lower than average the harvest in Mvomero. But the variation was significant because in the same ward, some farmers harvested 1 bag, while others harvested 109 bags. Farmers' differences in working capital could explain differences in harvest. Many farmers in Mvomero rented tractors, thereby cultivating large areas within a short time. Others applied fertilizer, insecticides and could irrigate when the weather was not favourable. Productivity was also higher in Mvomero District than Kishapu District due to climatic differences.

4.5 Decisions Taken by Farmers on Affected Crops

For many farmers, separation was the means to stop further spreading of contamination. Others peeled the grains that had not been greatly affected, before consuming them. In Dakawa, some farmers made alcohol out of affected grains. They assumed inactivity of aflatoxin in fermented food. In Adekoya et al.(2017), 98 percent of respondents did not perceive aflatoxin in fermented food. Some farmers fed their animals with affected crops, believing that the problem ends with the animals. They were surprised to know that humans can ingest the fungus through meat and milk of animals fed with contaminated grains. Nevertheless, some farmers even mixed contaminated grains with safe grains. However, for others low harvest was the reason for consuming contaminated grains. Throwing away contaminated grains highly reduced their food stock.

Table 10: Actions towards Affected Crops (Percentage)

Ward	Alcohol	Animal Feed	Mixed	None	Peeling	Separated
Dakawa	3.85	2.56	6.41	20.51	0.00	66.67
Kishapu	0.00	0.85	7.63	50.00	0.00	41.53
Mvomero	0.00	2.00	8.00	29.00	11.00	50.00
Mwakipoya	0.00	3.41	10.23	19.32	1.14	65.91

Source: Field data

4.6 Maize Grain Quality in the Study Area

The statistics in Table 11 show a significant association between quality of the crops and the methods used to reduce aflatoxin contamination among farmers who detected aflatoxin. Generally, the table shows a large number of farmers revealing high quality, followed by those who said their crops were of moderate quality, then farmers with low quality grains.

Grain separation was effective in quality improvement. Farmers encountered grain contamination in their food stock, either during harvest or storage periods. But most farmers made the right decision of destroying affected crops. Others separated the crops, but resorted to alternative uses, which had health impacts. Farmers who peeled affected maize highly reduced aflatoxin content, which made consumption safe. They only experienced a slight reduction in food stock. Even though, peeling is only effective for crops which are not highly affected.

Table 11: Tabulation of Actions and Grain Quality

	Action						
Quality	Alcohol	Animal feed	Mixed	None	Peeling	Separated	Total
High	3	5	6	76	10	178	278
Moderate	0	3	5	36	2	27	73
Low	0	0	20	9	0	4	33
Total	3	8	31	121	12	209	384

Pearson chi2 (10) = 158.3438 Pr = 0.000

Source: Field Data

Of those who separated affected grains, only few revealed low crop quality foods stock. This was because a large portion of their food stock had been affected. They could afford to remove only highly affected grains to remain with food for consumption. Surprisingly, some farmers who mixed affected grains claimed to have high quality grains. This is when huge quantities were harvested, with affected crops accounting for a small portion with low levels of contamination.

Farmers who used affected crops for alcohol and animal feed retained high quality. However, mycotoxin was indirectly taken into their bodies through alcohol and milk as well as meat of animals fed with contaminated grains. Even if all the animal products and alcohol were sold to no family members, health risks prevailed in the public. Some farmers did not detect aflatoxin in their maize stock but still reported low quality. Other aspects like insects could lead to low quality even without aflatoxin contamination.

4.7 Farmers' Opinions

Most farmers suggested an education campaign to increase awareness. Others pleaded for insecticides for crop productivity and quality improvement. Storage suggestions combined building standard food stores, proper drying, provision of storage facilities, affordable storage sacs prices, storing in dry place, provision of drying technology and grain separation, had a considerable favour. One farmer, in Kishapu District, expressed her concern showing that drying technology could greatly help her. That timely harvesting did not help due to the humid nature of the area. But if maize was left to dry in the farm, grains could still be contaminated due to humidity. Fast drying technology could significantly reduce post-harvest losses among farmers.

Table 12: Farmers' Opinions on What should be Done

Opinion	Frequency	Percent
Build standard food stores	1	0.26
Control livestock	1	0.26
Drying challenge	1	0.26
Educate farmers	243	63.28
Good farming practices	2	0.52
Harvest at maturity	1	0.26
Increase eradication efforts	2	0.52
Proper drying	1	0.26
Proper storage	17	4.43
Provide agricultural land	3	0.78
Provide drying technology	1	0.26
Provide fertilizer	3	0.78
Provide insecticides	79	20.57
Provide quality seeds	8	2.08
Provide storage facility	2	0.52
Reduce storage sacs price	4	1.04
Reduce tractor renting cost	1	0.26
Separate affected crops	10	2.60
Store in dry place	1	0.26
Subsidize insecticides	2	0.52
Take precaution	1	0.26

Source: Field Data

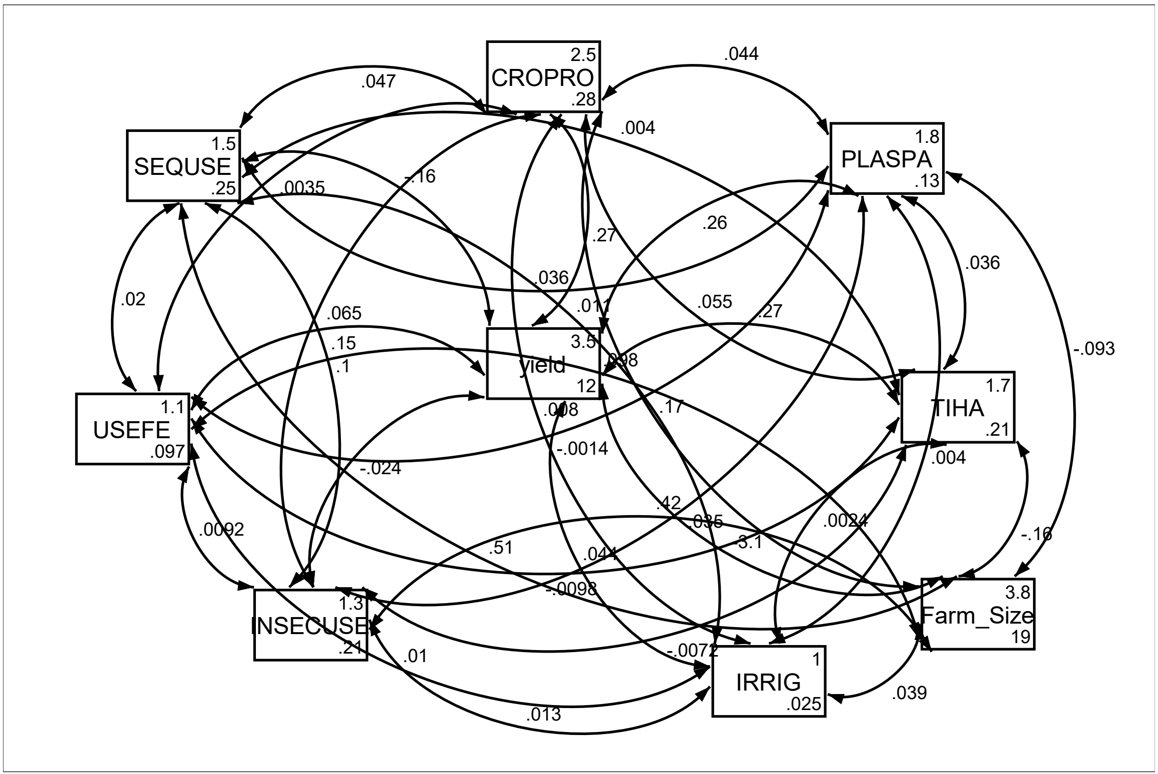
Farmers from Sokoine Village needed land access support to make significant farming investments. Most farmers grew crops on land already planned for government infrastructural development. They request the government to provide alternative farming land. Farmers were also forced to harvest early to leave green maize stems for pastoralists to graze their animals. One farmer observed the importance of being cautious before consuming grains to make sure that contaminated stocks are not mixed with uncontaminated stocks for food consumption. Peeling, a norm for some farmers in Mvomero, could improve food quality.

5 EMPIRICAL FINDINGS

5.1 Covariance Analysis

The structural analysis of covariance between farming practices, farm size and crop yield shows both significant and insignificant correlations among variables. The coefficients of covariance lie along the double headed arrows.

Figure 4: Covariance Analysis of Farming Practices, Farm Size and Crop Yield



Source: Field Data

The variables used in the analysis are used quality seeds (SEQUSE), crop rotation (CROPRO), plant spacing (PLASPA), timely harvest (TIHA), irrigation (IRRIG), used insecticides (INSECUSE), used fertilizer (USEFE), farm size and crop yield (yield). The covariance analysis informed the study on the importance of each farming practice in determining crop yield. Although not in the conceptual framework, farm size was added due to its importance in determining crop yield.

Table 13: Structural Analysis of Covariance

Covariance	Coefficient	Variable	Mean	Variance
CROPRO, yield	.2690***(.0943)	CROPRO	2.492***(.0268)	.2760***(.0199)
CROPRO, INSECUSE	.0648***(.0127)	yield	3.453***(.1776)	12.11***(.8741)
CROPRO, USEFE	.0035(.0084)	INSECUSE	1.297***(.0233)	.2087***(.0151)

CROPRO, IRRIG	.0080(.0043)
CROPRO, TIHA	.0550***(.0125)
CROPRO, SEQUSE	.0468***(.0136)
CROPRO, PLASPA	.0444***(.0099)
CROPRO, Farm Size	.1695(.1175)
yield, INSECUSE	-.0238(.0811)
yield, USEFE	.1458***(.0559)
yield, IRRIG	.0438(.0284)
yield, TIHA	.2714***(.0819)
yield, SEQUSE	-.1601(.0891)
yield, PLASPA	.2598***(.0654)
yield, Farm Size	-3.130***(.7928)
INSECUSE, USEFE	.0092(.0073)
INSECUSE, IRRIG	.0131***(.0038)
INSECUSE, TIHA	-.0072(.0106)
INSECUSE, SEQUSE	.1028***(.0128)
INSECUSE, PLASPA	.0352***(.0086)
INSECUSE, Farm Size	.4199***(.1042)
USEFE, IRRIG	.0102***(.0026)
USEFE, TIHA	-.0098(.0073)
USEFE, SEQUSE	.0197**(.0080)

USEFE	1.109***(.0159)	.0974***(.0070)
IRRIG	1.026***(.0081)	.0254***(.0018)
TIHA	1.708***(.0232)	.2066***(.0149)
SEQUSE	1.487***(.0255)	.2498***(.0180)
PLASPA	1.846***(.0184)	.1300***(.0094)
Farm size	3.816***(.2231)	19.12***(1.380)

Covariance	Coefficient
USEFE, PLASPA	-.0014(.0057)
USEFE, Farm Size	.0983(.0698)
IRRIG, TIHA	.0024(.0037)
IRRIG, SEQUSE	.0108***(.0041)
IRRIG, PLASPA	.0040(.0029)
IRRIG, Farm Size	.0387(.0356)
TIHA, SEQUSE	.0040(.0116)
TIHA, PLASPA	.0359***(.0086)
TIHA, Farm Size	-.1612(.1018)
SEQUSE, PLASPA	.0358***(.0094)
SEQUSE, Farm Size	.5096***(.1145)
PLASPA, Farm Size	-.0934(.0806)

Source: Field Data

In each square box, the mean appears at the top right and the variance at the bottom right. The diagram is not exhaustive since standard deviations and confidence intervals are not displayed. Table 13 enabled the study to make statistical inferences. Mean and variance were statistically significant at 5 percent for each variable. A very large yield variance indicated that some farmers were more productive than others due to large variation in farm size.

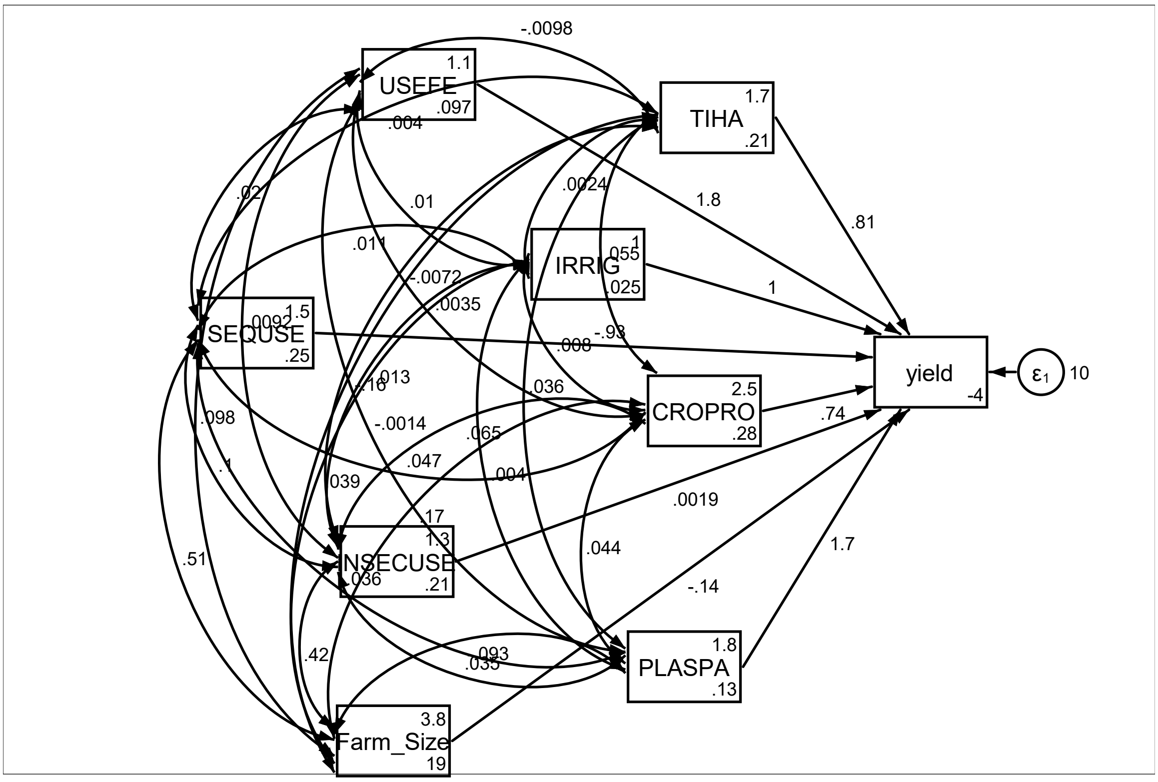
The rest of the variables had variances of less than unit because they are binary, ranging from 0 to 1. With this variation, the variance could not exceed unit.

In covariance analysis, there are 17 insignificant and 15 significant correlations. Variables with insignificant correlations were left in the model because of significant correlation with other variables. For instance, the correlation between crop rotation and farm size is insignificant. But crop rotation is significantly correlated to crop yield, and farm size is significantly correlated to crop yield.

5.2 Path Analysis of Crop Yield

From Figure 5, the single-headed arrows display the regression coefficients showing the influence of independent variables on yield. In structural equation model, dependent variables are assumed to be measured with error.

Figure 5: Path Diagram of Crop Yield



Source: Field Data

Only two variables, namely irrigation (IRRIG) and use of insecticides (INSECUSE), were insignificant. The rest of the variables were statistically significant in influencing crop yield, because the 95 percent confidence intervals did not cross zeros. The use of quality seeds reduced crop yield, because in covariance analysis, farmers who used quality seeds cultivated larger farms. Farm size also negatively influenced crop yield, since small farms were easily managed compared to large farms. However, larger farms produced higher harvests.

Table 14: Structural Regression of Crop Yield

Variable	Coefficient	95% Confidence Interval	
TIHA	.8086**(.3825)	.0590108	1.558282
USEFE	1.797***(.5428)	.7334637	2.861299
IRRIG	1.044(1.073)	-1.058267	3.146548
SEQUSE	-.9273**(.3789)	-1.67	-.1845496
CROPRO	.7370**(.3394)	.0716627	1.402241
INSECUSE	.0019(.4241)	-.8292506	.833065
PLASPA	1.663***(.4904)	.702036	2.624292
Farm Size	-.1420***(.0394)	-.21914	-.0647948
Constant	-3.983***(1.521)	-6.963562	-1.001605
Var(e.yield)	10.36***(.7477)	8.994219	11.93504

LR test of model vs. saturated: chi2 (0) = 0

Source: Field Data

The LR test of model versus saturated chi2 test was insignificant, indicating that the model was a good fit. The post-estimation test for modification indices was irrelevant.

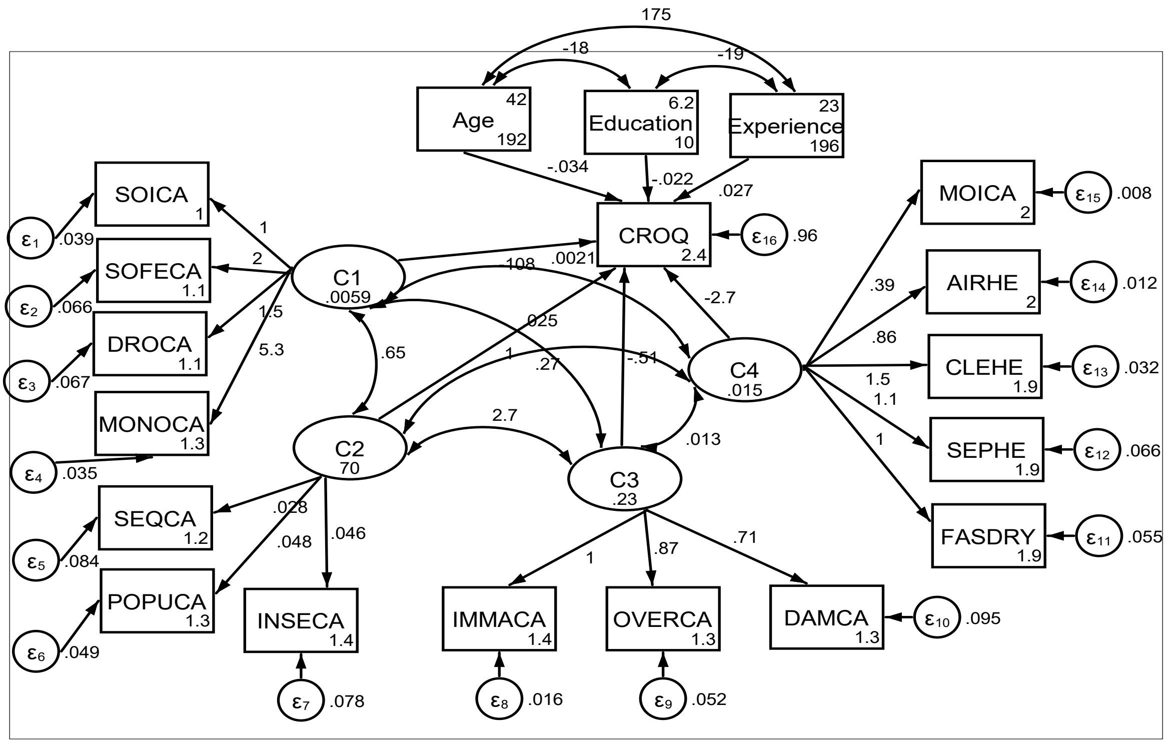
5.3 Path Analysis of Crop Quality

The measurement models C1, C2, C3 and C4, are cognitive levels at the first stage, which together formed a comprehension through correlation analysis using double headed arrows. C1 was measured by awareness variables at farm preparation stage based on farmers' knowledge of aflatoxin causes, soil type causes (SOICA), soil fertility causes aflatoxin (SOFECA), drought can cause aflatoxin (DROCA) and monoculture can cause aflatoxin (MONOCA). Each of these variables was binary with 'yes' or 'no' responses.

C2 was cognitive at planting and growing stages, measured by binary variables with 'yes' or 'no' responses. Whether a farmer knew that seed quality can cause aflatoxin (SEQCA), plant population can cause aflatoxin (POPUCA) and insects can cause aflatoxin (INSECA). C3 was the cognitive level at the harvesting stage. Whether farmers knew that harvesting crops while immature can cause aflatoxin (IMMACA), over-maturity can cause aflatoxin (OVERCA) and crop damage can cause aflatoxin (DAMCA). The cognitive level during storage, C4, was measured by awareness on the causes of aflatoxin during storage. The questions aimed to uncover if farmers were aware that fast drying can prevent aflatoxin (FASDRY), separation of affected crops can reduce aflatoxin (SEPHE), custody cleanness can prevent aflatoxin contamination (CLEHE), sufficient air circulation can reduce aflatoxin (AIRHE) and moisture foreign can cause aflatoxin (MOICA).

All the cognitive latent variables, except C2, together with observable variables (age, education and experience) influenced crop quality (CROQ). However, SEM system used crop quality as an encoring variable of C2 for normalization. SEM and GSEM use anchoring to normalize latent variables for model identification. Table 15 provides estimates of structural equation model for crop quality together with the post estimation test results.

Figure 6: The Path Diagram for Crop Quality



Source: Field Data

Age, education and experience influenced crop quality at least at 10 percent levels of significance. However, education was insignificant when 95 percent confidence interval was used. Because quality was coded as high=1, moderate=2 and low=3, positive coefficients implied negative influence.

The cognitive at farm preparation stage, C1, positively influenced crop quality. Farmers' awareness on causes of aflatoxin at farm preparation stage improved grain quality, thereby improving food security. Alternatively, crop quality significantly determined farmer's awareness at farm preparation stage. The cognitives at harvesting and storage stage were all insignificant, but retained because their co-variances with C1, and their individual variances were significant. The Wald Test in panel (e) proved that crop quality equation was significant.

Table 15: Model Estimation and Wald Test Results

(a) Structural

Variable	Coefficient
Age	-.0338***(.0064)
Education	-.0219*(.0131)
Experience	.0271***(.0064)
C1	-107.42**(44.87)
C2	1 (Constrained)
C3	-.5137(.8864)
C4	-2.673(2.812)
Constant	2.370***(.1930)

(b) Measurement

Latent	Observed	Coefficient	Constant
C1	SOICA	1(Constrained)	1.047***(.0108)
	SOFECA	1.987***(.3187)	1.099***(.0152)
	DROCA	1.509***(.2656)	1.089***(.0145)
	MONOCA	5.313***(.7482)	1.281***(.0229)
C2	SEQCA	.0283**(.0126)	1.169***(.0191)
	POPUCA	.0483**(.0213)	1.307***(.0235)
	INSECA	.0464**(.0205)	1.357***(.0244)
C3	IMMACA	1(Constrained)	1.414***(.0251)
	OVERCA	.8664***(.0347)	1.333***(.0241)
	DAMCA	.7110***(.0374)	1.299***(.0234)
C4	FASDRY	1(Constrained)	1.924***(.0135)
	SEPHE	1.063***(.1729)	1.909***(.0147)
	CLEHE	1.455***(.2198)	1.932***(.0128)
	AIRHE	.8559***(.1267)	1.977***(.0077)
	MOICA	.3930***(.0687)	1.990***(.0052)
Mean	Experience	23.44***(.7143)	
	Age	41.54***(.7069)	
	Education	6.167***(.1644)	

(c) Covariance

Cov(C1,C2)	.6455**(.3241)
Cov(C1,C3)	.0247***(.0042)
Cov(C1,C4)	.0021***(.0007)
Cov(C2,C3)	2.724**(1.224)
Cov(C2,C4)	.2649*(.1394)
Cov(C3,C4)	.0133***(.0041)
Cov(Exper., Age)	175.1***(13.33)
Cov(Exper., Educ.)	-19.27***(2.503)
Cov(Age, Educ.)	-18.29***(2.461)

(d) Variance of error

var(e.SOICA)	.0388*** (.0028)
var(e.SOFECA)	.0658***(.0049)
var(e.DROCA)	.0672***(.0050)
var(e.MONOCA)	.0352***(.0045)
var(e.CROQ)	.9606***(.2656)
var(e.SEQCA)	.0844***(.0065)
var(e.POPUCA)	.0491***(.0051)
var(e.INSECA)	.0783***(.0068)
var(e.IMMACA)	.0163***(.0057)
var(e.OVERCA)	.0524***(.0059)
var(e.DAMCA)	.0954***(.0074)
var(e.FASDRY)	.0552***(.0045)
var(e.SEPHE)	.0663***(.0054)
var(e.CLEHE)	.0321***(.0038)
var(e.AIRHE)	.0122***(.0013)
var(e.MOICA)	.0080***(.0007)
Var(Experience)	195.9***(14.14)
Var(Age)	191. 9***(13.85)
Var(Education)	10.38***(.7490)
var(C1)	.0059**(.0017)
var(C2)	70.11(61.78)
var(C3)	.2263***(.0183)
var(C4)	.0146***(.0038)

(e) Wald test for Equations Ho: Zero coefficients

Observed	Chi2	df	p-value
SOICA	0.00	0	.
SOFECA	38.87	1	0.0000
DROCA	32.29	1	0.0000
MONOCA	50.43	1	0.0000
CROQ	35.57	6	0.0000
SEQCA	5.09	1	0.0241
POPUCA	5.17	1	0.0230
INSECA	5.15	1	0.0232
IMMACA	0.00	0	.
OVERCA	624.30	1	0.0000
DAMCA	362.36	1	0.0000
FASDRY	0.00	0	.
SEPHE	37.78	1	0.0000
CLEHE	43.81	1	0.0000
AIRHE	45.64	1	0.0000
MOICA	32.72	1	0.0000

Note: ***, **, and * represent significance levels at 1, 5, and 10 percent levels of significance respectively. The numbers in parentheses are observing information matrix, OIM standard errors which are default with SEM.

Source: Field data

Panel (b) of Table 15 provides estimates of the measurement model. SEM resolved the problem of measurement error of endogenous variables (Raykov and Marcoulides, 2000) and provided estimates for the variance of error in each endogenous variable. Observed variables were all statistically significant in measuring the latent variables.

5.4 Modification Indices

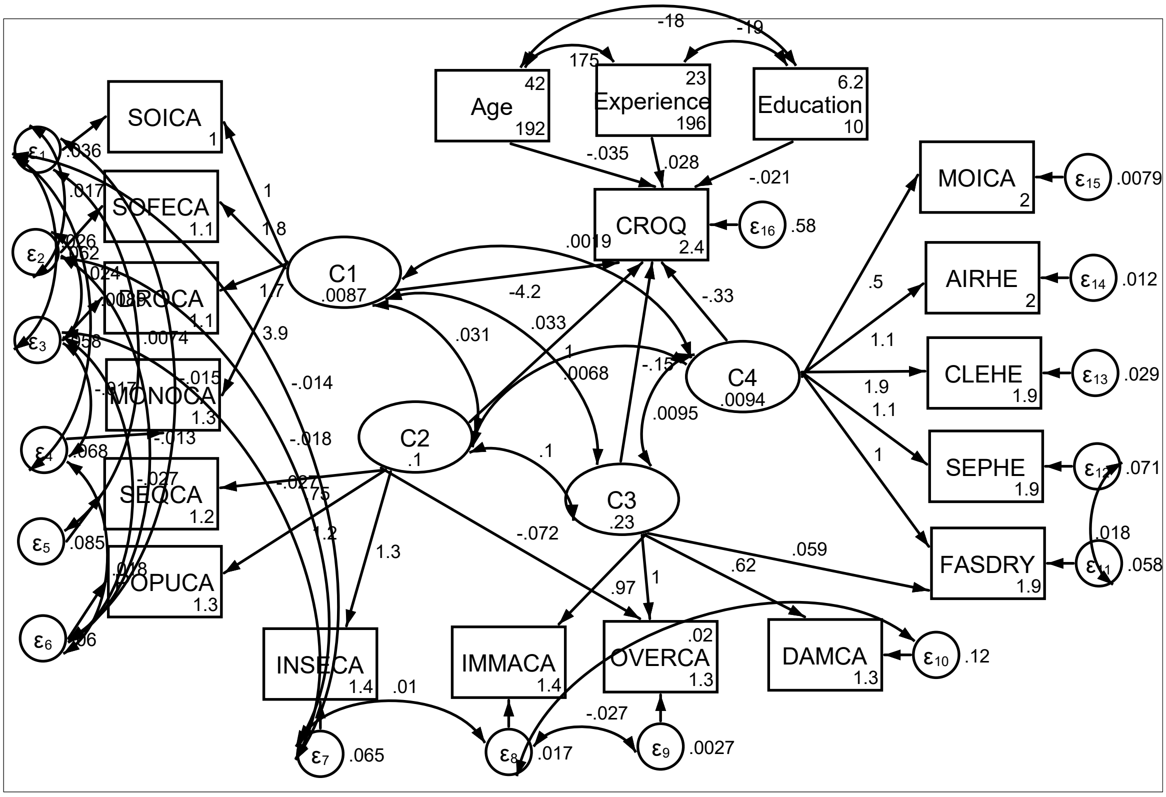
The LR test of the model versus saturated was not reported because the fitted model was not full rank. This necessitated the study to look for modification indices, in appendix, to improve the analysis. The modification indices (MI) were statistically significant, and some had theoretical meanings. For instance, if a farmer knew that immaturity accelerated aflatoxin, then he or she could facilitate faster crop drying. However, the study did not incorporate most modification indices for convergence.

Larger modification indices (McCoach, Black and O'Connell, 2007), improve the model's fit. Covariance between SOICA and DROCA was the largest and together with others like SOICA and SOFECA, were given high priority. Other modification indices were also considered, given their orders of magnitude, from highest to lowest. For the measurement modification indices, the study included only two indices, C3 on FASDRY and C2 on OVERCA.

The modified model was full rank, but not a good fit because the chi2 was statistically very significant. No further modification was considered as the test for modification indices provided no statistics. Significant changes were made in modified model in Table 16. The use of OVERCA to measure C2 and C3 at the same time changed the anchoring variable for C3 from IMMACA to OVERCA. IMMACA changed from anchoring C3 to positively determine C3. OVERCA became an anchoring variable for normalization. C2 became an insignificant determinant of observed variables. In the measurement model, all except constant coefficients changed in magnitude. All structural equation estimates changed in magnitudes with excessive change in C1, that is, from -107.42 to -4.173, indicating a biasness reduction. The changes in the variance of errors were not uniform. Some coefficients increased, while others decreased in magnitude, but their standard errors changed in the same direction.

The correlations between Cs turned insignificant but retained as they make a comprehension for appropriate action because their observed endogenous variables had significant correlations. The positive correlation indicated that an increase in the measurement error in one variable increased the measurement error in another variable. For instance, an increase in the measurement error of POPUCA reduced the measurement error in SOFECA. This means that farmers who were aware that plant population caused aflatoxin were not aware that soil fertility could cause aflatoxin proliferation.

Figure 7: Modified Structural Equation Model



Source: Field Data

In the structural equation, quality was influenced positively by age, but negatively by experience because experience and education were negatively correlated. Although education and age were negatively correlated, the influence of education was more powerful on experience than on age. The mean value of experience was lower than the mean value of age. Nevertheless, the standard error of mean age was slightly lower than the standard error of mean experience.

Only one cognitive latent variable, C1, was significant in influencing crop quality. Quality of crops improved with cognition at farm preparation stage. From the measurement model, farmers who knew that aflatoxin was caused by soil fertility (SOFECA), drought (DROCA) and monoculture (MONOCA), improved quality from preparation stage. A farmer, who applied fertilizer, alternated crops and did irrigation, harvested high quantity and quality crops.

Cognitions C3 and C4 were not significant determinants of crop quality but were significantly determined in the measurement model. Awareness on the causes of aflatoxin, like immaturity (IMMACA), crop damage (DAMCA) and fast dry (FASDRY), positively influenced cognition at harvesting stage. Nevertheless, awareness on prevention during storage also positively influenced cognition at storage stage. The combination of these cognitive latent variables made a comprehension that led into right actions for crop quality improvement.

Table 16: Estimation Results for Modified Model

(a) Structural

Variable	Coefficient
Age	-.0347***(.0064)
Education	-.0210*(.0130)
Experience	.0282***(.0065)
C1	-4.173***(3.647)
C2	1
C3	-.1544(.1299)
C4	-.3071(.5248)
Constant	2.374***(.1928)

(b) Measurement

Latent	Observed	Coefficient	Constant
C1	SOICA	1	1.047***(.0108)
	SOFECA	1.762***(.2446)	1.099***(.0153)
	DROCA	1.667***(.1980)	1.089***(.0146)
	MONOCA	3.938***(.5954)	1.281***(.0229)
C2	SEQCA	.7476(.7789)	1.169***(.0191)
	POPUCA	1.237(1.298)	1.307***(.0235)
	INSECA	1.278(1.330)	1.357***(.0243)
	OVERCA	-.0724(.2943)	
C3	OVERCA	1	1.333***(.0241)
	IMMACA	.9742***(.2656)	1.414***(.0250)
	DAMCA	.6173***(.1762)	1.299***(.0234)
	FASDRY	.0587**(.0283)	
C4	FASDRY	1	1.924***(.0135)
	SEPHE	1.130***(.2065)	1.909***(.0147)
	CLEHE	1.899***(.3372)	1.932***(.0128)
	AIRHE	1.077***(.1855)	1.977***(.0077)
	MOICA	.5040***(.0982)	1.990***(.0052)
	Mean	Age	41.54***(.7069)
		Education	6.167***(.1644)
		Experience	23.44***(.7143)

(c) Variances of error

Variable	Coefficient
var(e.SOICA)	.0362***(.0030)
var(e.SOFECA)	.0625***(.0050)
var(e.DROCA)	.0576***(.0053)
var(e.MONOCA)	.0677**(.0124)
var(e.CROQ)	.5756***(.0485)
var(e.SEQCA)	.0848***(.0064)
var(e.POPUCA)	.0602***(.0081)
var(e.INSECA)	.0646***(.0084)
var(e.OVERCA)	.0027(.0371)
var(e.IMMACA)	.0172(.0349)
var(e.DAMCA)	.1207***(.0165)
var(e.FASDRY)	.0581***(.0045)
var(e.SEPHE)	.0708***(.0055)
var(e.CLEHE)	.0291***(.0042)

(d) Covariance

Variable	Coefficient
Cov(e.SOICA,e.SOFECA)	.0166***(.0031)
Cov(e.SOICA,e.DROCA)	.0261***(.0033)
Cov(e.SOICA,e.MONOCA)	-.0089**(.0041)
Cov(e.SOICA,e.SEQCA)	.0074**(.0029)
Cov(e.SOICA,e.POPUCA)	-.0147***(.0048)
Cov(e.SOICA,e.INSECA)	-.0137***(.0051)
cov(e.SOFECA,e.DROCA)	.0236***(.0043)
cov(e.SOFECA,e.POPUCA)	-.0130***(.0062)
cov(e.SOFECA,e.INSECA)	-.0185***(.0061)
cov(e.DROCA,e.MONOCA)	-.0175***(.0051)
cov(e.DROCA,e.POPUCA)	-.0269***(.0061)
cov(e.DROCA,e.INSECA)	-.0271***(.0063)
cov(e.MONOCA,e.POPUCA)	.0185***(.0071)
cov(e.INSECA,e.IMMACA)	.0104***(.0040)
cov(e.OVERCA,e.IMMACA)	-.0273*(.0141)
cov(e.IMMACA,e.DAMCA)	.0199(.0209)
cov(e.FASDRY,e.SEPHE)	.0176***(.0037)
cov(Age,Education)	-18.29***(2.461)
cov(Age,Experience)	175.1***(13.33)
cov(Education,Experience)	-19.27***(2.503)
cov(C1,C2)	.0314(.0322)
cov(C1,C3)	.0331(.0105)
cov(C1,C4)	.0019***(.0007)
cov(C2,C3)	.1030(.1141)
cov(C2,C4)	.0068(.0075)
cov(C3,C4)	.0095**(.0038)

var(e.AIRHE)	.0119***(.0015)
var(e.MOICA)	.0079***(.0006)
var(Age)	191.9***(13.85)
var(Education)	10.38***(.7490)
var(Experience)	195.9***(14.14)
var(C1)	.0087***(.0025)
var(C2)	.0998***(.2083)
var(C3)	.2339***(.0964)
var(C4)	.0094***(.0030)

LR test of model vs. saturated: chi2(121) = 179.03, Prob > chi2 = 0.0005

Source: Field data

After introducing modification indices, only one latent variable, C1, remained significant. But the determinants of C1 were connected to the determinants of C2. The determinants of C2 were also connected to the determinants of C3. Nonetheless, C1, C2 and C3 were all connected to C4 through covariance indices. If these modifications led to loss of significance for latent variables, then insignificant latent variables were significant determinants of crop quality through their connection to C1.

6 CONCLUSION AND RECOMMENDATIONS

The current survey revealed a large number of farmers who were unaware of aflatoxin. Some of them had not encountered the terminology before. Others have heard the terminology before the current survey but did not know the occurrences of aflatoxin. Many farmers in the study area have not heard about aflatoxin, but through visual illustration, they were able to discern the economic consequences. Most farmers were able to identify the economic consequences of aflatoxin like reduced price and harvest. However, on the health aspect, a large number of farmers did not know that aflatoxin could lead to liver cancer or even cause sudden death. Some gave their animals contaminated feed and others mixed the contaminated with uncontaminated crops for consumption, due to low productivity.

On aflatoxin awareness, many farmers did not know the causes of aflatoxin on the first two stages of farming. That is preparation and planting as well as harvesting. A large number of farmers were not aware, for instance, that soil fertility could lead to aflatoxin. These were very technical portions of aflatoxin occurrences. Storage was the portion of which farmers were greatly aware. All farmers knew that moisture foreign, insufficient air circulation and dirt could cause aflatoxin contamination. Therefore, this is an area where almost every farmer paid much attention.

Some prevention measures taken by farmers were hindered by financial capabilities. For instance, farmers could easily rotate crops because there were no financial implications. Others could easily observe plant spacing because it was costly to plant without proper spacing if seeds were purchased from the shop. The financial cost of irrigation prevented farmers from using irrigation methods in their farming practices. Most farmers who used quality seeds also used insecticides to avoid loss from stalk borer.

Aflatoxin awareness has to some extent shown a significant influence on crop quality. The question of food security could easily be addressed if farmers were well educated on the occurrences. Most farmers suggested that proper education be given to farmers because of the health consequences of consuming contaminated crops. Therefore, the government, through Ministry of Agriculture, should raise awareness in the most economical and efficient way. For instance, information can reach farmers through the conducting of seminars to village leaders. Agricultural Extension Officers should start working in the fields where farmers are found, to offer technical advice. Moreover, the program could also be introduced to school children, to raise awareness from an early age.

In the long-run, irrigation schemes should be put in place to improve soil quality for improved crop quality and productivity. Irrigation was not one of the many options in farmers’ opinions. However, from the analysis, it was easy to tell that irrigation was very important for the improvement of farmers’ productivity. Most farmers did not use irrigation in fighting drought. Their drought fighting method was mainly timing and others harvested very little amount as they were highly dependent on rain-fed agriculture. Irrigation is very important for the food security agenda of economic development.

The study could not test crop quality using appropriate aflatoxin kits. Relying on the views of the farmers concerning the quality of crops presented a critical concern for validity of information. Further investigation using aflatoxin kits can improve accuracy of the results.

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APPENDIX

Modification indices

Measurement	Variable	MI	P>MI	EPM	Standard EPM
SOICA	SOFECA	63.344	0.00	.3186652	.4501752
	DROCA	147.766	0.00	.4782143	.6427072
	SEQCA	21.221	0.00	.1661885	.2948287
	INSECA	3.906	0.05	-.0797116	-.1806538
	OVERCA	5.649	0.02	.0650532	.145081
	DAMCA	15.900	0.00	.1033786	.2240129
SOFECA	SOICA	63.352	0.00	.5410775	.3830121
	DROCA	86.412	0.00	.481004	.4576066
	POPUCA	8.915	0.00	-.2320363	-.358515
	INSECA	7.746	0.01	-.1516644	-.2433112
	OVERCA	5.346	0.02	.0841854	.1329021
	DAMCA	7.923	0.00	.0965734	.1481333
DROCA	SOICA	147.775	0.00	.829385	.6171142
	SOFECA	86.413	0.00	.4913293	.5164509
	MONOCA	19.048	0.00	-.4608773	-.729421
	SEQCA	11.002	0.00	.1582138	.2088442
	POPUCA	15.774	0.00	-.2972861	-.4828167
	IMMACA	4.037	0.04	.0751447	.130291
	OVERCA	12.781	0.00	.1294909	.2148774
	DAMCA	17.873	0.00	.1448678	.2335735
	Education	4.768	0.03	.0090371	.102484
	C3	7.517	0.01	.11458	.1918691
MONOCA	SOICA	17.796	0.00	-.2937288	-.1380902
	DROCA	19.047	0.00	-.2410783	-.1523229
	IMMACA	41.680	0.00	.7214173	.7402893
	OVERCA	4.837	0.03	-.1558007	-.170684
	DAMCA	21.493	0.00	-.1738249	-.1770805
	C3	9.285	0.00	-.2553656	-.2701878
SEQCA	SOICA	20.171	0.00	.3518285	.198318
	DROCA	10.418	0.00	.1927864	.1460488
	IMMACA	8.483	0.00	-.1284575	-.1687321
	OVERCA	5.631	0.02	-.1003327	-.1261292
	C3	7.630	0.01	-.1365802	-.1732629
POPUCA	SOICA	14.517	0.00	-.2663501	-.1220266
	SOFECA	9.233	0.00	-.1739147	-.1125602
	DROCA	16.334	0.00	-.2177105	-.1340515
	MONOCA	45.094	0.00	.9884345	.9632367
	IMMACA	11.549	0.00	-.1637242	-.174792
	OVERCA	9.199	0.00	-.1283411	-.1311322
	DAMCA	11.785	0.00	-.1266953	-.1257779
	C3	14.496	0.00	-.2078112	-.214268
INSECA	SOICA	4.645	0.03	-.1743832	-.0769448
	SOFECA	8.498	0.00	-.1879152	-.1171341

	DROCA	4.380	0.04	-.129699	-.0769134
	IMMACA	36.864	0.00	.2988061	.3072352
	OVERCA	16.554	0.00	.1860959	.1831275
	DAMCA	6.895	0.01	.109414	.104614
	C3	34.901	0.00	.3270683	.3247879
IMMACA	SOICA	8.099	0.00	-.1671565	-.0717326
	SOFECA	8.301	0.00	-.1276598	-.0773917
	DROCA	4.463	0.03	-.0938352	-.054119
	INSECA	9.031	0.00	.1088128	.1058275
	OVERCA	14.367	0.00	-.8231169	-.7877649
	DAMCA	7.116	0.01	.195058	.181384
OVERCA	SOICA	6.897	0.01	.1658505	.0743661
	SOFECA	11.143	0.00	.1567343	.0992816
	DROCA	9.929	0.00	.1499488	.0903632
	MONOCA	4.131	0.04	.0853231	.0813782
	IMMACA	14.367	0.00	-2.641429	-2.759966
	C1	5.855	0.02	.7084569	.1155935
	C2	6.736	0.01	.0071242	.1267964
DAMCA	SOICA	8.791	0.00	.2363325	.1090639
	DROCA	4.893	0.03	.1324886	.0821726
	MONOCA	21.402	0.00	-.2219982	-.2179168
	POPUCA	14.357	0.00	-.1744824	-.1757551
	INSECA	8.289	0.00	-.1216321	-.127213
	IMMACA	7.116	0.01	1.140099	1.226047
	C1	13.714	0.00	-1.207301	-.202738
	C2	14.199	0.00	-.0114247	-.2092744
FASDRY	INSECA	4.797	0.03	.0595932	.1080418
	IMMACA	5.650	0.02	.0633568	.1181055
	OVERCA	6.123	0.01	.06822	.1217092
	SEPHE	26.380	0.00	.2704519	.2945937
	CLEHE	4.382	0.04	-.2116425	-.2012417
	C3	6.248	0.01	.0710919	.1279902
SEPHE	MONOCA	4.052	0.04	.0638562	.0997523
	POPUCA	6.833	0.01	.0813459	.1303977
	DAMCA	6.033	0.01	.0751916	.1196597
	FASDRY	26.381	0.00	.3249926	.2983596
	CLEHE	11.555	0.00	-.3716366	-.3244143
	C1	5.651	0.02	.4635165	.1238692
	C2	5.676	0.02	.0042937	.1251657
CLEHE	CROQ	4.277	0.04	.0300376	.0947352
	FASDRY	4.382	0.04	-.1232791	-.1296506
	SEPHE	11.555	0.00	-.1801467	-.2063692
	AIRHE	6.386	0.01	.5254604	.3164089
	MOICA	6.267	0.01	.3914378	.1581818
AIRHE	INSECA	5.862	0.02	-.0358817	-.1136172
	IMMACA	10.123	0.00	-.0468577	-.1525576
	OVERCA	6.323	0.01	-.0377978	-.1177753
	DAMCA	12.405	0.00	-.052924	-.1602289
	CLEHE	6.386	0.01	.1988583	.330244
	C1	4.924	0.03	-.2196438	-.1116675
	C2	4.432	0.04	-.0019267	-.1068499
	C3	10.567	0.00	-.0511871	-.1609508

MOICA	CLEHE	6.267	0.01	.0979981	.2425068
Covariance					
cov(e.SOICA,e.SOFECA)		63.352	0.00	.0209738	.4152524
cov(e.SOICA,e.DROCA)		147.775	0.00	.0321495	.6297913
cov(e.SOICA,e.MONOCA)		17.795	0.00	-.0113857	-.3083875
cov(e.SOICA,e.SEQCA)		20.328	0.00	.0136928	.2394553
cov(e.SOICA,e.POPUCA)		14.799	0.00	-.0104288	-.2391276
cov(e.SOICA,e.INSECA)		4.514	0.03	-.0066665	-.1209759
cov(e.SOICA,e.IMMACA)		8.791	0.00	-.0069025	-.2744427
cov(e.SOICA,e.OVERCA)		4.716	0.03	.0054871	.1217863
cov(e.SOICA,e.DAMCA)		16.259	0.00	.0129791	.2134535
cov(e.SOFECA,e.DROCA)		86.413	0.00	.0323361	.4861405
cov(e.SOFECA,e.POPUCA)		9.606	0.00	-.011688	-.2056768
cov(e.SOFECA,e.INSECA)		8.227	0.00	-.012183	-.1696711
cov(e.SOFECA,e.IMMACA)		9.723	0.00	-.0095726	-.2920984
cov(e.SOFECA,e.OVERCA)		7.606	0.01	.0091557	.1559562
cov(e.SOFECA,e.DAMCA)		8.461	0.00	.0122971	.1552076
cov(e.DROCA,e.MONOCA)		19.047	0.00	-.0162067	-.3333274
cov(e.DROCA,e.SEQCA)		10.548	0.00	.0130428	.1731983
cov(e.DROCA,e.POPUCA)		16.686	0.00	-.0148011	-.2577091
cov(e.DROCA,e.INSECA)		4.233	0.04	-.0085772	-.1181924
cov(e.DROCA,e.IMMACA)		5.010	0.03	-.0068818	-.2077743
cov(e.DROCA,e.OVERCA)		7.103	0.01	.008885	.1497463
cov(e.DROCA,e.DAMCA)		11.671	0.00	.0145085	.1811844
cov(e.MONOCA,e.POPUCA)		44.642	0.00	.0365573	.8800803
cov(e.MONOCA,e.DAMCA)		15.302	0.00	-.0149248	-.2577039
cov(e.SEQCA,e.IMMACA)		4.825	0.03	-.0077409	-.2086357
cov(e.INSECA,e.IMMACA)		13.885	0.00	.0135964	.3802701
cov(e.IMMACA,e.OVERCA)		14.367	0.00	-.0431049	-1.474512
cov(e.IMMACA,e.DAMCA)		7.116	0.01	.0186052	.4715813
cov(e.FASDRY,e.SEPHE)		26.381	0.00	.0179319	.2964708
cov(e.FASDRY,e.CLEHE)		4.382	0.04	-.0068021	-.1615277
cov(e.SEPHE,e.CLEHE)		11.555	0.00	-.0119443	-.2587457
cov(e.CLEHE,e.AIRHE)		6.386	0.01	.0063913	.323253
cov(e.CLEHE,e.MOICA)		6.267	0.01	.0031496	.1958574
cov(Experience,C1)		3.936	0.05	.0258946	.0240511
cov(Experience,C2)		7.308	0.01	-3.764726	-.0320558
cov(Age,C2)		4.304	0.04	2.884562	.0248196

EPC = Expected parameter change

Source: Field data

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