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Identification of Determinants of the Use of Improved Seeds and Involvement in the SDP by Smallholder Maize Farmers

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A B S T R A C T

This study aims to delineate the socioeconomic characteristics of smallholder maize farmers within the Kwali area of Nigeria, while also delving into the determinants impacting their adoption of improved seeds and engagement with the National Agricultural Seeds Council's (NASC) seed demonstration program (SDP). Employing a meticulous multistage sampling strategy was utilized to obtain 250 cross-sectional data points from nine wards (rural settlements) in the Kwali Area Council. Our analysis, conducted through linear and logistic regression models, unveils significant insights. Specifically, the linear model emphasizes the pivotal role of variables such as total farm size and participation in the NASC's SDP in influencing smallholder farmers' propensity to utilize improved maize seeds. The logit model elucidates how household income and well-being influence the likelihood of smallholder farmers' participation in the NASC's SDP. These findings underscore the necessity for federal government and policymakers to implement targeted policies and interventions aimed at fostering increased adoption of maize seeds across Nigeria.

Keywords: Determinant, Improved seeds, Linear model, Logit model, Seed demonstration program, Smallholder maize farmer

Introduction

According to PwC Nigeria (2020), agriculture has contributed an average of 24% to the GDP of Nigeria, making it the country's largest sector over the last seven years (2013 − 2019). The sector also employs more than 36% of the country's labor force, a feat that ranks the sector as the largest employer of labor in the country. Maize, cassava, guinea corn, and yam are the major crops in Nigeria's households and 70% of them practice crop farming.

Maize is the most commonly cultivated arable crop (Adesoji et al., 2016), it holds an important place in its food economy due to the embargo on rice and wheat flour imports (Osundare, 2013). According to Food and Agriculture Organization (2018), over the 2009 − 2014 period, there was an increase in harvested maize area from 3.4 to 5.9

million hectares, with an increase in production from 3.3 to 6.8 million tons. Currently, Nigeria's annual maize production is about 12.745 million metric tons (Statista, 2023).

However, despite the evidence of sustained maize production in the last two decades, maize yields are still low compared to its potential outcomes. Guilpart et al. (2017) revealed that on-farm maize yields are about 1 − 2 tons per ha compared to the possible outcomes of up to 7 tons per ha. The agriculture sector has faced several challenges that have led to the disparity between the potential and realized yield. These challenges include an antiquated land tenure system that restricts access to land (1.8 ha per farming household), a shallow level of irrigation development (less than 1 percent of cropped land under irrigation), limited adoption of research findings and technologies, high farm input costs, poor credit availability due to the mismanagement of specialized institutions established for the sector's development and farmers' lack of collateral security; ineffective procurement and distribution of fertilizer; inadequate storage facilities; and, more recently, variations in average temperatures, rainfall, climate extremes, and infestation of pests and diseases.

Studies reveal that improved technology adoption is critical for agricultural productivity and the livelihoods of small-scale farmers in developing countries. Promoting agricultural productivity and global food security requires improved seeds (Almekinders et al., 2019). Improved seeds are high-yielding, disease-resistant, and drought-tolerant, as well as responsive to inorganic fertilizer (Simtowe et al., 2019; Lee, 2020), but traditional seeds, which are more adapted to the local environment, have lower yields (Anang, 2019). The Nigeria Government through the National Agricultural Seeds Council (NASC) introduced the Seed Demonstration Program (SDP) to provide solutions to the above challenges. Despite the SDP of NASC across the nation, the use of improved seeds is still low. This supports the need to look into the factors influencing smallholder farmers' use of the improved maize seed and their participation in the SDP of NASC. The upgraded technologies principally chosen for this study were the enhanced SDP of NASC and improved maize seeds, which were introduced by the Nigerian government in 2010.

Therefore, given the significance of this study on the advancement of improved technology, the study seeks to identify the factors influencing the use of the improved maize seed and participation in the SDP of NASC by smallholder farmers. The findings of this study will be crucial to making recommendations on areas to provide support and interventions that will boost the use of improved maize seeds and participation in the SDP of NASC.

Materials and Methods

Study Area

This study was conducted at the Kwali Area Council of the Federal Capital Territory (FCT), Abuja, Nigeria. The FCT of Abuja was established on February 3, 1976, and is Nigeria's capital, located in the center of the nation. The FCT of Abuja is divided into six Area Councils: Abuja Municipal Area Council (AMAC), Gwagwalada, Bwari, Kuje, Kwali, and Abaji. The Kwali is an agricultural area council comprised of rural settlements. Its population is

predominated by smallholder farmers, and their main source of livelihood is through agricultural activities. The Kwali Area Council is purposively selected due to the SDP of NASC activities in the area and it covers nine maize-growing areas across the nine farming communities namely; Ashara, Dafa, Gumbo, Kilankwa, Kwali, Pai, Wako, Yangoji, and Yebu. These areas are presented in Table 1 below.

Sampling Techniques and Data Collection

The study used a multistage sampling technique to identify 250 maize smallholder farmers from across the nine farming communities in the Kwali Area Council surveyed. The sampling strategy was employed to divide the Area Council's huge population into manageable stages, allowing for the Council to be sufficiently represented in the survey. The first stage of the selection was the purposive selection of the Kwali Area Council as a result of the NASC SDP activities in the Council. The next stage is the identification of the nine farming communities. The final stage is the random and proportionate selection of 250 maize smallholder farmers. However, the target population across the nine farming communities in this study is about 2,500 smallholder farmers (NASC, 2020). These farming communities represent the communities in which the improved maize seeds have been introduced through the SDP of NASC. Consequently, in a cross-sectional approach, 250 smallholder farmers were surveyed across these selected sites between May and June of 2023. Primary data was collected through the administration questionnaires by agricultural extension agents, through a face-to-face dialogue, and focused group meetings. The questionnaires were made up of three sections and sampled variables related to maize smallholder farmers' household characteristics, economic factors, and impact-related characteristics of the technology.

Conceptual Structure and Methodology

In order to address the study's objectives, three models were used in this investigation. To describe the socioeconomic traits of smallholder farmers, descriptive statistics were employed. Descriptive statistics highlights the features of a data collection in three types of measures: 1) central tendency (mean, median) 2) data dispersion

Table 1. Study areas and sampling sites in the Kwali Area Council of FCT

Area Council	Study Areas	Target population	Number Surveyed
Kwali	Ashara	680	68
	Dafa	260	26
	Gumbo	240	24
	Kilankwa	120	12
	Kwali	380	38
	Pai	220	22
	Wako	300	30
	Yangoji	240	24
	Yebu	60	6
TOTAL		2,500	250

Source: NASC, 2020

(variability), such as variance, standard deviation, min, and max; and 3) data occurrence (frequency distribution).

The socioeconomic factors influencing smallholder farmers' use of improved maize seeds were identified using a linear regression model. Ordinary least square (OLS) is typically used with one or more independent variables and one or more response variables (dependent variables). The independent variable (X) and the dependent variable (Y) have a linear relationship.

Smallholder farmers' participation in the SDP of NASC was found to be influenced by several factors, which were identified using a logit regression model. Logit regression is a statistical method for calculating the probability of a binary outcome given one or more predictor variables. Unlike linear regression, which predicts continuous outcomes, logistic regression is used when the dependent variable is categorical and contains two categories (for example, yes/no or success/failure). To accomplish the goal of this study, twenty variables and seven variables were used in the linear regression model and the logit regression model, respectively.

Socio-economic characteristics of smallholder maize farmers

Socio-economic characteristics of smallholder maize farmers in the study area were analysed and presented using descriptive statistics mainly through mean, percentage, and frequency of their variables. The socio-economic characteristics in comparison with the participation and non-participation groups assessed in this study are gender, age, marital status, education level, farming experience, household size, farm size, farmers' membership, household monthly income, farming system, and type of labor used.

Factors influencing the use of improved maize seeds by smallholder farmers

This study applies a linear regression model to investigate the factors influencing smallholder farmers' usage of enhanced maize seeds. A generalized linear modelling method called OLS can be applied to one or more independent variables and one or more response variables (dependent variables). According to this model, the vector of independent variables, X, and the dependent variable, Y, have a linear relationship. The linear model is written in the equation (1):

$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \cdots + \beta_K X_K + \varepsilon \quad (1)$$

The regression coefficients are defined as a vector of β. In the k-dimensional space of the independent variables a vector of X, this model describes a hyperplane. When all other predicted variables remain constant, the parameter β indicates the expected change in the dependent variable Y, which is income in this case, per unit change in X. This study uses this model to identify the impact of the independent variables (X_1 to X_{19}) on the dependent variable (Y), which is the quantity of improved maize seeds used as the proxy of income. Variables are defined as follows:

Y = quantity of improved maize seeds used

β_0 = constant

β_i = parameters to be estimated (i = 1, 2, 3, ⋯ 19)

X_1 = age of household head

X_2 = education status of household head

X_3 = size of household

X_4 = total farm size

X_5 = farmer's experience

X_6 = household income gap

X_7 = social networking

X_8 = increase in financial status

X_9 = poor extension PR

X_{10} = illiteracy level of household head

X_{11} = participation in the SDP of NASC

X_{12} = high cost of improved seeds

X_{13} = poor organization of demonstration and field day

X_{14} = inadequate information on improved seeds

X_{15} = demonstrated varieties over local varieties

X_{16} = unavailability of improved seeds

X_{17} = inadequate information from other farmers

X_{18} = unfavourable government policy

X_{19} = lack of credible vendors

ε = the error term

Factors influencing the participation of Smallholder farmers in the NASC Seed Demonstration program

The logit regression model is another tool used in this study to identify the variables affecting smallholder farmers' participation in the NASC seed demonstration program in the research area. The logit regression is a mathematically extremely flexible and user-friendly function with a theoretically meaningful interpretations, it is more significant than other linear regression when the outcomes are binary. The logit model used in this study is in the equation (2):

$$\ln Y = \ln [(P(X)/ (1\text{-}P(X)] = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \cdots + \beta_6 X_6 \quad (2)$$

Y is the latent variable with dichotomous choice, $P(X)$ is the probability of the event to occur, given by 1, while the probability of the event not occurring is 1-$P(X)$. The $P(X)$/ (1-$P(X)$) is the odds ratio in favor of the event to occur. With a notion of intercept, β_0, a vector of β represent the independent variables' coefficients and a vector of

X are the independent variables of the model.

The results of its analysis are presented as odds ratios because logit regression determines the likelihood of success over the likelihood of failure. Knowledge of the connections and strengths between the variables is another benefit by using logistic regression.

This logit formula can be used to estimate the change in the probability of smallholder farmers who participated in the SDP of NASC and comparison with non-participation which identifies the factors influencing smallholder farmers in the program. The variables are defined as follows :

Y = participation in the SDP of NASC; 1 = participate, 0 = otherwise
β_0 = constant
β_i = parameters to be estimated (i = 1, 2, ⋯, 6)
X_1 = size of household
X_2 = total farm size
X_3 = farmer's experience
X_4 = incomegap
X_5 = wellbeing of farmers
X_6 = social networking
ε = the error term

Results and Discussions

Descriptive Statistics of smallholder farmers

Table 2 presents the descriptive statistics of variables which describes the main variables about smallholder farmers surveyed in Kwali Area Council of FCT of Nigeria in 2023. The most frequent gender of smallholder farmers who participated in the program was male (n = 200, 80%) in this survey.

The majority of smallholder farmers are aged between 31 and 40 years old (n = 83, 33.2%), and the majority of smallholder farmers are married (n = 204, 81.6%). Furthermore, the most frequent smallholder farmers' household size is between 6 and 10 people (n = 204, 81.6%). Also, the study revealed that most smallholder farmers in the study area are of tertiary level education (n = 110, 44%) and the farming experience of smallholder farmers with most frequent is between 11 and 20 years (n = 99, 39.6%). However, the majority of the smallholder farmers surveyed are non-members of agricultural associations (n = 211, 84.4%) while most frequent smallholder farmers have farm sizes between 0.01 to 2 ha (n = 225, 90%).

In addition, most smallholder farmers in the study practice mixed cropping farming systems (n = 187, 74.8%) and the most frequent labor type is Family and Hired (n = 201, 80.4%). The most frequently grouped monthly income earning is between 100,001 and 200,000 Nigeria naira per month (n = 131, 52.4%), and most smallholder farmers engaged in trading as an alternative occupation (n = 131, 52.4%).

Table 2. Descriptive statistics of sampled smallholder farmers in the Kwali Area Council

Variables	Frequency (n)	Percentage (%)
Participation in NASC Seed demonstration program		
Participant = 1	204	81.6
Non-Participant = 0	46	18.4
Total	250	100
Age of Household Head (Years)		
< 21	13	5.2
21 − 30	38	15.2
31 − 40	83	33.2
41 − 50	77	30.8
51 − 60	30	12
> 60	9	3.6
Total	250	100
Gender		
Male = 1	200	80
Female = 0	50	20
Total	250	100
Marital Status		
Single = 1	44	17.6
Married = 2	204	81.6
Widowed = 4	2	0.8
Total	250	100
Household Size		
1 − 5 number	88	35.2
6 − 10 number	126	50.4
> 10 number	36	14.4
Total	250	100
Education status of Household Head (Years)		
Informal education == 1	31	12.4
Primary education = 2	38	15.2
Secondary education = 3	64	25.6
Tertiary education = 4	110	44
No education = 5	7	2.8
Total	250	100
Farmer's Farming Experience (Years)		
1 − 10	77	30.8
11 − 20	99	39.6
> 20	74	29.6
Total	250	100
Agric. Association Membership status		
Member = 1	39	15.6
Non-Member = 0	211	84.4
Total	250	100

Table 2. Continued

Variables	Frequency (n)	Percentage (%)
Farm Size (Hectares)		
0.01 − 2.00 Ha	225	90
> 2.00 Ha	25	10
Total	250	100
Farming System Practiced		
Sole cropping = 1	48	19.2
Mixed cropping = 2	187	74.8
Mixed agriculture = 3	15	6
Total	250	100
Labor Type		
Family = 1	33	13.2
Family and Hired = 2	201	80.4
Hired = 3	16	6.4
Total	250	100
Household Monthly Income (Naira)		
1 − 100,000	89	35.6
100,001 − 200,000	131	52.4
> 200,000	30	12
Total	250	100
Farmer's Alternative occupation		
Trading = 1	131	52.4
Civil servant = 2	57	22.8
Private sector worker = 3	22	8.8
Artisan = 4	40	16
Total	250	100

Factors influencing the use of improved maize seeds by smallholder farmers

The results of applying the linear regression model to data analysis to address the study's second objective are displayed in Table 3, revealing the main factors influencing the use of improved maize seeds by smallholders. The findings show variables total farm size, household income gap, and participation in the SDP of NASC are significant variables at $p < 0.01$ while the age of the household head, farmer's farming experience, and inadequate information from other farmers (on improved seed information) are significant at $p < 0.05$, $p < 0.05$, $p < 0.1$, respectively. The interpretations of the results are the following:

The coefficient of the total farm size cultivated is statistically significant at $p < 0.01$ and has a positive influence on the likelihood of smallholder farmers using improved maize seeds. The findings indicate that the amount of improved maize used increases by 10.78 as the total farm size increases by one unit. This suggests that farmers with larger farms are more likely to use improved maize seeds. It demonstrates that farmers who own more land are better able to employ improved maize seeds to raise yields. This outcome is consistent with the research conducted

by Nkonya et al. (2008), which shows that improved maize seed adoption is positively and significantly (at the 0.002 level) influenced by farm size.

In addition, the coefficient of participation in the SDP of NASC by smallholder farmers in the study area is statistically significant at $p < 0.01$ and positively influences the likelihood of smallholder farmers using improved maize seeds. The result shows that as the participation in the SDP of NASC increases by one unit, the quantity of improved maize used increases by 16.34. It means that farmers who participate in the SDP of NASC are more likely to use improved maize seeds, which implies that the farmers who participate in the SDP are encouraged to use improved maize seeds.

The study area's smallholder farmers' income gap coefficient result is positively correlated and statistically significant at $p < 0.01$. The result reveals that as the income gap of smallholder farmers increases by one unit, the quantity of improved maize used increases by 0.05. The positive significance suggests that farmers with more income gaps are trivially likely to use improved maize seeds, which means that the farmers' income gap would not significantly motivate them to use improved maize seeds.

Moreover, the findings demonstrated that the probability of smallholder farmers utilizing improved maize seeds is positively correlated with the farmers' farming experience, with a significant correlation ($p < 0.05$). The result reveals that as the farming experience of smallholder farmers increases by 1 unit, the quantity of improved maize used increases by 0.22. The positive significance of years of farming experience suggests that farmers with more experience are a little more likely to use improved maize seeds. This illustrates that experienced farmers may have a better understanding of the benefits of improved seeds, such as increased yields and disease resistance. They may also have developed the skills and knowledge necessary to effectively use these seeds, making them more inclined to adopt them.

Another finding is that the coefficient of age of the smallholder farmers is negative and significant at $p < 0.05$ influencing the likelihood of smallholder farmers using improved maize seeds. The result reveals that as the age of smallholder farmers increases by one unit, the quantity of improved maize decreases by 0.18. It suggests that the use of improved seeds is more common among younger farmers. This result supports research by Zavale et al. (2005) showing that younger farmers are more likely than older farmers to adopt improved maize seeds. In line with the aforementioned results, Sinyolo (2020) reported that a farmer's age increase of one year was linked to a 2% decline in the likelihood of utilizing improved maize varieties.

The coefficient of inadequate information on improved seeds by smallholder farmers in the study area is significant at $p < 0.05$ and has a negative influence on the likelihood of smallholder farmers using improved maize seeds. The result reveals that as inadequate information on improved seeds increases by one unit, the quantity of improved maize decreases by 1.02. The negative sign implies that inadequate information on improved seeds would negatively influence the use of improved maize seeds. This means that the denial of smallholder farmers to adequate information on improved maize seeds will lead to the non-use of improved seeds thereby preventing them from enjoying the benefits of using improved maize seeds. Therefore, the results suggest that variables of total farm

Table 3. Results of linear regression model: factors influencing the use of improved seeds by smallholder farmers

Variables	coefficient	Std. err.	T-value
Constant	-20.95***	7.33	-2.86
Age of household head	-0.18**	0.08	-2.17
Education status of household head	0.12	0.54	0.22
Size of household	-0.2	0.18	-1.08
Total farm size	10.78***	0.75	14.48
Farmer's farming experience	0.22**	0.1	2.16
Household income gap	0.05***	0.01	9.05
Social networking	0.44	1.05	0.42
Household financial status	2.05	1.33	1.54
Poor extension PR	-0.32	0.57	-0.56
Illiteracy level of household head	-0.92	0.6	-1.54
Participation in the SDP of NASC	16.34***	3.13	5.23
High cost of improved seeds	-0.17	0.63	-0.27
Poor organization of demonstration and field days	0.18	0.58	0.31
Inadequate improved seed information	-1.02*	0.54	-1.88
Demonstrated varieties over local varieties	0.53	0.62	0.86
Unavailability of improved seeds	0.25	0.63	0.39
Inadequate information from other farmers	0.59	0.82	0.72
Unfavourable government policy	0.07	0.97	0.07
Lack of credible seed vendors	-0.64	0.86	-0.74

Note: *, **, *** indicate significance 10%, 5% and 1% respectively.

size and participation in the SDP of NASC critically influence the likelihood of smallholder farmers in the study area using improved maize seeds.

Factors influencing the participation of smallholder farmers in the SDP of NASC

The logit regression model was used to identify the factors influencing the participation of smallholder farmers in the SDP of NASC in the study area. Three variables namely the total farm size, the household income gap, and household well-being are all significant at $p < 0.01$, $p < 0.01$, and $p < 0.05$, respectively, according to the findings from the 250 observations. Based on the results displayed in Table 4, the interpretive tables for the predictor variables below offer details on the related dependent variable (engagement in the SDP of NASC).

The result reveals that the coefficient of total farm size is statistically significant at $p < 0.01$ and negatively influenced the participation of smallholder farmers in the SDP of NASC. The negative relationship means an increase in total farm size leads to a decrease in the participation of smallholder farmers in the SDP of NASC. This means that for smallholder farmers with larger farm size, the likelihood of participating in the NASC seed demonstration tends to decrease. It can be said that smallholder farmers with larger farm sizes may be occupied with farm activities which could prevent them from participating in the SDP of NASC.

Table 4. Results of logit regression model: factors influencing the participation of smallholder farmers in the NASC seed demonstration program

Variables	coefficient	Std. err.	Z-value	P-value
Constant	-10.23***	3.61	-2.83	0.005
Household size	-0.27	0.17	-1.56	0.118
Total farm size	-10.31***	3.10	-3.33	0.001
Farmers' farming experience	0.10	0.11	0.92	0.360
Household income gap	0.03***	0.01	3.28	0.001
Household well-being	3.82**	1.57	2.44	0.015
Social networking	-1.04	1.33	-0.79	0.431

Note: *, **, *** indicate significance 10%, 5% and 1% respectively.

The coefficient of the household income gap is positive and significant at $p < 0.01$ influencing the participation of smallholder farmers in the SDP of NASC. The result reveals that smallholder farmers with more income gaps are more likely to participate in the SDP of NASC. This implies that the earning income affects smallholder farmers' decisions to participate in the SDP of NASC. This result is consistent with Berna et al. (2020) which states that the participation of smallholder farmers in Savings and Credit cooperatives (SACCO) in Uganda is positively influenced by more income earnings.

The coefficient of the well-being variable is positive and significant at $p < 0.05$ influencing the participation of smallholder farmers in the SDP of NASC. The result shows that smallholder farmers with better well-being have a likelihood of participating in the SDP of NASC. This implies that as the well-being of smallholder farmers gets better, their participation in the SDP of NASC would considerably increase.

Conclusion and Recommendation

This paper is purposely to identify the factors influencing the use of improved maize seed and participation in the SDP of NASC by smallholder farmers. Primary data was collected and analysed using descriptive statistics, linear and logit regression models. Descriptive statistics show that the age distribution of the smallholder farmers in the study area is 33.20% between 31 and 40 years old, with a mean age of 40 and 3.60% above 60. With a mean farming experience of 19, 39.60% of farmers have 11 − 20 years of experience, and 81.60% of the smallholder farmers are married.

The majority of households (50.40%) have 6 − 10 individuals, with an average of 7 people and most of the farmers have attained tertiary education level (44%) with 89% of the smallholder farmers having farm sizes of 0.01 to 2.0 hectares. The farmers' alternative occupation is trading with 52.40% and 80% of the smallholder farmers are male. The majority (80.40%) of the smallholder farmers use both family and hired labour.

According to the findings of the linear regression model analysis of the factors influencing the use of improved maize seed by smallholder farmers, the quantity of improved maize seeds used would increase with an increase in

farm size, farmers' income gap, farming experience, and participation in the SDP of NASC while it decreases with an increase in farmers' age and inadequate information on improved seeds. The results show that farming experience, farmers' income gap, participation in the SDP of NASC, and farm size are positive, while farmers' age and inadequate information are negative.

The logit regression model identified that total farm size, household income gap, and household well-being are factors influencing smallholder farmers' participation in the SDP of NASC. The findings show that for smallholder farmers with larger farm sizes, the likelihood of participating in the NASC seed demonstration tends to decrease while the smallholder farmers with more income gaps and better well-being are more likely to participate in the SDP of NASC.

Conclusively, smallholder farmers in Nigeria are encouraged to actively participate in the SDP of NASC and adopt the new technologies that will be showcased in the future program to improve their household income and well-being. Accordingly, the government and policymakers are advised to implement policies and interventions that will encourage the use of improved maize seeds in Nigeria. Also, suggested is that the federal government of Nigeria should provide enough budgetary allocations for the yearly SDP of NASC to create more awareness about the use of improved seeds, especially maize seeds among farmers in the nation.

Limitation of the Study

The first limitation of this study is a lack of time and funding to collect sufficient information to identify the factors influencing smallholder farmers in the Kwali Area Council of the Federal Capital Territory, Abuja, Nigeria, to use improved seeds and participate in the NASC seed demonstration program. Out of the 2,500 farmers in the research area, only 250 contributed data for the analysis and collection, which may not be enough to make major findings. Notably, acquiring a large amount of data is strongly recommended for producing reliable results.

Another research drawback is the lack of quantifiable data on off-farm income for smallholder farmers in the study area. The majority of respondents failed to estimate their monthly income from non-farm activities during the data collection process. These elements were critical to the study's outcome. Furthermore, most cross-sectional statistics lack the authenticity of the information provided by respondents or the interviewer's documentation of the information gathered.

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