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Assessment Of Post-Harvest Losses On Soybeans Profitability In Three Sectors Of Nyagatare District Of Rwanda

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Abstract – This study used quantitative and qualitative analysis to analyze the effects of post-harvest losses on soybeans productivity and farmers' income. It was conducted in Nyagatare District of Rwanda with a sample size of 120 farmers, 61.7% male and 38.3% female. The study aimed to examine the factor influencing soybeans post-harvest losses and determine the impact of post-harvest losses on farmer's income generated from soybeans production. Data was collected using questionnaires and interview methods with a sample size of 120 soybeans farmers.

The researcher used a Multiple Linear regression model to identify post-harvest losses in the research region, which were influenced by a number of variables. The model was deemed significant at the 5% threshold of significance for all 11 variables used. 99 (82.5%) of the respondents had experienced postharvest losses in the previous season of 2022A, compared to 21 (17.5%) who had not experienced any.

This study examines scientific approaches such as modern soybean production and harvesting methods, developed transportation and storage facilities, and outreach to minimize losses and maximize profits. Postharvest activities such as processing and marketing are also recommended to maximize profits. Results show that for every 1 ton of soybeans harvested, the farmer lost an average of 6.703Kg/ton, reducing their average income by 4,124Rwf/ton.

Keywords – Postharvest losses, Income, Soybeans, farmers, production, Profitability.

I. INTRODUCTION

1.1. Background of the study

Soybean (Glycine max L) is a leading crop due to its high protein content and high-quality edible vegetable oil. It has the potential to improve the economic and nutritional well-being of individuals and communities involved in its production and consumption (RAB, 2016). Soybeans form nodules that contain bacteria called rhizobia. Rhizobium fixes nitrogen from the air into a form that soybeans can use to grow. This is a process commonly referred to as biological nitrogen fixation. Some of the nitrogen is also left behind by fallen leaves and roots to improve soil fertility. This makes soybeans suitable as a cover crop or for rotation with other crops. Because these other crops also benefit from nitrogen (N2Africa, 2014).

INEAC (Institut National pour l'Etude Agronomique du Congo Belge) first introduced soybeans to Rwanda in the 1920s (Munezero, Patrick , Fredah , Ntaganira, & Nsengiyumva , 2018). The Rwandan government has encouraged soybean production in Rwanda, including through seed price subsidies that enable farmers to purchase seeds at affordable prices. However, with current seed varieties, farming practices and fertilization rates, yields are below potential and the crop does not compete with kidney beans (ONE ACRE FUND , 2016).

According to the February 18, 2022 Official Gazette, the soybean varieties that can be grown in Rwanda are: SC. Sequel, SC. Squire, SC. Safari, RW Soy 20-1, RW Soy 20-2, RW Soy 20-3, RW Soy 20-4, RW Soy 20-5, RW Soy 20-6, RW Soy 20-7, RW Soy 20-8, and (MINAGRI 2022). Statistics show that in season A of 2022, the average yield per soybean area of Nyagatare district was 719 kg and the national average yield per area of soybean was 509 kg (NISR, 2022).

To date, Rwanda's soybean production is hampered by poor germplasm, low soil fertility, climate change, pests and diseases, farmers do not have access to quality seed sources resulting to a scarcity of improved varieties that are suited to the country's climatic conditions. We face various major constraints such as badness, limited knowledge, etc. Lack of best agricultural practices and access to post-harvest handling and storage facilities (RAB, 2016). Investing in the soybean value chain has emerged as a potential strategy because of current competitiveness and may convert and boost soybean farmers' profitability and income, unrelenting market demand for soybeans (Peter, Altair, & Anamaria, 2015). The purpose of this study was to assess the post-harvest loss of soybean profitability, in Karangazi, Rwimiyaga and Matimba sectors of Nyagatare District of Rwanda.

II. Research Methodology

2.1. Study area

Nyagatare District is among seven Districts of the Eastern Province. It is bordered by Gatsibo to the south, Gicumbi to the west, Uganda to the north and Tanzania to the East. It is composed of 14 sectors which are: Gatunda, Karama, Rukomo, Karangazi, Katabagemu, Kiyombe, Matimba, Mimuli, Mukama, Musheli, Nyagatare, Rwempasha, Rwimiyaga and Tabagwe (Nyagatare 2018). Based on EICV 5, the over-all population in Nyagatare District is 603,607 occupants among of them, 73.9% are non-youth while 26.1% are youth (EICV5, 2018). The main economic activities are agriculture production and livestock in Nyagatare District. The 2022 season statistics show that, Nyagatare has total land area of 191100 hectares; 148100 hectares of the total in were used for agriculture while 746 ha were cultivated by soybeans (NISR, 2022). This study concentrated in Karangazi, Rwimiyaga and Matimba sectors of Nyagatare District as case study.

2.2. Research Design of the study

A research design, according to (Tesfaye, 2018)**,** is a strategy for acquiring, analyzing, interpreting, and reporting data in research projects (Akhtar, 2016)**.** Three methods available to perform a search: Quantitative, qualitative and mixed methods (Tesfaye, 2018)**.** A mixed methods approach was implemented in this study as it is necessary to gather and analyze A combination of quantitative and qualitative information are required in order to respond to the research question. Both descriptive and econometric analyzes were used in this study. In addition, the procedure of this research is as follows:

2.3. Sampling strategy

In this study, the researcher applied a random sampling method. According to Roscoe (1975 who offered a general guideline for determining sample size, he recommended that a questionnaire's respondent count be greater than 30 and lower than 500. He also demonstrated the need for sample sizes to be at least ten times as large as the number of variables in multivariate studies like multiple regression analysis (Khong , Yee , & Le, 2018).

Under this study, 12 independent and dependent variables were used for multiple regression analysis (farmer experience, education level, land size, type of crop transport, weather conditions, soybean seed quality, cooperative membership, PHL value, road accessibility, age , gender and post-harvest loss). All rules of thumb were strictly followed in this study to ensure reliable data generation and analysis. In all, 120 soybean producers were sampled in the research region.

2.4. Instruments for gathering data

Primary as well as secondary data were used in this research. The Secondary data were gathered from available literature such as previous research papers, reports and websites of various stakeholders containing information on the subject of the study.

In this study, the researcher also used interview and questionnaire tools to gather primary data. To assist in gathering data from respondents, a structured questionnaire was created.

2.5. Methods of statistical analysis

Analysis of the raw data must be done in order to make sense of the gathered data. This study included both inferential and descriptive statistics. To learn more about the respondents' characteristics, descriptive statistics were used. It also helped measure the central tendency, variability, and distribution shape of the variables introduced into the model. Inferential statistics, on the other hand, were used to understand at what level the selected independent variables explained the dependent variables of the model. In addition to allowing explicit control for many other unobserved factors, multiple regression analysis is useful for determining the influence of an explanatory variables on the explained variables. Explanatory factors have an impact influencing post-harvest losses in soybeans was estimated using multiple regression analysis. The model used in this study was specified as follow:

$Y= f(X_1, X_2, X_3, X4, X5\ldots\ldots\ldots\ldots..Xn)$

Where:

Y=Post-harvest losses

Xs are various factors that can lead to PHL at any stage.

$$Y= \alpha+ \beta_{1X1} + \beta_{2X2} + \beta_{3X3} + \beta_{4X4} + \beta_{5X5} + \beta_{6X6} + \beta_{7X7+} \beta_{8X+} \beta_{9X+} \beta_{10X+} \beta_{11X+} £$$

Where:

Y=Post-harvest losses

α=constant

β1- β11 = parameters to be estimated

X_1=Farmer experience (years in soybean farming),

X_2= Education level

X_3=Land size cultivated by soybeans

X_4= Soybeans seed quality

X_5= Cooperative membership

X_6= Mode of transport

X7= Weather condition

X8= Road accessibility

X_9= Value of Soybean PHL

X10= Age

X11= Gender

£= error term

2.6. Data analysis tools

The authors of this study employed multiple linear regression analysis to provide descriptive and inferential statistics for the data. Data were manipulated, analyzed and interpreted using Stata version 13 and MS Excel as required. Descriptive statistics, graphics, and tables were integrated into the work to make it meaningful.

III. Discussion Of The Results

3.1. The respondents' socioeconomic and demographic characteristics

Results based on demographic and socioeconomic background of the respondents are displayed in Table 1 below. Table 1's findings demonstrate that 38.3% of respondents were from Karangazi sector, 27.5% from Rwimiyaga and 34.2% from Matimba sector. It shows also the gender of the respondentsin which 120 soybean farmers surveyed, 46 were female, accounting for 38.3% of respondents, and 74 were male, accounting for 61.7% of the sample size. This indicates that more male respondents participated in this survey than female respondents.

The findings regarding the respondents' ages show that 6.7% of the respondents are between the ages of 18 and 25. 21.7% of respondents were aged 26 and 35, 31.7% were between the ages of 36 and 45, 22.5% were between the ages of 46 and 55, and 17.5% of respondents were over the age of 55. The ages above clearly indicate the maturity of the respondents and their ability to provide relevant answers to the questions. The wide age range also reflects a wide range of opinions on the subjects covered in this study. This is good for removing biases from specific age groups, resulting in more reliable and representative results.

Most respondents (37.5%) attended primary (primary) education and 33.3% attended secondary education. 15% of respondents had no education, 9% had higher education such as university, and 5% had other types of education such as vocational training. This distribution therefore indicates that the level of education of respondents may have influenced their degree of awareness of losses that occurred after harvesting.

Table 1: The socioeconomic and demographic characteristics of the sample

Variables	Frequency	Percentage
Sector		
Karangazi	46	38.3
Rwimiyaga	33	27.5
Matimba	41	34.2
Total	**120**	**100.0**
Sex		
Female	46	38.3
Male	74	61.7
Total	**120**	**100.0**
Age		
18-25	8	6.7
26-35	26	21.7
36-45	38	31.7
46-55	27	22.5
Above 55	21	17.5
Total	**120**	**100.0**
Marital status		
Single	38	31.7
Married	82	68.3
Total	**120**	**100.0**
Education level		
None	18	15.0
Basic	45	37.5
Secondary	40	33.3
Tertiary	11	9.2
Other	6	5.0
Total	**120**	**100.0**
Family size		
1-2	40	33.3

3-4	43	35.8
5-6	10	8.3
Above 6	27	22.5
Total	**120**	**100.0**
Average land size 1.9 ha		
Average farming experience 10 years		

Source: Authors' computation, 2022.

It is observed from the research findings that the mean land size for soybean production in the study area was 1.9 ha well as the average farming experience of soybean producers was 10 years as indicated in table1 above.

3.2. Percentage of respondents who experienced PHL in the research area.

To assess the postharvest soybean profitability loss in the study area, the researcher asked respondents a number of questions in line with the study objectives. The results after interviewing surveyed soybean growers, whether they suffered post-harvest losses or not, are shown in Figure 1 below.

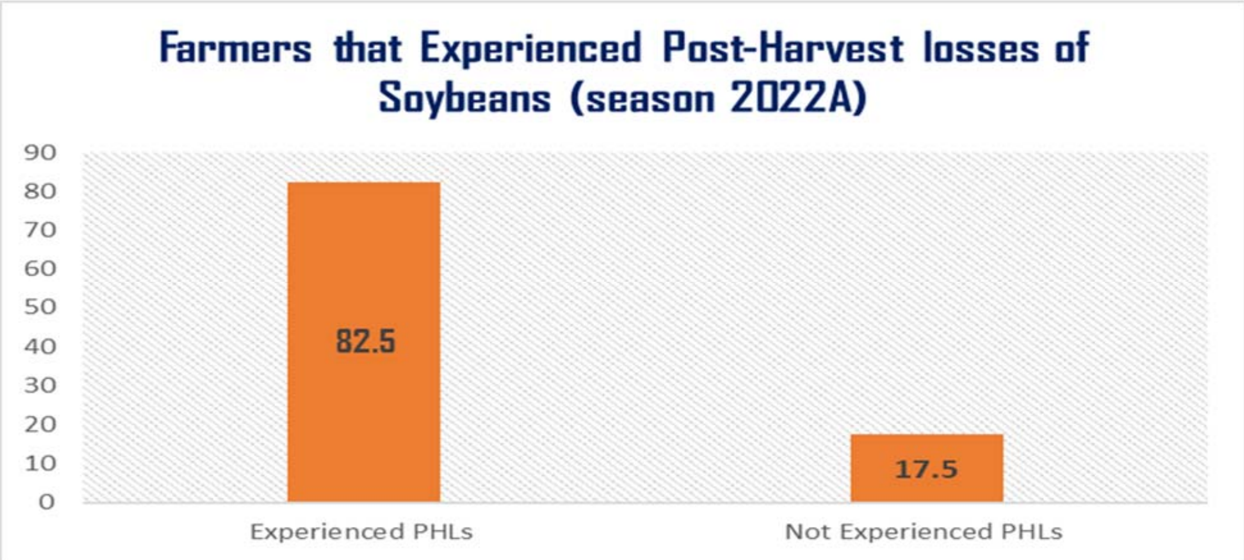

Figure 1: Percentage of respondents who experienced PHL in the study area.

Source: Authors' computation, 2022.

The results showed that 99 (82.5% of respondents) experienced a post-harvest loss in the previous 2022A season, but only 21 said they did not experience a post-harvest loss in the 2022A season (17.5% of respondents). This demonstrates clearly that many soybean Farmers in the study area lost some of their production due to post-harvest losses, which led to lower profit/income.

3.3. Causes of Postharvest loss in the area of study

Table 2 reveals that the most of the respondents (58 farmers), representing 48.3%, indicate that farmers' losses are due to bad farming practices. Nine farmers, representing 7.5% of respondents, attributed losses to cultivar selection, and 41 (34.2% of respondents) attributed bad weather to the main cause of post-harvest losses. 12 (10% of respondents) cite incorrect harvest timing as the main cause of loss, as shown in Table 2 below.

Table 2: Causes of Postharvest Loss

Respondent's perception of PHL Causes	Frequency	Percentage
Seed variety (Quality)	9	7.5
Poor agronomic practices	58	48.3
Bad weather Condition	41	34.2
Wrong harvesting time	12	10.0
Total	**120**	**100.0**

Source: Authors' computation, 2022.

3.4. Accessibility of trainings on postharvest losses by soybeans growers.

To deeply analyze and understand the reasons behind the postharvest losses of soybeans in the study area, it is very crucial to know how the respondents have acquired knowledge about postharvest loss management and how they put the knowledge into practice. The figure below indicates respondents' rate of attendance for training on Postharvest loss management.

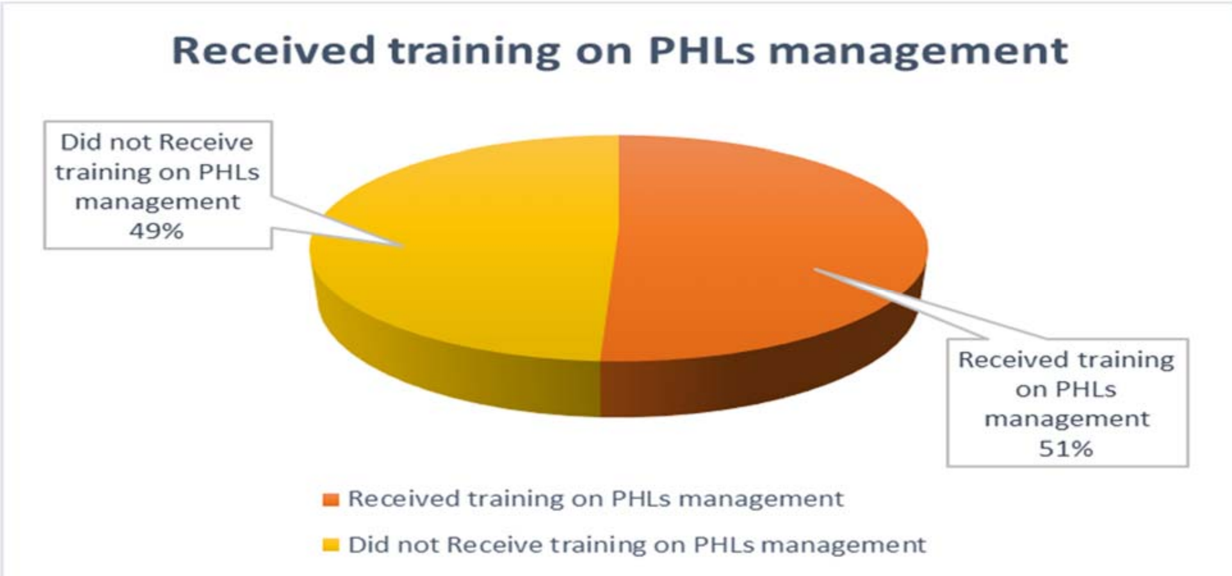

Figure 2: Accessibility of trainings on postharvest losses Management by soybeans growers.

Source: Authors' computation, 2022.

The figure2 above shows how respondents having or not having trainings on PHLs management affects their losses. Study findings indicate that 61 soybean farmers (51% of respondents) received training on postharvest loss management which is believed to be there source of know-how about good agronomic practices while 59 soybean farmers (49% of respondents) did not receive any training on soybean postharvest loss management.

More still, training on PHLs management has been cross-tabulated with farmers that experienced losses to find how they are related, and results were presented in table3 below;

Table 3: Farmer trainings Vs postharvest losses of soybeans

Received training on PHLs management	Experienced any PHL in soybeans production (Frequency per sector)												Total (N=120)			
	Karangazi				Rwimiyaga				Matimba							
	Count		Percentage (%)		Count		Percentage (%)		Count		Percentage (%)		Count		Percentage (%)	
	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No
YES	29	8	24.2	6.7	9	0	7.5	0	7	8	5.8	6.7	45	16	37.5	13.3
NO	9	0	7.5	0	24	0	20	0	21	5	17.5	4.1	54	5	45	4.2
Total (n=120)	**38**	**8**	**31.7**	**6.7**	**33**	**0**	**27.5**	**0**	**28**	**13**	**23.3**	**10.8**	**99**	**21**	**82.5**	**17.5**

Source: Authors' computation, 2022.

From table3 above, the results show that the majority (38) of soybean farmers (31.7% of the total respondents) who experienced Postharvest losses in soybeans production were from Karangazi sector even though it had the most number of soybean farmers (24.2% of the total respondents) who had received certain trainings on soybean Postharvest losses management in comparison to other sectors. This can be concluded that trainings on soybean Postharvest losses management in Karangazi sector of Nyagatare district were not effective or the respondents did not put in place what they have trained as losses continued to exist despite having been given trainings on soybean Postharvest losses management.

More still, results above indicate that all respondents from Rwimiyaga sector experienced Postharvest losses whereby 20% of the total respondents from Rwimiyaga sector had never received any soybean Postharvest loss management-related training however, only 7.5% of all respondents from that sector had received the training. Furthermore, 17.5% of the total respondents from Matimba sector experienced Postharvest losses and had never received training while only 5.8% did receive training but still experienced Postharvest losses.

This implies that trainings on Postharvest loss management in Rwimiyaga and Matimba sectors had a positive impact, as farmers who got training and experienced losses were fewer in comparison to those that did not receive any training on soybean postharvest loss management but experienced Postharvest losses in soybeans production.

3.5. Impact of Contract farming on postharvest losses of soybeans

This study assumed that contract farming is necessary for soybean farmers to unite and build a necessary number to support the value chain for soybeans. Farmers need to ensure that markets for their produce are ready when producing soybean, thereby reducing post-harvest losses. The results in Table 4 below show the impact of contract farming on soybean post-harvest losses.

Table 4: Contract farming on postharvest losses of soybeans

		Contract farming				Total	
		Yes		No			
		Count	Percent (%)	Count	Percent (%)	Count	Percent (%)
Experienced any PHLs	**Yes**	17	14.2	82	68.3	99	82.5
	No	0	0	21	17.5	21	17.5
Total		**17**	**14.2**	**103**	**85.8**	**120**	**100**

Source: Authors' computation, 2022.

According to Table 4's survey findings, 85.8% of respondents equivalent to 103 out of 120 farmers did not have access to a ready and reliable market for their products. However, 17 of 120 farmers surveyed, or 14.2% of respondents, said that none of the contracted farmers (0%) had experienced post-harvest losses on their farms. indicating that it was connected to the contracted market channel. Observations like these show how contract farming can help reduce post-harvest losses.

3.6. Influence of field-to-warehouse/market distance PHL of soybeans in the area of study.

Survey results found that respondents reported losses from their yards to storage facilities or markets. These PHL losses, especially in developing countries, are due to long distances, poor or nonexistent roads, and old equipment in particularly poor condition to cover distances in most rural communities considered to be a problem. Walking or biking increases post-harvest losses for soybean farmers. Table 5 below displays the results:

Table 5: Distance from field to storage/market Vs postharvest loss

		Distance from field to storage				**Total**	
		Below 1 km		1 km & Above			
		Count	Percent (%)	Count	Percent (%)	Count	Percent (%)
Experienced any PHLs	**Yes**	49	40.8	50	41.7	99	82.5
	No	16	13.3	5	4.2	21	17.5
Total		**65**	**54.1**	**55**	**45.9**	**120**	**100**

Source: Authors' computation, 2022.

From the table5 above, most of the respondents (13.3%) who did not experience any postharvest losses were from a distance less than 1 Km while those from 1 km and above only 4.2% had not experienced any postharvest losses in their soybeans production. Such results are a good indicator of how long distances from farmer fields to farmer homesteads, storage or market places may increase soybeans postharvest loss.

On the other hand, soybean producers who had their fields in a distance range of 1Km and above, 41.7% experienced postharvest losses in their production while respondent farmers having their fields in a distance range of less than 1 Km were 40.8%. Such a big rate of losses can be derived from the poor muddy roads, poor transportation equipment like bicycles or head carrying that are more likely to increase losses during transportation.

3.7. Production stages with high soybeans postharvest losses

Finding as in figure3 below indicate that the postharvest losses occurred at various stages, and were found to be maximum during harvesting at a rate of 43.4%. The findings indicated that access to harvesting equipment is limited for smallholder farmers. 24.2% of those surveyed, said they experienced more loss during storage. This can be interpreted to mean that most household soybeans are stored exposed, making them vulnerable to changes in temperature, insects and humidity.

Findings revealed that 14.14% had much loss during transportation as they had poor road condition resulting in high transportation costs that limit produce delivery to markets a fact of reduced profit made by producers. Shelling and sorting loss was reported at a rate of 8.1%. Soybean drying was reported at a rate of 6.1% whereas winnowing was reported at a rate of 4.04% as shown in the figure below.

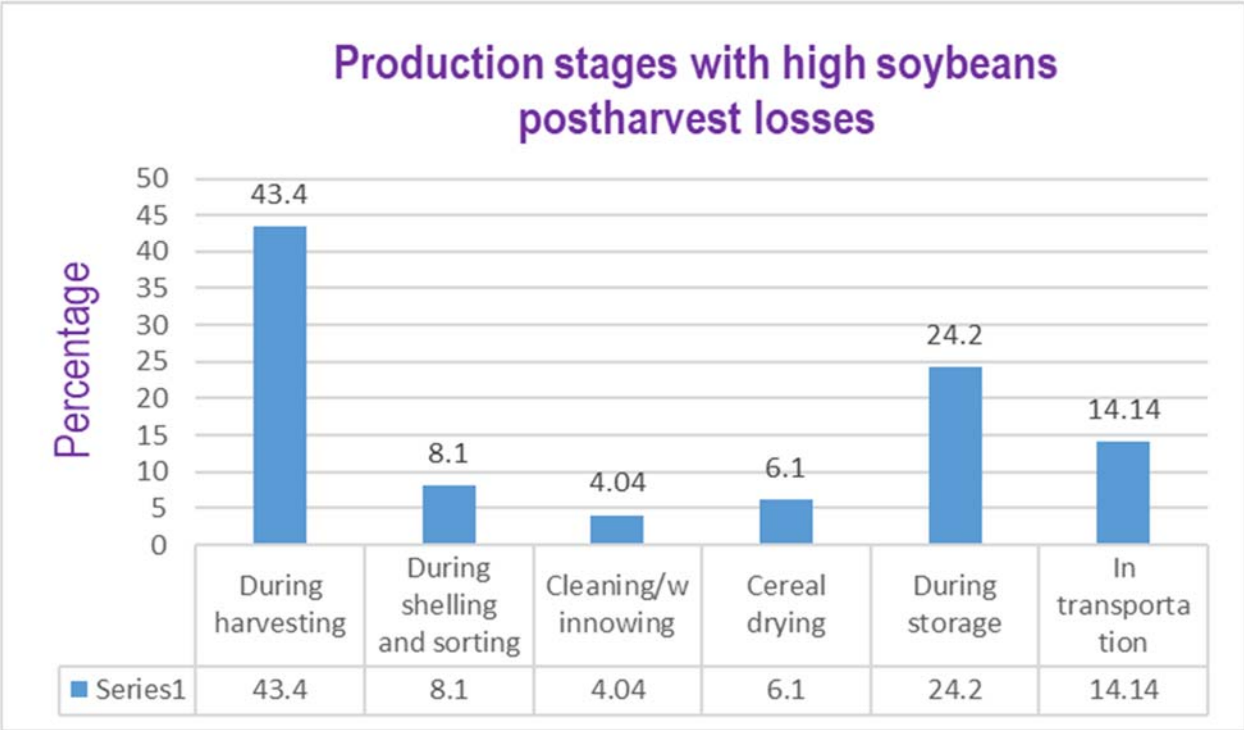

Figure 3: Production stages with high soybeans postharvest losses

Source: Authors' computation, 2022.

3.8. Correlation of estimated variables

In this work, a correlational approach was utilized to evaluate the degree of correlation between potential causal variables of PHL loss. In general, a VIF larger than 4 or an error tolerance less than 0.25 suggests the possibility of multicollinearity and the need for additional inquiry. If the VIF is greater than 10 or the tolerance is less than 0.1, a correction is required due to significant (serious) multicollinearity. Table 6 below shows the correlation levels between the estimated variables.

Table 6: Correlation of selected independent variables

Variables	VIF	1/VIF
Age	4.980	0.201
Farmer Experience	2.730	0.366
Land size	2.680	0.373
Cooperative membership	2.270	0.441
Education Level	2.260	0.443
Mode of Transport	2.140	0.467
Weather Condition	2.080	0.480
Soybean Variety	2.010	0.497
Gender	1.890	0.529
Road accessibility	1.450	0.688
Value of PHL	1.200	0.830
Mean VIF	2.340	

Source: Authors' computation, 2023

From results in table 6 above, none of the variables has a VIF greater than 10. More still, none of the variables has tolerance less than 0.1. This is a clear sign of less correlation among selected the variables a fact that they are all considered fit to be estimated in the model a fact that leads to a conclusion that there is no multicollinearity among the variables.

3.9. Analysis of the Multiple Linear regression

While analyzing factors influencing Postharvest losses of soybeans and their impact on farmers' income in Nyagatare district, a multiple linear regression analysis was used under this study. The model's highlighted variables 8 of them were all statistically significant. The coefficient of determination reflected the extent to which the explanatory variables explained the variable that is being measured. The value of $\boldsymbol{R^2}$ indicates how effective the regression model was. $\boldsymbol{R^2}$ equals 0.708, or 70.8%. It indicates that Postharvest loss of soybeans can be explained by the factors affecting Postharvest loss of soybeans in the research region at a rate of 70.8% and conclude that the fitness of the model is at 70.8% i.e. Education level, Land size for soybeans, Soybean Farming Experience, Soybeans seed quality, On farm Soybeans storage, Mode of transportation, bad weather condition and Natural causes (e.g. insects, rats…).

Table 7: Table showing results from Multiple Linear regression analysis

Soybean PHL	Coef.	St.Err.	t-value	p-value	Sig
Education level	-1.896	.496	-3.82	0	***
Farmer experience	-.129	.07	-1.84	.068	*
Land size	2.357	.324	7.27	0	***
Soybean Variety	-3.116	.664	-4.69	0	***
Cooperative membership	-.855	1.138	-0.75	.454	
Road accessibility	-.329	.854	-0.39	.7	
Mode of transport	-.052	.44	-0.12	.905	
Value of PHL	0	0	3.01	.003	***
Weather condition	2.867	1.292	2.22	.029	**
Age	-1.514	.626	-2.42	.017	**
Gender	4.416	.925	4.78	0	***
Constant	9.615	6.461	1.49	.14	

Number of observation	120	Standard deviation var.	6.309
R^2	0.708		
F-test	23.749	Prob > F	0.000

**** p<.01, ** p<.05, * p<.1*

Source: Authors' computation, 2022.

3.9.1 Results discussion

The table7 above presents the estimation results from the linear regression model analysis. The dependent variable is the *''soybean postharvest losses''*. The coefficients reported in the table7 above represent the change in postharvest losses with regard to a unit change in the independent continuous variables. The researcher used a linear regression model with multiple variables to identify drivers influencing Soybeans postharvest loss in the study area. In the model, all predictors estimated were found to be statistically significant and all have an influence on postharvest losses of soybean production. Table 7 results revealed that the model's overall fitness is shown by the determination factor R^2, i.e., the estimated explanatory variables explained approximately 70.8% of the proportion of all changes in the explained variable. The coefficients revealed that cooperative membership, mode of transportation, and road accessibility have an inverse relationship with postharvest loss, whereas the variables Education level, Famer Experience, and Soybeans have an inverse relationship. Postharvest losses are directly related to land size, weather conditions, PHL value, age, and gender.

Farmer's Education level: Education was found to be significant at 1% as it has a p-value of 0.000 in significance column (Sig column) which is less than 1% (0.000<0.01). It was discovered to have a negative correlation with postharvest loss in that being more educated reduces postharvest loss by 1.896% compared to the uneducated Farmers. This findings are closer agree with those of Yeshiwas & Tadele (2021) who found that as the education status of the farmer increases the post-harvest losses decreases (Yeshiwas & Tadele, 2021).

Farming experience: At the 10% level of significance, farmers' experiences were also shown to be statistically meaningful. According to the experience coefficient for every one-year increase in experience, postharvest losses would be reduced by 12.7%. And this attributed to the factor that the more years' farmers do soybean farming the more he/she become more familiar with soybeans Post-harvest handling techniques hence experience low rate of losses.

Land size for soybeans: According to the analysis results, Land size for soybeans' has a p-value of 0.000 and is highly significant at the 1% level of significance in the significance column (Sig column) that is less than 0.01 (0.000<0.01). This implies that increase by one hectare of Land size for soybeans is more likely to increase the postharvest losses of soybean at the rate of 12.9%. Therefore, it can be concluded that increase in the size of land reserved for soybean can contribute significantly to increased postharvest losses of soybean as farmers can hardly manage their big lands. This means that the size of land for soybeans influence postharvest losses. And this upholds what Mary, et al. (2021) have found, where the authors reported that large farm are associated with higher losses than farmers with smaller land sizes (Mary, Akito, Marcos , & Pery , 2021).

Soybeans seed quality: Soybean seed quality was also found to be statistically significant at the 1% level, with a p-value of 0.000. This means that the sowing of good soybean quality seed by the farmer would reduce the postharvest losses of soybean at the rate of 311.6%.

Mode of transportation: Having a p-value of 0.000, transportation was determined to be significant in statistical terms at 5% in the significance column (Sig column) and a negative sign coefficient.. This implies that increase in better transport means by one unit is more likely to reduce the postharvest losses of soybean at the rate of 13.59%.

Weather condition: At the 5% significance level, bad weather is also positively and significantly related to postharvest losses. Farmers who have experienced bad weather are more likely to suffer losses. These findings are agree to those reported by the study of Ognakossan, et al. (2018) where they reported that rodents accounted for less than 0.5% of stored grain weight losses (Ognakossan, et al., 2018)

Value of PHL: In the significance column (Sig column), the variable "Post-Harvest Loss" was likewise found to be highly significant at 1%, with a probability value of 0.000. This result implies that Value of PHL causes have a negative severe relationship which decrease the income of soybean farmers ((Chegere, 2018).

Age: Farmers between the ages of 36 and 45 experience smaller post-harvest loss, as predicted. At the 5% level of significance, the coefficient of 1.514 is significant. This indicates a reduction on postharvest losses by 151.4% when a farmer increase by one unit.

Gender: It was observed in the study area that being Male, participation in soybean production reduces soybean PHL highly significant as p value is greater than 1% with a coefficient of 4.416. This gender distribution conforms to existing notion and statistics about the pattern of men participation in post-harvest. Women may be more vulnerable to high post-harvest losses due to limited access to resources and information, as well as a lower ability to implement loss-reduction technologies (Nordhagen, 2021).

3.10. Soybean PHL's impact on farmer income

From the study findings, Table 8 shows that the average farmers' yield of Soybeans in the study area is 3,528Kg per hectare whereby the minimum yield recorded was 270 Kg while the highest yield recorded was 25,500 Kg. This figure demonstrated that the region under consideration is an attractive producer of soybeans.

The average production cost of Soybean farmers recorded was 251,994 Rwf /ha with maximum being 1,400,000rwf and a minimum of 53,650rwf. Furthermore, the average market price of soybeans as reported by respondents was 615.25 Rwf/Kg with a maximum price of 1000 Rwf/Kg and a minimum of 400 Rwf/Kg.

According to the table below, the average gross income of a Soybean farmer is 1,763,947 Rwf/ha, with a minimum income of 135,000rwf and a maximum income of 12,750,000rwf. According to the study, post-harvest losses in soybeans range from zero to 150 kg, with an average loss of 23.12 kg/ha harvested.

Table 8: Soybeans postharvest losses VS farmers' incomes

	Soybeans harvested (Kg)/ha	Cost (Rwandan francs)/ha	Soybeans Market Price (Rwandan francs)	Gross income from sales (Rwandan francs)/ha	Soybeans lost/PHLs (Kg)/ha	Amount lost due to PHLs/ha (Rwandan francs)
Mean/Average	3,528	251,994	615.25	2,170,602	23.12	14,224.6

Source: Authors' computation, 2022.

From study findings in table above, it is observed that the average postharvest loss of soybeans is 23.12Kg per hectare. This can be interpreted that for every hectare planted with soybeans 23.12Kgs are lost equivalent to 14,224.6 frw which means that the income the farmer should gain per every hectare cultivated with soybeans is reduced by 14,224.6 frw due to post-harvest losses. The results above clearly indicate how much postharvest losses of soybeans reduce farmers' incomes cultivating Soybeans in the study area.

3.11. Farmers' Suggestions on how to minimize Post-Harvest Losses

Table9 below shows Farmers' suggestions on how to minimize losses in soybean crop.

Table 9: Suggestions for minimizing post-harvest losses

Description	Frequency	Percent (%)
Accessing appropriate drying system	11	9.2
Accessing storage infrastructures	45	37.5
Provision of post-harvest training	14	11.7
Provision of PHH equipment	17	14.2
Trainings on PHLs best management practices	33	27.5
Total	120	100

Source: Authors' computation, 2022.

Under this study, it was reported by the farmers that not setting proper storage infrastructures causes lots of postharvest losses of soybeans. This is also reflected in the suggestions of 37.5% farmers who had suggested developing proper storage infrastructures at least one (1) at village level efficient to minimize the losses. Trainings on PHLs best management practices was the next important suggestion by 27.5% of farmers followed by the suggestions of 14.2% and 11.7% of the farmers who suggested Provision of PHH equipment & Provision of post-harvest management training respectively. Lastly, 9.2% of the respondents suggested access to appropriate drying system to minimize losses.

IV. Conclusion And Recommendation

4.1 Conclusion

This research project looked at the root causes and impacts of losses after harvest (PHLs) in soybean profitability in Rwanda, Nyagatare District. It focused on the Karangazi, Rwimiyaga, and Matimba sectors. The majority of respondents (61.7%) were men and the majority of soybean farmers (31.7%) were within the ages of 36 and 45.

Postharvest losses are a major issue for soybean growers in the area, with 48.3% attributed to poor agronomic practices, 9.5% to varietal selection, 34.2% to poor weather, and 10% to harvesting at the wrong time. Most respondents blamed poor agronomic practices, varietal selection, poor weather, and harvesting at the wrong time.

The value of R^2 computed from the multiple linear regression approach's findings was 0.708 or 70.8% indicating goodness of fit of the specified model. Results show that out of 11 independent variables estimated, Only 8 variables (education level, land size for soybeans, soybean farming experience, soybean seed quality, PHL value, weather condition, age, and gender) were statistically important at the 5% degree of significance and had an influence on the variations of the dependent variable (soybeans postharvest losses).

4.2. Recommendations

The study showed about 82.5% of the respondents lost some of their soybeans yield during their post-harvest operations. Such a high magnitude of the loss is a matter of concern. Therefore, efforts need to be put in place by stakeholders to curb such losses by adopting appropriate measures. Basing on study findings, this study comes up with the following recommendations; -

The massive soybean PHL losses are the result of poor soybean production, poor harvesting and postharvest handling techniques, inadequate storage infrastructure, and a lack of a market. This study recommends using a scientific approach such as modern soybean production and harvesting methods, improved transportation and storage facilities, and outreach (training and education) to minimize losses and maximize profit.

In addition, this study highly recommends postharvest actions like processing and marketing which are considered as value-addition activities that minimize the perishability problem of soybeans by reducing postharvest losses hence improved farm-level productivity a fact that will increase farmers' incomes.

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Conflict Of Interest

The author of this article declare that there is no conflict of interest related to this publication manuscript.

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