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Determinants of post-harvest losses of plantain in the Sassandra-Marahoué district, Côte d'Ivoire

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This study analysed the determinants of post-harvest losses of plantain in the Sassandra-Marahoué District to contribute to the reduction of post-harvest losses of agricultural products. To this end, a fractional response regression model was implemented on primary data randomly collected from 220 plantain growers. The results indicated that the area of production, the place of plantain in the production system, membership of a producer organisation, and the place of grouping and storage influenced post-harvest losses. These results suggest that post-harvest losses of plantain are greater in areas of high production where the road infrastructure is deficient and among small producers who have not mastered good handling, storage, and conservation practices. To reduce post-harvest losses, rural and agricultural tracks need to be re-profiled, harvests need to be optimally planned and small-scale growers need to be empowered to apply good harvesting and post-harvesting practices.

Key words: Post-harvest loss, fractional response regression, plantain, Ivory Coast. JLE: C35 D24 Q12

INTRODUCTION

Addressing post-harvest losses and food waste poses a significant challenge in meeting the goal of feeding 10 billion people by 2050. Post-harvest losses, defined as the measurable reduction in the supply of agricultural products, occur between the farm and buyers. The analysis of post-harvest losses gained attention in the 1970s, particularly at the inaugural World Food Conference in 1974, where reducing losses by 50% by 1985 (Parfitt et al., 2010) was a resolution. Interest in this issue has surged amid the COVID-19 pandemic, which disrupted food supply systems and affected both the supply and demand for food products.

Since the 1974 conference, efforts to reduce losses have been in vain. Prusky (2011) and Foley et al. (2011) indicated that a third or even half of the world's food production was lost or wasted. These losses represented 1.3 billion tonnes of food per year (Gustavsson et al., 2011). Food security has deteriorated sharply in certain areas of Sub-Saharan Africa (SSA), Southeast Asia, and Western Asia. Kumar and Kalita (2017) estimated that a 70% increase in food production was needed to feed the world's population. Sub-Saharan Africa is the part of the

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world where concerns about food insecurity have increased, due in part to the huge post-harvest losses of food products. In this part of the world, between 20% and 40% of the food supply was lost during and after the harvest (FAO-AfDB, 2011).

In Côte d'Ivoire, plantain was the third most important food crop after yam in terms of quantity produced. Its annual production was estimated at 2,029,986 tonnes in 2019 (FAOSTAT, 2022). Its average annual per capita consumption was 120 kg. Plantain is therefore an essential food for the Ivorian population. Despite its importance in the local diet, plantain cultivation in its current traditional form is most often carried out on plateau, with few good farming practices and no chemical inputs (N'Da, 1993). The two plantain cropping systems are pure cropping and associated cropping. The associated cropping system is 92% dominant (Traoré et al., 2009). Association is either with other food crops (cassava, maize, rice, vegetables, groundnuts, yams, etc.) or with export crops (cocoa, rubber). In addition, the size of the majority farms is whithin 1 and 5 ha (Traoré et al., 2009). In Côte d'Ivoire, plantain is produced throughout the forest zone, although the main production areas are the Bas-Sassandra, Haut-Sassandra and Marahoue regions (Perrin et al., 2015). The supply of plantain is seasonal, due to the seasonal nature of production.

Post-harvest loss rates for plantain have been estimated at between 30% and 40% of total production (MINADER, 2017). These losses can have various causes. However, the Ivorian literature provides very little information on the determining factors. The shortfall in plantain supply resulting from losses creates an imbalance in the plantain market every year. One of the consequences is an increase in plantain prices at certain periods, which in turn exacerbates food insecurity. Reducing post-harvest losses of plantain is therefore a solution for market stability (Hodges et al., 2011; Goldsmith et al., 2015). Moreover, reducing post-harvest losses helps to reduce poverty and improve the quality of nutrition (Affognon, 2015) and pressure on natural resources and improve farmers' livelihoods (Kumar and Kalita, 2017).

The study aims to provide an answer to the fundamental question of how to reduce post-harvest losses of food products in Côte d'Ivoire. Fractional response logistic regression implemented on 220 plantain grower data provides evidence that good production management on the one hand, and capacity building of stakeholders in good post-harvest practices on the other, contribute to reducing post-harvest losses of food products.

LITERATURE REVIEW

Post-harvest losses concern the reduction in the potential offer of food for human consumption (Tyler and Gilman, 1979; Kiaya, 2014) at each level of the value chain to the final market. Food losses are both quantitative and qualitative. The economic consequences of post-harvest losses are the reduction of economic and nutritional value (Kiaya, 2014) of the availability of food and the incomes of actors (World Bank, 2011). Post-harvest losses are therefore at the origin of market instability.

Many researchers have examined various options for reducing post-harvest losses. Factors relating to organisational aspects, handling techniques, social aspects, and infrastructure have been identified. Kader and Rolle (2005) identified the time taken for a food product to reach the sales market as one of the main factors explaining post-harvest losses. The longer the time taken, the greater the losses (Kader and Rolle, 2005). Another time factor identified was the distance between the place of production and the place of sale. Long distances significantly increase post-harvest losses of food products (Adewumi and Ayinde, 2009; Babalola et al., 2010; Kaminski and Christiaensen, 2014; Ansah and Tetteh, 2016). Road infrastructure and the proximity of the market to the place of production therefore influence post-harvest losses of food products. In addition, high food prices reduce post-harvest losses (Babalola et al., 2010; Kaminski and Christiaensen, 2014). Indeed, a relatively high selling price is an incentive to sell large quantities in a short space of time. However, producing large quantities influences post-harvest losses. Basavaraja et al. (2007), Mbuk et al. (2011), and Mebratie et al. (2015) showed, respectively in the cases of rice (in India), tomato (in Nigeria), and banana (in Ethiopia), that the greater the quantity produced, the greater the post-harvest losses. The causes put forward were high transaction costs and the lack of adequate storage infrastructure. However, Ansah and Tetteh (2016) came to the opposite conclusion. Indeed, Ansah and Tetteh (2016) showed that the Ghanaian producers who managed post-harvest yam losses better were those who produced large quantities. The positive relationship between quantity produced and post-harvest losses is controversial.

Similarly, some studies have indicated that strengthening human capital (level of education, experience in the activity) has a beneficial effect on reducing post-harvest losses. All the studies (Basavaraja et al., 2007; Kaminski and Christiaensen, 2014; Mebratie et al., 2015; Ansah and Tetteh, 2016) concluded that producers who had a high level of education (acquisition of general knowledge) managed post-harvest losses better (reduction). Indeed, the accumulation of knowledge by the producer enables him to adopt better handling, storage, and sales practices; all of which would reduce post-harvest losses. The variable experience, measured in years of practice in each activity and corresponding to an accumulation of practical knowledge, is also a determining factor. A long accumulation of practical knowledge about the activity reduces post-harvest losses. Evidence was provided by Adewumi and Ayinde (2009) and Mebratie et al. (2015) in the case of plantain in Lagos (Nigeria) and Ethiopia, respectively. With the accumulation of general and

practical knowledge, producers acquire new expertise and management techniques that enable them to reduce post-harvest losses of food products.

Farm size, measured by the total area of arable land under cultivation, had been identified as a determinant of post-harvest losses. Farm size has an effect like that of production. All other things being equal, the larger the size of a farm, the greater the quantity produced. Basavaraja et al. (2007), Babalola et al. (2010), and Ansah et al. (2014) showed that farmers with large farms suffered greater post-harvest losses.

In addition, studies have shown that producers who are members of cooperatives or professional organisations suffer fewer post-harvest losses. Evidence has been provided in the case of bananas (Adewumi and Ayinde, 2009; Mebratie et al., 2015) and tomatoes (Babalola et al., 2010; Aidoo et al., 2014). Economic players (producers, traders) who join cooperatives or professional organisations obtain some form of technical and/or financial assistance, which enables them (all other things being equal) to better manage the quantities offered and reduce post-harvest losses.

Finally, the duration, period, and methods of storage of food products increase post-harvest losses, regardless of whether the product is perishable or not. Post-harvest losses in wheat have been associated with storage methods and conditions (Basaravaja et al., 2007). For Adewumi and Ayinde (2009), the storage period and cost increase the post-harvest losses suffered by plantain traders. Storage time increases tomato losses (Mbuk et al., 2011; Aidoo et al., 2014) and plantain losses (Mebratie et al., 2015). For Kaminski and Christiaensen (2014), the main factor responsible for post-harvest losses among Tanzanian maize growers was storage duration.

All the studies identified various determinants of post-harvest losses. However, the issue of post-harvest losses of food products has been addressed much more in English-speaking countries than in French-speaking SSA countries such as Côte d'Ivoire. Furthermore, these studies have not sufficiently addressed the geographical (production zone), market (exchange price), and psychological (importance of the product in the system of a multi-product farm) factors.

METHODOLOGY

Study area

This study is being conducted in the Sassandra-Marahoué District, located in central-western Côte d'Ivoire. This district lies between latitude 6° 53′ 00″ N and longitude 6° 27′ 00″ W. The district includes the regions of Haut-Sasssandra and Marahoué. The Sassandra-Marahoué district covers 23,940 km^2 of which 17,761 km² is covered by the Haut-Sassandra region.

The population of the district was estimated at 2,720,876 according to the 2021 General Population and Housing Census (RGPH), including 1,739,697 in the Haut-Sassandra region and 981,180 in the Marahoué region. In addition, 61.8% of the population of the Haut-Sassandra region live in rural areas, compared with 55.4% in the Marahoué region (INS, 2022). Daloa, the capital of the Sassandra-Marahoué district, is 383 km from Abidjan. The district's main economic activity is agriculture. The district is a major production area for coffee, cocoa, oil palm, rubber, and various food crops, including plantain. The district has a tropical climate. The average annual rainfall is between 1,100 and 2,000 mm. The Haut-Sassandra region (rainfall between 1,600 and 2,000 mm per year) receives more rainfall than the Marahoué region (1,100 and 1,400 mm). The terrain is relatively flat, consisting of low plateaux and hills. The deep soils over many areas are rich in organic matter and suitable for cash crops, food crops, and market gardening. All these agroecological conditions make the Sassandra-Marahoué district a highly favourable area for plantain cultivation.

Theoretical and empirical analysis model

Plantain growers engage with the market to differing extents due to post-harvest losses, which represent a fraction of the total production. This fraction is calculated using an Output/Input ratio (Equation 1), where the Input is the total production available for sale (total production minus own consumption), and the Loss is the disparity between the total production intended for sale and the actual production sold. Due to the variability in quantities sold, the Output/Input ratio yields values ranging from 0 to 1. It is assumed that there are no commercial stocks, and no value exceeds 1.

$$Y = \frac{production\ \ for\ sale - production\ \ effective\ \ sold}{production\ \ for\ sale} \quad (1)$$

Y is the post-harvest loss rate for plantain. If *Y=0*, this means that all the plantain intended for sale has been sold. There were no post-harvest losses. If *Y=1*, then all the plantain intended for sale has been lost.

Linear estimation methods such as OLS are not suitable for estimating fractional dependent variables. Bounded dependent variables often exhibit non-constant responses (slope) to changes in the explanatory variables, whereas linear models imply constant marginal effects, regardless of the initial value of the explanatory variable. Linear models can also produce forecasts outside the unit interval. One solution could be to use models that estimate continuous and bounded dependent variables such as censored and truncated regressions, for example, a Tobit model. However, according to Baum (2008), in the case of proportional data, values outside the unit interval are not censored; rather, they are not feasible.

Papke and Wooldridge (1996, 2008) proposed a fractional response model to handle outcome variables whose values are measured in proportion. Papke and Wooldridge (1996) applied this method to estimate a model of employee participation rates in 401 (k) pension plans. The proposed model synthesises and extends the methods of generalised linear models (GLM) and quasi-likelihood to a class of functional forms with satisfactory properties that overcome most of the known limitations of other conventional econometric models for bounded dependent variables. This model for the conditional expectation of the fractional response variable is estimated as follows (Equation 2):

$$E(y_i|x_i) = G(x_i\theta) \quad with\ \ i = 1, 2, \ldots, N \quad (2)$$

where $0 \leq y_i \leq 1$ is the dependent variable and (1 x k row vector), x_i represents the explanatory variables for observation, $G(.)$ is a function satisfying the condition $0 \leq G(z) \leq 1$, for all $z \in \mathbb{R}$. A typical choice for $G(.)$ is a cumulative distribution function, the most popular being a logistic distribution $G(z) = \exp(z)/(1 + \exp(z))$ which maps z in the interval (0,1), directly estimated using non-linear techniques. Bernoulli log-likelihood function (Equation 3) is well defined for 0 <G

(.) < 1 and, is attractive for several reasons. One reason is that maximising the Bernoulli log-likelihood is easy. Another reason is that it is a linear exponential equation. The estimation procedure proposed by Papke and Wooldridge (1996, 2008) is a particular quasi-maximum likelihood (QML) method based on a Bernoulli log-likelihood function, given by:

$$LL_i(\theta) = y_i Log[G(x_i\theta)] + (1 - y_i) Log[1 - G(x_i\theta)] \quad (3)$$

The QML estimator of θ is defined by Equation 4, because the Bernoulli distribution is a member of the linear exponential family (LEF),

$$\theta = \text{argmax}_\theta \sum_{n=1}^{N} LL_i(\theta) \quad (4)$$

It is constant and asymptotically normal, whatever the actual distribution of y_i conditional on $x_i$and y_i can be a continuous variable, a discrete variable, or have both continuous and discrete characteristics.

The Quasi-Maximum Likelihood logit is used to estimate the fractional response regression model (Chegère, 2018). The empirical form (Equation 5) for estimating post-harvest losses of plantain is as follows:

$$E(Y|x) = G(\beta_0 + \beta_1 Region + \beta_2 ProdP + \beta_3 PositP + \beta_4 DistF_M + \beta_5 Member + \beta_6 ExpF + \beta_7 StockD + \beta_8 PlaceG) \quad (5)$$

where, *Y is* the post-harvest loss rate for plantain and the explanatory variables are:

"Region" refers to the plantain production area. This is a dichotomous variable, which takes the value 1 if the production area is the Haut-Sassandra region and 0 if it is the Marahoué region. Given that the Haut-Sassandra region is larger and contributes more to national plantain production, post-harvest plantain losses are expected to be greater there.

"ProdP" is the total production of the farm. It is a quantitative variable, expressed in kilograms of plantain. Probably, producers with a higher level of production should have higher loss rates. The relationship between production and post-harvest losses should be positive.

"PositP" refers to the place of plantain in the production system. This is a dichotomous variable that takes the value 1 if plantain is the farm's main product and 0 if it is not. It is difficult to predict the relationship between place in the production system and post-harvest losses because the literature does not mention it.

"DistFM" is the distance between the farm and the market. It is a continuous quantitative variable, measured in kilometers. The relationship between distance and post-harvest losses of plantain should be negative.

"Member" refers to being a member of a producer group or cooperative. This is a dichotomous variable that takes the value 1 if the producer is a member of a group or cooperative and 0 otherwise. The relationship between membership of the association and post-harvest losses of plantain should be negative.

"ExpF" refers to the producer's experience in plantain production. It is a quantitative variable, expressed as several years. According to the literature, the relationship between grower experience and post-harvest losses should be negative.

"StockD" refers to the length of time the plantain was stored before being sold. It is a quantitative variable, expressed as a number of days. According to the literature, the relationship between storage time and post-harvest losses is positive.

"PlaceG" designates the place where the plantain is grouped together before being sold. It is a dichotomous variable that takes the value 1 if the plantain is stored in the shade and protected against theft and the value 0 if the plantain is stored by the roadside, in the open air, in the sun and where theft is possible. According to empirical studies, the more plantain is exposed to the open air and sun, the greater the post-harvest losses.

Data analysis

Hejase et al. (2012) argue that informed, objective decisions are founded on factual and numerical data, which are real, realistic, and timely. Furthermore, as noted by Hejase and Hejase (2013), "descriptive statistics involves summarizing a dataset by condensing the data into simple representative numerical measures or plots that enhance understanding of the collected data" (p. 272). Therefore, this study employed descriptive statistics, such as frequencies, percentages, means, standard deviations, and maximum and minimum values, supported with tables for clarity. Additionally, inferential analysis was conducted as specified by the chosen model outlined earlier. STATA 14 was utilized to derive the descriptive statistics and econometric results.

Data for analysis

The data used for this study were extracted from a database at the Ecole Supérieure d'Agronomie. The data were collected by agricultural engineering students as part of an FAO-funded study of post-harvest losses in the plantain, cassava, tomato, and mango value chains. The surveys targeted all players in the value chains. The data extracted for analysis concerned 220 plantain growers, 100 of whom were from the Marahoué region and 120 from the Haut-Sassandra region. The extracted data were analysed, and the results are presented in the following section.

RESULTS AND DISCUSSION

Descriptive statistics on producers and their farms

The results of the data analysis showed that plantain production in the Sassandra-Marahoué district was dominated by men (91%) compared with 9% of women. The average age of growers was 41years. The majority of growers (65%) had not attended school. Similarly, the vast majority (95.45%) of growers were not members of groups or cooperatives. In addition, only 15% of producers said that plantain was the main crop in their production system. Plantain farms ranged in size from 0.25 to 10 ha, with an average of 2 ha. On average, plantain farms were located 4.45 km from the market (the place of sale). The longest distance between the farm and the market was 20 km (by track). Total plantain production from the farms varied between 240 and 160,000kg, with an average of 9,612.54kg. Before sale, the majority (62%) of producers stored the plantain in sheds on the farms or in the village, without ventilation, which resulted in quality losses. In addition, 23% of growers store their produce by the roadside, in the open air, and under the sun. Few (15%) of

Table 1. Characteristics of the sample of producers and their farms.

Variable	Observation	Average	Std. Dev.	Min	Max
Age (year) of the producer	220	41.25	12.05	19	78
Surface area (ha) of the farm	220	2.02	1.73	0.25	10
Experience (year) of the producer	220	11.41	9.21	1	45
Production (kg)	220	9,612.55	20,271.11	240	160,000
Distance (km) between plantain farm and market (place of sale)	220	4.45	3.86	0.10	20
Gender		**%**	**Cumulative**		
Men	20	9.09	9.09		
Woman	200	90.91	100.00		
Education					
No	142	64.55	64.55		
Yes	78	35.45	100.00		
Plantain is the main product of the farm					
No	187	85.00	85.00		
Yes	33	15.00	1000.0		
Member of an association/cooperative					
No	210	95.45	95.45		
Yes	10	4.55	100.00		
Storage location					
1. Under cover (under trees or in a shed, with ventilation)	169	76.82	76.82		
0. By the roadside, in the open air and in the sunshine	51	23.18	100.00		
Storage life (days) for plantain					
0 day	5	2.27	2.27		
1 day	107	48.64	50.91		
2 days	87	39.55	90.45		
More than 3 days	21	9.55	100.00		

Source: Analysis results (2023).

the producers apply good grouping practices, that is, in the shade, out of the sun, and protected from theft. In addition, 2.27% of growers do not store their plantain production, compared with 48.64% who store their production for 1 day. Subsequently, 39.55% of growers stored their plantains for two days, and finally, 9.54% stored their produce for more than three days. Table 1 presents the characteristics of the growers and their farms.

Post-harvest loss rates and mechanical causes

The results of the data analysis indicate that the average post-harvest loss rate for plantain is 23.2%, with a standard deviation of 11.4%. The minimum post-harvest loss rate is 10% and the maximum is 60% (observed in Marahoué). Looking at the frequencies of post-harvest loss rates, 87.8% of growers suffered post-harvest losses of between 10 and 30% (Table 2). This result shows that post-harvest losses are increasing. Moreover, post-harvest losses are a threat to food security because of the reduced supply of agricultural products on the markets.

Losses occur at all stages of the production chain and primary marketing. At the farm level, 78% of losses are due to mechanical injuries caused by handling the plantain. According to the producers, in 63% of cases, losses occurred during the grouping and stacking of the plantain. In 10% of cases, losses were caused by workers rushing to load and unload the plantain. Rodents (13% of cases) also cause losses during storage. Lastly, since the plantain is stored on the plot or along the roadside, production is stolen. In 9% of cases, theft was the cause of losses. At

Table 2. Frequency of post-harvest loss rates for plantain.

Index	Frequency	%	Cumulative
[0 - 10%]	61	27.73	27.73
[10% - 20%]	66	30.00	57.73
[20% - 30%]	66	30.00	87.73
[30% - 40%]	21	9.55	97.27
[40% - 60%]	6	2.73	100.00
Total	220	100.00	

Table 3. Results of the fractional response regression model of the determinants of post-harvest. losses in plantain.

Variable	Coefficients	Standard error	Average marginal effect (dy/dx)
Y= post-harvest loss rate			
Region	-0.32***	0.08	-0.06
ProdP	3.60e-06***	1.03e-06	6.34e-07
PositP	0.43***	0.12	0.07
DistF_M	-0.00	0.01	-0.00
Member	0.21*	0.12	0.04
ExpF	-0.00	0.01	-0.00
StockD	-0.03	0.06	-0.00
PlaceG	0.11*	0.06	0.02
Constant	-1.33***	0.20	-0.06
Observations = 220			
Wald chi2(8) = 51.46			
Prob > chi2 = 0.000			
log likelihood = -117.9			
Pseudo R2 = 0.0113			

***, ** and * indicate significance levels of 1, 5 and 10% respectively.
Source: model results (2023).

the primary marketing stage, the main cause of losses is a market failure (lack of customers, plantain selling prices considered high).

Determinants of plantain post-harvest losses

The econometric estimates from the fractional regression model indicate that the variables "production area", "production volume", "membership of a producers' association", "place of plantain in the production system" and "storage location" significantly determine post-harvest losses of plantain. The fractional regression model is convergent after 4 iterations. The Wald test indicates a Chi2 (at 8 degrees of freedom) of 51.46; highly significant (Table 3).

Production area

The "Region" variable has a negative and highly significant effect on post-harvest losses of plantain. If the number of producers in the Haut-Sassandra region increases by 1%, post-harvest losses of plantain decrease by 5.6%. Post-harvest loss of plantain is lower in the Haut-Sassandra region (20.4%) than in Marahoué (26.6%), although production is higher in Haut-Sassandra (14,526kg on average) than in Marahoué (3,716.4kg). The average area is smaller (1.4ha) in the Haut-Sassandra region than in the Marahoué region (2.7ha). In addition, farms in Haut-Sassandra are closer to the market (on average 3.9 km from the market compared with 5.2 km for the Marahoué region). In summary, post-harvest losses are lower in Haut-Sassandra because the areas are smaller, and the farms are closer to the points of sale. Producers therefore have quicker access to markets than in the Marahoué region.

This result suggests that production in small areas and close to markets helps to reduce post-harvest losses of food products. Similar results were obtained by Aidoo et al. (2014), Kaminski and Christiaensen (2014), and Ansah and Tetteh (2016).

Total production

Post-harvest losses of plantains exhibit a strong and statistically significant positive correlation with the level of production. Put simply, there is a positive correlation between post-harvest losses and the quantity of plantains produced. The findings from the econometric analyses reveal that a 1% increase in production results in a corresponding increase in losses by 6.34e-07. This finding aligns with the results observed by Mebratie et al. (2015) concerning bananas in Ethiopia.

Place of plantain in the production system

Post-harvest losses of plantain are also positively and highly significantly correlated with the position of plantain in the production system. If the number of producers whose plantain occupies the main place in the production system increases by 1%, the rate of post-harvest losses of plantain will increase by 75%. The position of an agricultural product in the production system has a positive influence on the post-harvest loss rate. Indeed, when an agricultural product occupies first place in the production system, the producer is led to make more effort to produce more or to have an optimal allocation of production factors and resources to obtain maximum benefits. These efforts will lead to an increase in production, and an increase in production is positively correlated with post-harvest losses (Mebratie et al., 2015). The results of the analysis suggest that plantain growers behave in this way.

Member of a cooperative or organisation

The results of the analyses indicate that growers who are members of cooperatives or associations lose more plantain. This result is contrary to the findings of Adewumi and Ayinde (2009) and Mebratie et al. (2015). Producers who are members of cooperatives or associations do not manage their plantain production well. Members of cooperatives and associations do not store plantain well. The majority (80%) store their plantain production in unsecured places exposed to the sun. In addition, cooperative members have poor handling practices. All cooperative/association members very often stack plantain bunches on the ground, which contributes to the deterioration of the quality of the plantain bunches. These findings show that cooperative members are not familiar with storage and preservation techniques. The capacities of cooperative/association members therefore need to be strengthened in terms of good plantain handling, storage and conservation practices.

Plantain consolidation site

The place where the plantain is grouped has a significant positive influence on post-harvest losses of plantain. The rate of post-harvest loss of plantain increases by 20% when the grouping is changed from "under shade, with aeration and protected from theft" to "without shade, without aeration". Reducing post-harvest losses of plantain also requires adequate storage facilities. Table 3 presents the results of the fractional regression model of post-harvest loss rates for plantain.

CONCLUSION AND POLICY IMPLICATIONS

The article aimed to address the issue of reducing post-harvest losses of plantains. To achieve this, a fractional response regression model was applied to data from 220 plantain growers in the Haut Sassandra-Marahoué district of Côte d'Ivoire. The econometric findings reveal that several factors significantly influence post-harvest losses of plantains, including the production area in Haut-Sassandra, production volume, membership in a producers' association, the role of plantains in the production system, and the storage location and conditions.

These results suggest that post-harvest losses are more pronounced in areas with high production and inadequate road infrastructure. Substandard storage practices, often attributed to insufficient training in handling, preserving, and storing agricultural produce, contribute to losses from the field to the point of sale. Furthermore, marketing challenges prolong storage durations, leading to a decline in plantain quality. Post-harvest losses are also prevalent among producers who lack proficiency or fail to implement good handling, storage, and conservation practices.

Efforts to mitigate post-harvest losses should prioritize the regular maintenance of roads, rural, and agricultural tracks, thereby reducing transportation time from production sites to markets. Additionally, capacity-building initiatives, particularly targeting small-scale producers, are essential to promote best practices in harvesting, handling, preserving, and storing plantain bunches. Furthermore, improving the organization of rural markets is crucial for enhancing the income of plantain producers. While not directly investigated in this study, the introduction of incentives for plantain processing could also contribute to loss reduction.

Reducing post-harvest losses represents a vital strategy for enhancing food availability and alleviating hunger and poverty in rural areas.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

REFERENCES

Adewumi O, Ayinde O (2009). Analysis of Post-Harvest Losses Among

Plantain/Banana (Musa Spp.L.) Marketers In Lagos State, Nigeria. Nigerian Journal of Agriculture, Food and Environment 5(2-4):35-38.
Affognon H, Mutungi C, Sanginga P, Borgemeister C (2015). Unpacking Postharvest Losses in Sub-Saharan Africa: A Meta-Analysis. World Development 66(C):49-68.
Aidoo R, Danfoku RA, Mensah JO (2014). Determinants of postharvest losses in tomato production in the Offinso North district of Ghana. Journal of Development and Agricultural Economics 6(8):338-344. https://doi.org/10.5897/JDAE2013.0545
Ansah K., Tetteh B (2016). Determinants of Yam Postharvest Management in the Zabzugu District of Northern Ghana. Advances in Agriculture 2016 (16):1-9. https://doi.org/10.1155/2016/9274017
Babalola D, Makinde Y, Omonona B, Oyekanmi M (2010). Determinants of post-harvest losses in tomato production: a case study of Imeko - Afon local government area of Ogun state. Journal of Life and Physical Sciences 3(2):14-18.
Basavaraja H, Mahajanashetti S, Udagatti N (2007). Economic Analysis of Post-harvest Losses in Food Grains in India: A Case Study of Karnataka. Agricultural Economics Research Review 20:117-126.
Baum C (2008). Stata tip 63: modeling proportions. The Stata Journal 8(2):299-303.
FAO-AfDB (2011). Continental post-harvest loss reduction programme. Rapid Needs Assessment. Working Paper 09/018 FAO-BAD CMR. 20 June 2010.
FAOSTAT (2022). Statistiques sur les uperficies ; le rendement et la production du plantains et des bananes à cuire en Côte d'Ivoire. https://www.fao.org/faostat/fr/#data/QCL
Foley J, Ramankutty N, Brauman K, Cassidy E, Zaks D (2011). Solutions for a Cultivated Planet. Nature 478:337-342.
Goldsmith P, Martins A, De Moura A (2015). The economics of post-harvest loss: a case study of the new large soybean-maize producers in tropical Brazil. Food Security **7**: 875–888. https://doi.org/10.1007/s12571-015-0483-4
Gustavsson J, Cederberg C, Sonesson U, Van-Otterdijk R, Meybeck A (2011). Global Food Loss Extent, causes and prevention. FAO Working Paper. 41p
Hejase AJ, Hejase HJ (2013). Research Methods: A Practical Approach for Business Students (2nd edition). Philadelphia, PA, USA: Masadir Incorporated.
Hejase HJ, Hejase AJ, Hejase HANJ (2012). Quantitative Methods for Decision Makers: Management Approach. Beirut, Dar Sader Publishers.
Hodges R, Buzby JC, Bennett B (2011). Postharvest losses and waste in developed and less developed countries: Opportunities to improve resource use. The Journal of Agricultural Science 149:37-45. https://doi.org/10.1017/s0021859610000936
INS (2022). General Population and Housing Census 2021, Final overall results. 68p. Accessed November 22, 2023. Available on https://www.ins.ci/RGPH2021/RESULTATS%20DEFINITIFSRP21.pdf
Kader A, Rolle R (2005). The role of post-harvest management in assuring the quality and safety of horticultural produce. FAO Agricultural Services. Bulletin 152 p.
Kaminski J, Christiaensen L (2014). Post-harvest loss in sub-Saharan Africa-what do farmers say? Global Food Security 3(3-4):149-158. http://dx.doi.org/10.1016/j.gfs.2014.10.002
Kiaya V (2014). Post-harvest losses and strategies to reduce them. Technical Paper on Postharvest Losses. Action Contre la Faim (ACF). Accessed February 14, 2023. Available on https://www.actioncontrelafaim.org/wp-content/uploads/2018/01/technical_paper_phl__.pdf
Kumar D, Kalita P (2017). Reducing Postharvest Losses during Storage of Grain Crops to Strengthen Food Security in Developing Countries. MDPI Journals Foods 2017:6-8.
Mbuk E, Bassey N, Udoh E (2011). Factors Influencing Post Harvest Loss of Tomatoe in Urban Market in Uyo, Nigeria. Nigerian Journal of Agriculture, Food and Environment 7(2):40-46.
Mebratie M, Haji J, Woldetsadik K, Ayalew A (2015). Determinants of Postharvest Banana Loss in the Marketing Chain of Central Ethiopia. Food Science and Quality Management 37:52-63.
Minader (2017). Address by the Minister at the ceremony to launch the post-harvest losses and agroindustry programme (PHAP). Accessed November 15, 2022. Available on https://news.abidjan.net/articles/626253/vers-la-reduction-des-pertes-apres-recolte-et-lagro-industrie
N'Da AA (1993). La qualité et la filière après récolte de la banane plantain au Cameroun et en Côte d'Ivoire. Fruits 48(2):125-132.
Papke LE, Wooldridge JM (1996). Econometric methods for fractional response variables with an application to 401 (k) plan participation rates. Journal of Applied Econometrics 11(6):619-632.
Papke LE, Wooldridge JM (2008). Panel data methods for fractional response variables with an application to test pass rates. Journal of Econometrics 145(1-2):121-133.
Parfitt J, Barthel M, Macnaughton S (2010). Food waste within food supply chains: quantification and potential for change to 2050. Philosophical Transactions of the Royal Society B: Biological Sciences 365(1554): 3065-3081. https://doi.org/10.1098/rstb.2010.0126
Perrin A, Ricau P, Rabany C (2015). Etude de la filière Banane Plantain en Côte d'Ivoire. Projet « Promotion et commercialisation de la banane plantain et du manioc en Côte d'Ivoire ». Rongead 66 p.
Prusky D (2011). Reduction of the incidence of postharvest quality losses, and future prospects. Food Security 3:463-474. https://doi.org/10.1007/s12571-011-0147-y
Traoré S, Kobenan K, Kouassi KS, Gnonhouri GP (2009). Plantain cultivation systems and pests management by smallholder producers in Côte d'Ivoire. Journal of Applied Biosciences 19:1094-1101
Tyler PS, Gilman GA (1979). Evaluation of post-harvest losses. Report of the Bamako seminar (Mali) pp. 137-151.
World Bank (2011). Missing food: The case of postharvest grain losses in Sub-Saharan Africa. Washington, DC: The World Bank 116 p.