Risk and Economic Perspectives of Post Harvest Decisions: An Application of Bayesian Theory to Smallholder Farming In Oyo State, South Western Nigeria

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Abstract: This study is conceived to quantitatively assess the profitability status of farmers’ post harvest actions, the risks and uncertainties attached to these actions and to ultimately determine the most optimally and economically viable and sustainable of the actions. A representative number of 300 smallholder farmers from 100 farming communities scattered over 20 local government areas (LGAs) from the 4 agricultural development project (ADP) zones of Oyo State were selected by a multistage stratified sampling technique. Data collected include (1) primary: types of food crops grown, outputs and sales there from, information on socioeconomic and demographic characteristics of the farming households; (2) secondary data: which include time-series information on monthly and periodic market and farm gate prices of food crops in the state. Data were analyzed by using the descriptive statistics such as percentage, tables, means and frequencies and the Bayesian (risk) decision theory. The Bayesian theory was used to determine farmers’ optimum farming strategies prior to market predictions and when markets are “normal” and in “short supply.” Results show that prior to market predictions, cocoa in Ibadan, Ibarapa and Oyo; Mango in Ogbomoso and groundnut in Saki zones are crops with the best (optimum) strategy. When market is predicted to be “normal” cocoa in Ibadan/Ibarapa and Oyo; mango and groundnut in Ogbomoso and Saki zones respectively, command optimum returns. With market being in “short supply,” cocoa has the highest expected return after processing and storage in Ibadan/Ibarapa and Oyo zones. In Saki zone, cassava has the highest return, while in Ogbomoso zone, Mango fruit commanded the highest expected return. Findings under “normal” and “short supply” conditions of market reveal that the prevention of financial and economic shocks resulting from market and price variability and fluctuations will involve the growing of annual and or perennial cash crops being intensified, while annual and seasonal crops be maintained at the level of recovering investment cost and satisfying the farm’s family immediate food need and the deserved reserve from output.

Keywords: post harvest, Bayesian theory, risk and uncertainty, South Western Nigeria

INTRODUCTION

There are several issues which have implications for the post- harvest sector in Africa today. These issues include, first, populations which have increased several fold, and it is no longer like the historical past when most Africans remained in their traditional rural communities and derived livelihood support, including food, from community, groupings to which they belonged[14]. The situation is that today, there is an active rural to urban migration due mainly to the youth fleeing rural poverty. Thus urban population have acquired urban tastes and are eating more processed foods instead of consuming traditional staples in their raw forms. Secondly, food quality and food safety are real concerns within the food systems at all levels including households, community, national and international levels. Some of the factors affecting food quality and safety in African markets, shops and homes include: poor physical quality, chemical contamination, bacterial and parasitic contamination, mycotoxin contamination, rapid rotting and contamination by other biological agents such as rodents and insects[19].

Thirdly, in the development arena, there has been a great concern for the amount of time women spend on various chores including food processing. Although numerous attempts have been made to introduce improved technologies to reduce the labour drudgery on women, the benefits have not always been fully realized by women because men tend to be more inclined towards mechanization than women and usually seize the money-making opportunities mechanization presents. Extension efforts aimed at addressing this problem and reaching women with
simple, affordable, improved post-harvest processing equipment have been limited. Fourthly, lack of access to profitable markets has limited production in certain cases. Roots, tubers, banana and plantains have accounted for some 40 percent of total food supplied in terms of food energy for about one half of the population of sub-Saharan Africa. Although production of these staples could be increased to meet future needs, farmers have tended to limit production in order to minimize the risk and uncertainties associated with farming. For example, when farmers in North West province of Cameroon produced potatoes as a crop, they limited their production to the estimated quantity that would be marketed before the roads were closed by floods from the rain\textsuperscript{[6]}. Farmers would definitely increase production if they had access to improved post-harvest processing or storage technologies and guaranteed markets for their produce.

Evaluation of post harvest development systems and food security in Nigeria shows that the issues involved in post harvest decisions have enormous risk and of course economic implications for food security advocacy in particular and for a stable and consistent economy in general\textsuperscript{[1,3]}. Reports by the Nigerian Institute of Food Science and Technology indicated that the deterioration of food which results in ample loss due to factors such as weight, quality, food, monetary, seed and of course goodwill losses has great economic, social and political implications on the overall wellbeing of the entity referred to as Nigeria\textsuperscript{[10]}. Quantitative assessment of post harvest losses have been difficult because of the extremely variable and complex traditions which influence processing and storage practices and the lack of suitable “loss survey” techniques. However, assessment made on farms, in traders’ stores and central storage depots from selected major farming communities in Oyo State, of Nigeria indicated serious depreciation in both quantity and quality of various stored products resulting in huge financial and economic losses due to the inadequate post harvest crop handling\textsuperscript{[6]}. A necessary step involved in the tackling of the numerous problems confronting post harvest decisions of most smallholder farmers is therefore to quantitatively assess the current profitability levels of farmers’ post harvest actions, the risks and uncertainties attached to these actions and ultimately determine the most economically viable and sustainable of these actions. Most of these farmers’ post harvest actions have been identified as one of either selling of crop at harvest, or processing to sell or storing to sell at off-season (when market conditions improve). While studies like those of Olayemi\textsuperscript{[29]} and Adetunji\textsuperscript{[31]} have quantitatively assessed the storage decisions and technologies of maize, no study has used any quantitative approach to evaluate the post-harvest financial and economic flexibility of the other major food crops which can be produced and used in risk mitigation of post harvest action.

The rest of this paper is divided into 3 sections. Section 2 discusses the research methodology which includes the description of the study area, sampling and data collection procedures. It also presents the theoretical and analytical framework of the statistical (Bayesian theory) model adopted. Section 3 discusses the results of the descriptive characteristics of the sampled farming households, and the Bayesian theory analysis. Section 4 concludes with implications for risk mitigation and targeting of appropriate post harvest technologies.

**MATERIALS AND METHODS**

The study was conducted in Oyo State. Oyo state is one of the six states located in the South Western geopolitical zone of Nigeria. Both primary and secondary (time series) data were collected for the analysis. The primary data collection was achieved by the use of pre-tested and validated structured questionnaire. The data were collected from a cross-sectional sample of food crop farming households in the study area. The primary data collected included types of food crop grown and outputs and sales there from, whether the farmers prefer to sell their outputs at harvest or process or store before sale. Also collected was information on the socioeconomic and demographic characteristics of the farming households.

The secondary data collected included time-series information on monthly and periodic market and farm gate prices of food crops in the state. These were collected from a combination of sources, viz: the state Agricultural development project (OYSADEP) office\textsuperscript{[13]}, the Rural Sector Enhancement Program (RUSEP)\textsuperscript{[16]} and the Federal Office of Statistics bulletin\textsuperscript{[11]}

A representative number of 300 respondents from 100 farming communities out of 20 local government areas (LGAs) from the four ADP zones was sampled through a multistage stratified sampling technique.

Descriptive analyses and the method of Bayesian decision theory were used to analyze the various types of data collected. The descriptive analysis involved the use of frequency counts, tables, figures to group the respondents into their different demographic and socioeconomic characteristics.

The major analytical framework adopted in this study is the Bayesian theorem which was used to estimate the conditional and in effect, posterior probabilities of the states of nature to determine the optimal strategy which an average farmer can adopt to maximize his profits. There were two states of nature; one was that the farmer sold his output at harvest and
two, that the farmer would either process and sell his farm produce or store for sometime and then sell when he feels that market conditions for maximum profits are conducive.

In the Bayesian theorem, there are 3 types of probabilities: (i) prior probabilities are those that are determined before any experimental information; (ii) conditional probabilities are probabilities that are gotten after some events have taken place and (iii) posterior probabilities are those determined after results of the experiments are known. Posterior probabilities are also called revisional probabilities.

Basically, the formulation of Bayesian theory stems from the derivation of the probability types mentioned above. Other probabilities involved in the computation of the Bayesian theorem include: marginal and conditional probabilities. These probabilities can be gotten under two conditions of either statistical independence or statistical dependence. For the sake of this study, the concept of the statistical dependence is implicitly derived; adopting a combination of the models of Freund [5], Hardaker et al[6], and Olayemi and Onyenwaku[7] as shown below.

Marginal probabilities under statistical dependence of an event A is the probability of occurrence of event A. This is given as:

\[ P(A) = P(A) \]  \hspace{1cm} 1

The joint probability of events A and B is the product of the probability of event B and the conditional probability of event B and the conditional probability of event A, given that event B has occurred. This is given as:

\[ P(AB) = P(B) P(A/B) \]  \hspace{1cm} 2

Or \[ P(BA) = P(A) P(B/A) \]  \hspace{1cm} 3

Where:

\[ P(A/B) = \text{the conditional probability of event A, given that event B has occurred} \]
\[ P(B/A) = \text{the conditional probability of event B given that event A has occurred} \]

In effect,

\[ P(B) P(A/B) = P(A) P(B/A) \]  \hspace{1cm} 4

The conditional probability of event A, given that event B has occurred is given as:

\[ P(A/B) = P(AB) / P(B) \]  \hspace{1cm} 5

Following from (2) above, if A and B are statistically dependent;

\[ P(AB) = P(B) P(A/B) \]

Therefore:

\[ P(AB) = P(B) P(A/B) / P(B) \]  \hspace{1cm} 6

Also,

\[ P(B/A) = P(BA)/ P(A) \]  \hspace{1cm} 7

And from (3) above,

\[ P(BA) = P(A) P(B/A) \]  \hspace{1cm} 8

Therefore,

\[ P(B/A) = P(A) P(B/A) / P(A) \]  \hspace{1cm} 9

In effect, given the marginal, joint and conditional probabilities of the statistically dependent events A and B, the Bayesian formula can be expressed as:

\[ P(B/A) = P(B) P(A/B) / P(A) \]  \hspace{1cm} 10

Where:

\[ P(B) = \text{the prior probability of the occurrence of event B} \]
\[ P(B/A) = \text{the posterior probability of event B} \]
\[ P(A/B) = \text{the conditional probability of the occurrence of event A} \]
\[ P(B) P(A/B) = P(AB) = \text{the joint probability of events A and B} \]

RESULTS AND DISCUSSIONS

Socio Economic Characteristics of the Respondents:
The summary of some socioeconomic characteristics of respondents is presented in Table 1. There appear to be some marked differences in the age range of the respondents with respect to their location in terms of the ADP zones. In Ibadan/Ibarapa, Oyo and Ogbomoso zones, farmers who are between ages 51 and 60 years form between 30 and 36 percent of the total respondents. In Saki, there is sharp contrast to the extent of having very few farmers (about 20 percent) who are between the above age range. The other age range which can be considered as an active productive age range (41 – 50) has fewer people falling into it.
The above depicts a scenario of farming activities being in the hand of fairly old to old men and women. In Ibadan/Ibarapa, Oyo, Saki and Ogbomoso, about 70, 64, 64 and 62 percent, respectively, of the respondents are male. This indicates that the men own most portion of the land for farming. In all the zones, most of the respondents are married. Also in all the zones, majority of farming households have between 6 – 8 people living in the family. A large percentage of the sampled respondents have no formal education. This is an indication that illiteracy may be very rampant among the respondents in all the zones. This is however noticeable only in the remote rural areas.

**Determination of the Farmers’ Optimal Decision Strategies:** On Table 2 below, farmers’ pay-off matrix shows the various crops that are grown in the study area with the average net revenue under each condition of either selling at harvest or selling after processing or storage. The various major crops that are grown are maize, yam, cocoa, citrus, cassava and tomato in Ibadan/Ibarapa zone; cassava, maize, potato, cocoa, groundnut and citrus in Oyo zone; yam, maize, potato, beans, cassava and groundnut in Saki zone and yam, maize, white cowpea, tomato, mango and cassava in Ogbomoso zone.

Revelations from the survey carried out indicated that, an average farmer in the study area thought that
over the years and based on his financial needs during harvest, the market will be “normal” and the probability of making good and optimum sale is 74 percent. The farmers’ thought on the other hand is therefore that the market will be in “short supply” (i.e. process or store before selling farm output) with a 26 percent probability. These probabilities can be referred to as prior probabilities meaning that they have been assessed prior to receiving some additional information about the future of the market for their crop.

It was also found that if most of the sampled farmers made use of the market forecasts of “normal” and “short supply” over the same period and compared predictions with actual occurrence, they would find out that some time, based on historical records, they:

- prepared to sell at harvest (B₁) and actually sold at harvest (A₁);
- prepared to sell at harvest (B₁) and sold only after processing and storage (A₂);
- prepared to sell only after processing or storage (B₂) and sold at harvest (A₁);
- prepared to sell only after processing or storage (B₂) and actually sold after processing or storage (A₂).

Scenarios (i) – (iv) above can be referred to as conditional probabilities. The conditional events from the study's survey are estimated and used in subsequent analyses.

Based on the average prior probability estimates, the expected net returns under the different states of nature were determined for the crop types grown in each zone (Table 3). The estimated expected returns reveal the optimal strategy to mitigate the market risks. Results reveal that in Ibadan/Ibarapa zone, the farmers optimal strategy is to continue to grow cocoa (being a perennial crop) and sell post-storage. Prior to market predictions, cocoa has the highest expected return and it equally commanded a better after storage market price. Since cocoa is a cash perennial crop which equally possesses a longer gestation period, yam whose expected net return is the second highest can also be suggested as a crop to be grown and sold at harvest. For Oyo zone, cocoa is also the grown crop with the best optimal strategy. This is also to be sold only after drying and storage. In Oyo zone, the second best crop which can be adopted for managing market risks is groundnut, a crop which is grown by most of the sampled respondents and mostly sold at harvest in the zone of the study area. In Saki zone, groundnut, sold at harvest is the crop with the best strategy followed by yam, also sold at harvest. Prior to market predictions, mango in Ogbomoso zone had the highest expected return at harvest, followed by yam, all at harvest. The result for Ogbomoso zone, especially for mango is expected. Mangos where they are mostly produced are sold even before they are ripe. This is done to forestall economic and financial losses experienced as result of the enormous wastages of the mango fruits that arise from the overflooding of the market environment during the annual mango season.

With market predictions, the farmers’ optimal strategies were also estimated to determine which of the grown crops can best be sustained to manage market risks. The expected returns in this instance were computed by combining the farmers’ prior probabilities with the additional information (conditional probabilities) provided by the state ADP and RUSEP offices. The ultimate results (expected returns) are however determined from a combination of joint and posterior probabilities which are also calculated from the above former probabilities (prior and conditional). Results (depicted on Table 4) show that with “normal” market predictions, cocoa sold after storage is still the crop with the best strategy to be grown to manage market risk in Ibadan/Ibarapa zone. For Oyo zone, cocoa sold after storage is also the crop with the best strategy with market predictions. In Saki and Ogbomoso zones, groundnut and mango are the respective crops with best strategies under market predictions. The estimated expected net returns discussed above are based on the fact that market conditions predicted good sales or “normal” condition at harvest (B₁). It then means that in Ibadan/Ibarapa zone, yam which has the second highest expected net return and which equally command better return at harvest can be recommended as market risk mitigating crop. The same can be said of groundnut at harvest in Oyo zone, beans in Saki zone and beans in Ogbomoso zone. Most of these crops command higher prices when sold at harvest.

With market conditions, predicting bad sales (or when market is in short supply) after processing or storage, the expected net return of cocoa (Table 5) is still the highest in Ibadan/Ibarapa zone. This means that cocoa remains the crop with the best market risk managing strategy in that zone of the state. In Oyo zone, cocoa also remains the crop with the highest expected return after processing or storage. In Saki zone, cassava had the highest expected returns, which means that if cassava were processed and sold instead of selling unprocessed roots at harvest, an optimum return would be generated. In Ogbomoso zone, mango would command highest expected return after processing or storage.
The application of subjective probabilities transforms the problem of decision making under uncertainty to that of decision making under risk[2]. Whether or not risk aversion matters, better decisions in a risky world can always be made if information is available. While acknowledging that in avoiding or reducing exposure to risks, life without risk would be dreary and dull, it is also the case that some unwanted risks do not need to be faced. This is so when actions or inactions based on for example, farming decisions carries with it the possibility of serious negative consequences. Such consequences in the case of this study for example may crop up from the decision of farmers to grow some familiar crops at the expense of other less market risky crops. If for instance, prior to market predictions as in this study, farmers in Ibadan/Ibarapa and Oyo zone have the need to sell some cocoa pods on the tree to merchants (forward sale), the consequences may show up in the sale of other crops at harvest which would have actually commanded higher returns when processed or stored before selling. Here, they may not have had to look before leaping because of serious exigencies, which would have been met if some cautions were introduced into the decision taking process. The risk averse nature of the farmer disregards the prevalent uncertainty at that moment and this could result in serious negative financial consequences for the farmer and the overall economy of the study area if these attitudes and financial status of the farmers in the area were a benchmark.

Also the above implies adding to the list of options usually available and considered to the decision maker. Looking before leaping here implies that, for example, instead of a choice between processing or storing a particular crop before selling or selling it at harvest, the option is also explicitly considered of delaying any growing of such crop for a time while more information is acquired on likely future profits and on alternative crops that may be more profitable than the one currently intended to be grown. Another way of handling the situation at hand if for example there is uncertainty about the more profitable financial and economic return of crops that are commonly grown and sold by smallholder farmers, growing it might be restricted or stopped until more conclusive evidence is available. In the two cases discussed so far, some actual or opportunity costs are incurred by acting cautiously, and these costs must be balanced against the achieved reduction in the chances of serious negative consequences. Risks, in the sense of the

| Table 3: Estimated expected returns prior to market predictions |
|-----------------|-----------------|-----------------|-----------------|
| ADP Zone        | Crops Grown     | Expected         | Corresponding    | Returns (₦ 00/ha of crop) |
| Ibadan/Ibarapa  | Maize; yam; cocoa*; citrus; cassava; tomato | 2264.52; 2704.97; 3678.25; 2563.13; 1123.61; 1171.88 |
| Oyo             | Cassava; maize; potato; cocoa*; groundnut; citrus | 1123; 2264.52; 126.83; 3678.25; 2987.48; 2563.13 |
| Saki            | Yam; maize; potato; beans; cassava; groundnut* | 2704.97; 2264.52; 126.83; 2683.27; 1123.61; 2987.48 |
| Ogbomoso        | Yam; maize; beans; tomato; mango*; cassava | 2704.97; 2264.52; 2683.27; 1171.88; 3008.23; 1123.61 |

*: Crop with highest zonal return
Source: Survey Data, 2006

| Table 4: Estimated expected returns with “normal” market |
|-----------------|-----------------|-----------------|-----------------|
| ADP Zone        | Crops Grown     | Expected         | Corresponding    | Returns (₦ 00/ha of crop) |
| Ibadan/Ibarapa  | Maize; yam; cocoa*; citrus; cassava; tomato | 2400.52; 2723.96; 3356.83; 2563.44; 448.57; 1085.99 |
| Oyo             | Cassava; maize; potato; cocoa*; groundnut; citrus | 448.57; 2400.52; 135.37; 3356.83; 3225.81; 2563.44 |
| Saki            | Yam; maize; potato; beans; cassava; groundnut* | 2723.96; 2400.52; 135.37; 2860.37; 448.57; 3225.81 |
| Ogbomoso        | Yam; maize; beans; tomato; mango*; cassava | 2723.96; 2400.52; 2860.37; 1085.99; 3043.38; 448.57 |

*: Crop with highest zonal return
Source: Survey Data, 2006

| Table 5: Estimated expected returns with market in “short supply” |
|-----------------|-----------------|-----------------|-----------------|
| ADP Zone        | Crops Grown     | Expected         | Corresponding    | Returns (₦ 00/ha of crop) |
| Ibadan/Ibarapa  | Maize; yam; cocoa*; citrus; cassava; tomato | 1824.84; 2643.54; 4717.43; 2562.12; 330.11; 1449.57 |
| Oyo             | Cassava; maize; potato; cocoa*; groundnut; citrus | 3306.11; 1824.84; 99.22; 4717.43; 2216.93; 2526.12 |
| Saki            | Yam; maize; potato; beans; cassava; groundnut* | 2643.54; 1824.84; 99.22; 2110.71; 3306.11; 2216.93 |
| Ogbomoso        | Yam; maize; beans; tomato; mango*; cassava | 2643.54; 1824.84; 2110.71; 1449.57; 2894.60; 3306.11 |

*: Crop with highest zonal return
Source: Survey Data, 2006

Risk and Economic Implications of Findings on Post Harvest Decisions: The application of subjective probabilities transforms the problem of decision making under uncertainty to that of decision making under risk[2]. Whether or not risk aversion matters, better decisions in a risky world can always be made if information is available. While acknowledging that in avoiding or reducing exposure to risks, life without risk would be dreary and dull, it is also the case that some unwanted risks do not need to be faced. This is so when actions or inactions based on for example, farming decisions carries with it the possibility of serious negative consequences. Such consequences in the case of this study for example may crop up from the decision of farmers to grow some familiar crops at the expense of other less market risky crops. If for instance, prior to market predictions as in this study, farmers in Ibadan/Ibarapa and Oyo zone have the need to sell some cocoa pods on the tree to merchants (forward sale), the consequences may show up in the sale of other crops at harvest which would have actually commanded higher returns when processed or stored before selling. Here, they may not have had to look before leaping because of serious exigencies, which would have been met if some cautions were introduced into the decision taking process. The risk averse nature of the farmer disregards the prevalent uncertainty at that moment and this could result in serious negative financial consequences for the farmer and the overall economy of the study area if these attitudes and financial status of the farmers in the area were a benchmark.

Also the above implies adding to the list of options usually available and considered to the decision maker. Looking before leaping here implies that, for example, instead of a choice between processing or storing a particular crop before selling or selling it at harvest, the option is also explicitly considered of delaying any growing of such crop for a time while more information is acquired on likely future profits and on alternative crops that may be more profitable than the one currently intended to be grown. Another way of handling the situation at hand if for example there is uncertainty about the more profitable financial and economic return of crops that are commonly grown and sold by smallholder farmers, growing it might be restricted or stopped until more conclusive evidence is available. In the two cases discussed so far, some actual or opportunity costs are incurred by acting cautiously, and these costs must be balanced against the achieved reduction in the chances of serious negative consequences. Risks, in the sense of the
possibility of bad outcome, can also be avoided or reduced by adopting effective crop market monitoring in the case of this study. This can be done by growing some other crops which have good storage capabilities. For example in spite of weather extremities, maize and citrus in Ibadan/Ibarapa; maize and groundnut in Oyo, maize, beans and groundnut in Saki and maize and beans in Ogbomoso can be grown and reserved with minimal risk of loosing them to damage. Late maize is almost usually dry on the farm before harvesting which gives it a kind of ample storage suitability.

In most cases, citrus juice is extracted and kept in bottles for the market and this can stay intact for months as evidenced in most rural and urban markets in Africa. Groundnut and beans are also seemingly low in moisture and can also be preserved for fairly long periods. So the chance of serious financial and economic losses due to market risks and uncertainties may be minimized by careful monitoring of evidence of beginning price and market conditions and fluctuations.

**Conclusion:** In conclusion, to prevent financial and economic shocks resulting from market and price variability and fluctuations, the growing of annual and or perennial cash crops be intensified while annual and seasonal crops can be maintained at the level of recovering the investment cost and satisfying the farm family immediate food need and the deserved reserve from farm output. The four ADP zones of the state that were studied can each boast of the profitable implementation of this risk mitigation strategy as they all have suitable farming environments for the growth of any of the above listed types of annual, seasonal or perennial crops.

**REFERENCES**