# POST-HARVEST LOSS IN TROPICAL SOYBEAN SYSTEMS: BRAZILIAN MANAGERS' PERCEPTIONS AND MITIGATION STRATEGIES: TWO MANUSCRIPTS

BY

ANAMARIA GAUDENCIO MARTINS

THESIS

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Adviser:

Associate Professor Peter D. Goldsmith, Chair

## ABSTRACT

As the world population grows and arable land availability is limited, concerns about increasing food production and reducing post-harvest loss (PHL) become more pressing. An extensive literature on PHL focuses on developing alternatives to reduce loss through the adoption of new technologies in less developed countries. The previous research specifically targets small land holders. Very limited attention was designed to analyze post-harvest loss on a large-scale production system, even though this system is responsible for most of the grain production in the fast developing agricultural regions of South America and Africa. Thus, this thesis proposes to understand PHL in a tropical soybean system.

This thesis is divided in two individual manuscripts. The first part analyses farmer's perceptions of post-harvest loss and the second examines a farmer's decision to accept soybean harvest loss to increase total yearly production of grain. The state of Mato Grosso, in Brazil, was chosen due its large-scale production system (average of 1,113 hectares of soybean area) and because a large part of the soybean area is double-cropped with maize, 38% in 2012/13 according to CONAB (2013). Double cropping or "safrinha" is a new production technology that portends huge productivity increases for low-latitude farms, has interesting implications for PHL. It is commonly thought that increased food production results from loss prevention, but in the case of safrinha systems, increasing PHL can be optimal, as "time" is a binding constraint and weather uncertainty is significant.

The objective of the first manuscript of this thesis is to analyze the role demographic characteristics and managerial decision making have on farmers' perceptions of the level and cause of PHL. The results offer evidence that there is no consensus regarding the main cause of PHL. Measuring loss interestingly does not imply less loss. But understanding that PHL is a management problem, not problem that is uncontrollable, is important for loss reduction.

The second manuscript contends that although loss mitigation is important to increase food supply, there exists an efficient level of loss in the case of double-crop systems in low latitude countries. Farmers trade off the benefits of reducing loss with the opportunity costs of an inferior second crop. Farmers appear to be willing to accept soybean harvest loss in order to plant maize earlier in the season to avoid yield risk and increase total production (soybean + corn). The findings show that farmers accept soybean harvest loss in Brazil because "*The financial benefits to reduce losses during harvest and post-harvest on their farms are small"* and "*The economic benefits of double-cropping compensate the costs of soybean harvesting losses*. Results also show that farmers who have on-farm storage and define themselves as risk-loving are more likely to accept soybean harvest loss.

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## 1.1. INTRODUCTION

The Food and Agricultural Organization of the United Nations - FAO - estimates that world agricultural production needs to increase at least 60% over the next four decades in order to reach the future demand for food. The projections are grounded on a growing population that is expected to reach more than nine billion people in 2050. In addition to agricultural expansion, prevention of postharvest losses (PHL) is a key component to meet this demand (Harvey, 1978; Greeley, 1982 and 1986; and U.N., 2011). Approximately 1/3 of the total annual food production fitted for human consumption is lost every year worldwide (U.N., 2011). Research on PHL in developing country settings is divided into three camps. There has been some published research measuring on-farm losses. Unfortunately dated, the research reveals a wide range level of losses and a large variability of estimates. Vacarro (1981) explains that the magnitude of the estimates of losses varies because of the differences in methodologies, techniques of loss valuation and sampling procedures. The second camp of PHL research identifies the particular reasons of losses by doing simulations within controlled environments. Greeley (1986) criticizes these studies arguing that the various estimates, or rather "guestimates" about food losses happens because the experiments are not grounded in the reality of a farm environment.  Thus the results possess weak power in terms of application for farm managers, policy makers, or technology providers. Finally there is a significant body of research linking PHL with food security. The prevention of postharvest loss is a central element. However, farm management practices and farmers' understanding of loss, which are crucial to loss reduction and remediation design, are missing.

Little research has been conducted on the farmer, and PHL management on farm, as a critical component of PHL reduction overall. Especially absent is research applied to the fastest growing segment of agriculture, emerging market farmers. These commercial production systems often operate in rough tropical environments with minimal infrastructure, and management systems involving significant mechanization and high labor inputs. This research fills an important gap in the PHL literature by providing a better understanding of farmer's perceptions of loss.

The objective of this paper is to analyze the role demographic and managerial characteristics have on farmer's perceptions of the level and the causes of PHL on their farms. Specific research questions are: what are the main causes of loss; what is a farmer's role in loss management; and does measuring loss reduce loss. The paper is divided in five sections. Section 2 gives an overview of the soybean production in Brazil and Mato Grosso. Section 3 discusses the Literature Review on the causes of PHL. Section 4 presents the data and research methods. Sections 5 and 6 presents the results and conclusion, respectively.

## 1.2. BACKGROUND

Brazil is one of the developing countries in the tropics that has undergone fast agricultural development and continues to raise expectations about the potential growth of global food production. According to the USDA (2013), Brazil is the second largest soybean producer in the world, following the United States. In 2011/12 Brazil total production reached 66.5 million tons. The same source estimates that Brazil will produce 82 million tons in 2012/13 and 85 million tons in 2013/14. Estimates from the Ministry of Agriculture, Livestock and Food Supply (MAPA, 2012), in Brazil, suggest that national production of grain will increase by 21.15%, or 32.3 million tons until 2021. The projections are based on the productivity growth and land incorporation of 17.29 million acres (including the conversion of pasture to agricultural use and double cropping system), with soybeans accounting for 11.61 million acres (67% of the increment) and corn for 1.48 million acres (9% of the increment). MAPA (2012) also argues that the state of Mato Grosso in the Midwest of Brazil, already the world's leader in grain production, will be responsible for most of the corn and soybeans production growth.

Located part at the Brazilian savannah and part at the Amazon Forest, Mato Grosso grain production increased 47% (largely due to an incremental increase in land use and productivity), going from 28.1 million tons to 40.3 million tons between 2008 and 2012 (CONAB, 2013).

In addition to the flat topography, warm weather, and regular rainy season, the development of the agricultural sector in Mato Grosso also results from a highly technical cropping system involving soil correction, pest management, and advanced genetics, and large-scale farm production. The average grain farm size is 1,113 hectares (IBGE, 2006), which is considerably larger than the average grain farm size in other Brazilian states. The scale element is pivotal in the analysis of postharvest losses proposed in this paper, whose focus is on large-scale farms in developing country settings.

## 1.3. LITERATURE REVIEW

Farmer decision making and their understanding of PHL have received very limited attention in studies of PHL. Basavaraja et al. (2007) estimate the post-harvest losses of rice and wheat in India through a survey of farmers, wholesalers, processors and retailers. The survey asks farmers their perceptions of post-harvest loss at each stage of the supply chain, including the farm level. The authors apply a multiple linear regression and find out that the level of losses on rice is negatively associated with age and education and positively related with total production, acreage, and bad weather conditions. For wheat, the losses are only significantly correlated with age and education - negatively, and with storage - positively, meaning bad storage conditions increases PHL.

Begum et al. (2012) also survey farmers to measure the level of post-harvest losses of wheat and rice in Bangladesh, adding whether they were food secure or not. The researchers use multiple linear regression analysis to examine factors affecting post-harvest losses at the farm level. They then employ logit regression to identify the determinants of food security among households. As in Basavaraja et al. (2007), the coefficient sign associated with the “bad weather conditions” variable is negative in the wheat model, implying a negative influence on the level of PHL, although the coefficient is not statistically significant. With respect to food security, the study finds a negative and significant correlation between the level of PHL and the probability of the food being secured. The greater the level of PHL the more food insecure is the household.

The aforementioned studies on farmer’s perception of PHL analyze the factors utilizing aggregated categories, namely, storage, harvesting, labor and weather. Vacaro (1981) structures the causes of postharvest losses into six different categories:

- Preharvest factors (e.g. quality loss)
- Harvesting factors (e.g. weather conditions, harvesting speed, early harvesting, carelessness, inefficient machinery)
- Threshing
- Drying factors
- Storage conditions (e.g. entry humidity of the grain and temperature control)
- Biological factors (natural causes e.g. insects, rodents)

### 1.3.1. Causes of postharvest losses

The focus of this paper is to study farmer’s perception of PHL on their farms. So among the six categories of losses pointed by Vacaro (1981), only Harvest factors and Short-Haul factors are included in this research. Additionally, three managerial causes are also studied: Measurement, Contracting and On-farm storage. These three causes originate from findings derived from a seven-farmer pilot study conducted in Mato Grosso in preparation of the research’s a statewide survey on PHL.

*Harvest Loss*

Producers want to harvest as soon as they can, sometimes not at the ideal time and with adequate care, which increases soybean harvesting losses (Roessing et al, 1981). Soybean harvesting loss was first studied in Brazil in 1973 for Dall'Agnol et al. (1973). The authors study the problem in six different regions in the state of Rio Grande do Sul (RS in Figure 1), the biggest soybean producer at that time, and find harvesting losses of 11.85%. Afterwards, researchers conducted experiments in other regions in Brazil. Among those, Magalhães et al. (2009) measures the quantitative losses of soybeans by varying harvesting speed and machinery type in the state of Mato Grosso do Sul (MS on Figure 1), and find that the differences in speed operation are not statistically significant. They detect that losses due to adjustments and maintenance of the cleaning system contribute most to the total loss. They conclude that operators training and conservation of the combines are important tools to reduce the soybean loss. This is important because of the relative high labor intensities and volume of labor employed in developing country soybean farms. Likewise, Campos et al. (2005) and Ferreira et al. (2007) do not find significant differences in loss by varying the speed.

However, Mesquita et al. (2001) evaluate quantitative loss and broken grains by varying the combine speed in Parana (PR in Figure 1) and conclude that losses tend to increase abruptly for speeds higher than 7 km per hour. Based on these findings, the same authors conducted a second study in several states of Brazil, and found that harvesting losses also increase with the displacement speed (Mesquita et al., 2002).

There are many causes for soybean harvesting losses: uneven soil surface; seed quality; weeds; late harvesting; soybean moisture during harvesting; bad machinery adjustments; and carelessness (Embrapa, 1999; Pinheiro Neto and Gamero, 2000). Consequently, it is imperative that soybean producers measure the losses, identify the major causes, and provide proper training to the operators (Pinheiro Neto, 1999; Pinheiro Neto and Troli, 2002).

Franz et al. (2001) identify obsolete machinery and untrained operators as the main reasons for a harvesting loss of 3.71%. Other measures of harvest loss are: 10.78% in Parana (Mesquita et al, 1980); 10.42% in Parana (Finardi and Souza, 1983); and 4.38 % in Mato Grosso do Sul (Sobrinho and Hoogerheide, 1998). The national agricultural research agency EMBRAPA sets the maximum acceptable level of harvest loss at 2.51% (EMBRAPA, 1999).

*Short-Haul loss*

A second area of loss relevant to developing country settings is short haul loss. These are the losses from the field either to storage or the commercial elevator. These losses are thought to be measure, especially in developing country setting because the distances are large, the roads are poor to nonexistent, and the capital equipment is old and in poor condition. The National Academy of Science (1978) in 1978 stated that there were very few studies on transportation losses in developing countries. More than 30 years later the scenario has not changed much as very little is known about transportation losses in Brazil (Caneppele et al, 2012). This is especially true for short-haul loss. Transportation losses may occur due to poor road conditions, improper conservation of trucks, type of body truck, overloads, inefficient transfer of grains, and negligent or inattentive behavior of drivers (Caneppele et al, 2012). Short-haul loss is especially difficult to measure because scales are not present in the field to weight grain prior to departure to the storage or commercial facility.

### 1.3.2. Management Characteristics affecting postharvest losses

*Measurement*

Identify the technical reasons for having harvesting losses is difficult, and accurate measurement is rare (Greeley, 1982). Shay et al. (1993) divide the major sources of harvesting losses as shatter loss at the combine header (caused by harvesting speed), stubble loss (caused by uneven soil), lodge or loose stalk loss (caused by lack of adjustments), cylinder loss (caused by high moisture content), and separation loss (caused by seed quality). The authors emphasize that measuring losses might take only 10 minutes, and this attitude is essential to achieve satisfactory combine operation. But according to Greeley (2009):

> *"To identify the precise cause requires examining one operation, for example different threshing methods, and keeping constant the methods followed in other operation. In the laboratory this is easy; under farm-level conditions it is far more difficult; for example, to ensure that the grain threshed today will be at the same temperature or moisture content as the grain threshed tomorrow*" (Greeley, 2009, p.53).

For Brazil, the only numbers on farmers measuring losses is find in Franz et al. (2001), where only 10% of farmers were measuring soybean losses in Distrito Federal in the 98/99's season.

Despite the lack of literature connecting measurement of harvest loss with the level of PHL, a more general literature on environmental problems such as groundwater pollution (Napier and Brown, 1993; Elnagheeb et al, 1995) and land degradation (Bayard and Jolly, 2007), points out that the prevention of a "problem" requires first the farmers' awareness of the problem, and then their willingness to act on it. In terms of postharvest losses, the awareness of the problem can be associated with the measurement of the loss. Farmers who actively measure harvest loss may be more willing to act to solve the problem and, hence, may perceive a lower level of postharvest losses.

*Contracting*

Large-scale producers who contract harvest operation are expected to perceive a lower level of postharvest losses. The few studies that examine the relationship between contracting with harvesting losses in Brazil find a positive relationship between the two variables. Campos et al. (2005), study soybean harvesting using machinery age, harvesting speed, and ownership in Minas Gerais, Brazil, in 2002-2003, and find 62% greater losses on the contract operations, 4.72% for contract harvesting against 2.92% per hectare or own machinery. Silva et al. (2002) find a similar result. Both studies point to the carelessness of the operator while driving the combine as the reason for the observed difference. When farmers operate the combine attention to loss and care in operation increases (Campos, 2005).

These findings on contracting diverge from the seven-farmer pilot study conducted in Mato Grosso prior to implementing our statewide survey on PHL. We find three models of managing the combine operation in Mato Grosso; owner harvesting, contracting, and employees. The first two are rarely used in the large operations of Brazil because owners manage and do not operate equipment, and larger operations require a lot of capital. Contractors would find it difficult to assemble the harvest capital necessary to provide high quality and timely service to a typical operator in Mato Grosso. Unlike harvesting in higher latitude regions, low latitude farmers engaged in succession cropping systems have very small windows for harvest, so the need for speed and flexibility limit the value of a contractor. Unpublished results from the seven-farmer pilot study that operators experience lower levels of loss when contracting compared with their own employees, because contractors are better trained. The greatest losses are thought to occur with employees, followed by contractors, and to be lowest when owners are equipment operators. Unfortunately with respect to the PHL question, employee operators dominate in low latitude farming systems.

*On-farm storage*

Australia serves as the setting for most of the studies that connect harvest loss and storage utilization in low latitude settings, where double cropping involves wheat as an important export commodity. These studies mention the advantage of having on-farm storage to reduce harvest loss, in addition to the standard benefits from improved marketing. Storage benefits include reducing weather damage by allowing farmers to harvest the first crop earlier and at higher moisture levels (Strahan and Page, 2003; Nawi and Chen, 2003). Storage also affords farmers more time to prepare the next crop (Strahan and Page, 2003).

Australia has weather characteristics similar to the Brazilian Midwest, in addition to the second crop season, but quantifying the real benefits of on-farm storage grain facilities (qualitative and quantitative) with respect to harvest loss is difficult. To solve this problem Abawi (1993) creates a simulation model to evaluate harvesting operations by varying weather conditions. The model considers moisture content to be a function of weather conditions. Using weather data from a 30-year period in Australia, the results show that returns could be significantly increased by harvesting the wheat earlier and at a certain level of moisture, followed by artificial drying.

## 1.4. DATA AND RESEARCH METHODS

To collect data necessary for this analysis, we conducted an on-line computer survey of farmers located in Mato Grosso, Brazil, in December 2012 and January 2013. It was the first online survey conducted with farmers in Mato Grosso, and also the first survey about postharvest losses.

A pilot study of seven farmers took place in Mato Grosso in June of 2012 to better understand the nature of PHL perceptions by farmers and help frame an on-line PHL survey instrument. Following the pilot a draft online survey instrument was developed and tested in November 2012. The final survey was emailed to 1,902 farmers listed in the database of the Mato Grosso Soybean and Corn Growers Association (Aprosoja) in December 2012. Farmers in Mato Grosso had never been surveyed online before, they are sporadic users of email, and do not use the Internet as their main source of information (Aprosoja, personal communication, November, 2013). Nonetheless, the response rate was 158, or 8.3%, which is still considered a good rate. Although the sample is not representative, as the farm size of the respondents is twice as large as the average farmer in the state of Mato Grosso, the survey results are still of great interest, since these are some of the largest and most dynamic farmers in the world, and their perceptions about PHL are unknown. They operate in the largest and fastest growing corn and soybean state in the world. These large producers operate in the tropical region where expansion is occurring most rapidly, and the survey results will have application to other high growth tropical regions such as Africa other parts of Brazil and Latin America, and Southeast Asia.

The survey was conducted through Surveymonkey.com. The general statement used as the subject line to recruit participants via email was: “Postharvest losses on soybeans”. There were a total of 32 questions divided into 3 sections. Part one asked farmers general information about the farm. Part two focused on farmer’s perception of PHL and the relationship between soybean harvest loss within a succession crop (“safrinha”) production system. Finally the last section included general questions about the respondent. Since it was not known whether more people had access to email within each farm, the survey had a question at the beginning asking if the person who was responding the survey was a farmer, manager, or someone else involved in the production system. In total, five were managers and three were involved in the production system but in a different role. The answers from these eight were not considered in the analysis.

Male respondents comprised 97% of the responses, which was already expected since in Brazil (Table 1) farm wives usually live in the city and have other business activities. They often are not directly involved in the farm decision process. Only 9% of the farms in Mato Grosso are managed by women (IBGE, 2006). Regarding age, 50% of the respondents from the sample are younger than 40 years old, whereas 47% are in between 40 and 60 years old. These numbers are very close to the sample from an in-person survey from Aprosoja (Aprosoja, personal communication, November, 2011), where 41% of the respondents were in between 18 to 44 years old and 50% of the respondents were in between 45 and 59 years old. It is also close to the 2006 census’ numbers, where 46% of the farmers are between 45 to 65 years old, and 46% are younger than 45 years old, according to IBGE (2006). During the 70’s and 80’s, most of the immigrants coming from Southern Brazil to Mato Grosso were families with children between 5 to 30 years old (Cunha, 2006). Thus many of the respondents probably arrived in Mato Grosso while still young, and had the opportunity to observe the land occupation and the development of the agriculture sector from the beginning of the colonization process.

In terms of education, 69% of the respondents have bachelors or graduate degree. Looking at this aspect, the sample from this survey does not represent the farmers from Mato Grosso. Numbers from the 2006 census show that 48% of the respondents have not finished high school, 12% have finished, and only 3% have bachelors or graduate degrees.

The farm size from the sample shows that 86% of the respondents plant more than 500 hectares of soybean. The 2006 census shows that 52% of the agricultural properties in Mato Grosso plant more than 500 hectares. Despite this different, the purpose of this research is to study medium to large-scale farms, where the production system involves different agents (owner, manager and operators). Thus, the sample is aligned with the main objective of this paper.

The small body of literature on the role of farmer management on post-harvest loss centers in Asia using a small holder setting. In such cases farming operations are less complex, may involve small scale irrigation, and at times may be a subsistence activity. Thus the application to commercial operations in the tropics is limited. The three papers found in the literature that discuss farmer's perception of postharvest losses of grains (Bassappa et al., 2007; Basavaraja et al., 2007; and Begum et al., 2012) use both farmer demographics (age and education) and farm characteristics such as area under crop and total production (Bassappa et al., 2007) plus area under irrigation and area under commercial crop (Basavaraja et al., 2007), or plus annual income from farm activity, inputs usage, household size and prices (Begum et al., 2012). Following the previous research the survey contains questions on demographics (gender, age, and education) and farm characteristics (area under soybean production), but adds a series of more managerial relevant questions reflecting the commercial nature of production in Mato Grosso. Managerial questions were tested during the pilot study of seven farmers. From the pilot study semi-structured interviews, three managerial areas emerged as relevant to PHL: 1) whether farms measure loss; 2) whether farmers engage harvest contractors; and 3) whether the farm has on-farm storage. All the interviews were recorded and transcribed, and involved two researchers at all times.1) whether the farm actively measures post-harvest loss. There is a common adage that you can't manage what you don't measure. This question in itself is of interest because the sample reflects educated and large farmers that are a subset of all farmers that would be most likely to be aware of the issue of PHL. Among the respondents, 36% are adopters of PHL measurement techniques. Despite being a small number in absolute terms, the coefficient is a lot higher than the one find in Franz et al. (2001), of 10% for the Distrito Federal. (One factor explored in paper #2 is the interaction between price and loss. Empirically such analysis is difficult in one survey, such as the one explored in this study). Clearly, the rise in grain prices since 2008 would, *ceteris paribus*, make farmers more attentive to PHL. Thus, the low level of measurement in 2001 (Franz et al, 2001) may reflect the low value of the grain compared with a survey of farmers in 2012. Measurement is a binary variable to capture the statistical differences in levels of perceived PHL between farms that measure PHL from the ones that do not measure. Note: there is no definitive measure of PHL on our survey farms. The survey asks farmers to state the level of harvest, short-haul, and storage losses. PHL is hypothesized to be negatively related to measurement.

*Hypothesis 1: Farmers who actively measure PHL perceive lower losses*,

*Hypothesis 2: Farmers who actively measure PHL understand the sources of loss differently than those that do not measure PHL.* Measurement allows managers to better understand the nuance of loss, as opposed to those that only indirectly understand loss on the farm.

2) The second managerial area of interest concerns the use of contracting. Agency is clearly an important aspect of PHL management. Theoretically when agents don't directly bear the risk of their actions, performance suffers. Thus an owner operator of equipment will, ceteris paribus, be more attentive to loss. Researchers in India identify their labor as a significant contributor to PHL (Bassappa et al., 2007; Basavaraja et al., 2007; and Begum et al., 2012). Contractors too are thought to have higher levels of loss compared to owner operators (Campos, 2005). Modern broad hectare farms in tropical regions like Mato Grosso engage significant levels of labor because of their size. Typical farms in Mato Grosso are hierarchical in their management. Farm owners do not operate equipment, including the combine. Thus

the tradeoff in Mato Grosso is between contractors and employees, not owners. This differs from the United States where contractors substitute for the owner. Contractors in Mato Grosso may operate harvest equipment with greater care as they are specialists, compared to employees.

The current level of respondents contracting for the harvesting operation is low (29%). The pilot study of seven farmers revealed a negative relationship between farmer's perception of harvesting loss and contracting. Therefore, it is hypothesized that farmers outsourcing part of the harvesting operation is negatively related to PHL. If the hypothesis is true, outsourcing might be an efficient strategy to reduce harvesting losses.

*Hypothesis 3: Farmers who actively engage in contract harvesting perceive lower PHL.*

3) The level of on-farm storage. There is relatively little on-farm storage in Mato Grosso, about 20% (Madeira and Goldsmith, 2013). Our survey sample is biased towards larger operators who have higher levels of on-farm storage: 34% of the producers from the sample have storage on their farms. On-farm storage is thought to add flexibility and speed to a farming operation. As discussed above, harvesting soybean during the rainy season in tropical environments causes: loss in quality and quantity discounts due to high moisture levels when selling. Farmers often will use a desiccant to clean plants of leaves and advance harvest; which increases loss due to poor combine performance when harvesting green soybeans. Distance from field to commercial elevators can be long in developing country environments like Mato Grosso. This affects the availability of transport equipment to support harvesting. The dependence on commercial elevators requires farmers to move directly from the field to the elevator. Conditions for travel may not be optimal. The great need for transport equipment causes farmers to utilize poorer equipment, which increases short-haul losses. Relatively nearby on-farm storage allows farmers the flexibility when and where to harvest, as well the ability to exert great care and employ slower speeds at harvest.

*Hypothesis 4: Farms with on-farm storage incur lower PHL.*

The survey asks farmers to estimate or state their harvest, short-haul, and storage losses. Special care was taken during the pilot study and survey pre-test to clearly define the terms, “harvest”, “short-haul,” and “storage.” The literature review and pilot study revealed the following potential drivers of PHL.

Harvesting Loss:

H_1: High harvesting speed

H_2: Lack of adjustments at the platform when needed

H_3: Lack of maintenance

H_4: Old technology of the combine

H_5: Bad weather conditions

H_6: Natural causes (insects, rodents etc)

H_7: Bad seed quality

H_8: Uneven soil surface

Short-Haul Loss:

Sh_1: Truck conditions

Sh_2: Lack of attention from the truck driver

Sh_3: Type of truck body

Sh_4: Overload capacity

Sh_5: Bad road conditions

Sh_6: Loading/unloading process

Storage Loss:

On-farm storage:

Os_1: moisture control

Os_2: mix of good and bad grain

Os_3: unqualified operators

Os_4: loading/unloading process

Private storage:

Ps_1: Grading

Ps_2: Long waiting line

The factors affecting storage losses were divided in two independent categories: one for producers that have on-farm storage and other for farmers who use private storage. As a consequence, the 94-record sample was divided into two smaller samples, which affected the analysis by reducing the degrees of freedom. Ultimately, this led to the decision not to include storage losses.

There are 8 causes of Harvest loss and 6 causes for Short-haul loss, thus the respondents were asked to rank from 1-8 with respect to harvest loss, and 1-6 with respect to short haul loss the importance of the variable on PHL for harvest loss. Respondents scored a factor from unimportant (1) through to very important (8)- harvest or (6)- short haul. For tractability and analytical purposes category results are combined. A dummy value of 1 was given to an answer falling into harvest loss category values of a 6, 7, or 8 and a short haul value of a 5 or a 6.

Thus, we model farmer's perception of postharvest losses as:

$$(1)\quad PHL = \alpha + \beta(Demo) + \gamma(ManagCaract) + \delta(Causes)$$

Where Causes and ManagCaract are vectors of exploratory variables reflecting causes and management characteristics, respectively, which might directly affect the PHL loss levels a farmer perceives; and Demo is a vector of demographic characteristics.

Correlation analysis identifies low levels of correlation among the 14 causal factors of harvest and short-haul loss (Tables 3 and 4). All variables with a correlation above .30 were dropped. Thus seed, soil, natural causes, and the body of the truck were dropped. The sample though is small, so degrees of freedom were of great concern. The full model contained twenty variables. High correlation reduced the model size to sixteen variables. Then a series of regions models were compared in an attempt to balance model performance with analytical scope. Six additional variables were eliminated without reducing the performance of the model: attention, technology, natural causes, overloading, road conditions, and loading problems. Thus the final model contains ten variables; three demographic, three managerial; and four causal.

$$(2)\quad PHL = \alpha + \beta_1(\text{age}) + \beta_2(\text{education}) + \beta_3(\text{acreage}) + \gamma_1(\text{measurers}) + \gamma_2(\text{contractors}) + \gamma_3(\text{storage}) + \delta_1(\text{speed}) + \delta_2(\text{adjustments}) + \delta_3(\text{weather}) + \delta_4(\text{truck\_condition}) + \varepsilon_i$$

Where:

- Age is the age of the respondent divided into 3 categories (< 40 years old, 41 to 60 years old, and > 61 years old);
- Education is the level of education separated into 3 categories: (high school, college graduate, and graduate school);
- Acreage is the soybean area in the 2011/12 season in hectares;
- Measurers is a dummy variable taking value of 1 when the producer measured loss;
- Contracting is a dummy variable taking value of 1 when the producer is outsourcing part of his harvesting operation;
- On_farm_storage is a dummy variable taking value of 1 when there is storage on farm;
- Speed is a dummy variable taking value of 1 when the respondent considers that high speed is an important factor (survey response of 6, 7 or 8) affecting PHL on his farm;

- Adjustment is a dummy variable taking value of 1 when the respondent considers that lack of adjustments when needed is an important factor (survey response of 6, 7 or 8) affecting PHL on his farm;
- Weather is a dummy variable taking value of 1 when the respondent considers that bad weather conditions is an important factor (survey response of 6, 7 or 8) affecting PHL on his farm;
- Truck_condition is a dummy variable taking value of 1 when the respondent considers that the condition of grain trucks is an important factor (survey response of 5 or 6) affecting PHL on the farm.

The model permits the investigation of the factors affecting the level of postharvest losses. A multiple linear regression is employed to examine the relationship between the dependent variable (PHL) with each of the ten independent variables and the intercept. The last coefficient on the model, $e_i$, is the error term that captures the variation explained by factors not included in the model.

## 1.5. RESULTS

The research employs several tests, both parametric and non-parametric, to better understand farmers' perceptions of post-harvest loss. Hypotheses # 1 and #2 focus on the value of measuring post-harvest loss and its effects on lowering loss and understanding the causes of loss. There appears to be very little difference between those farmers who state that they measure their PHL and those that don't, in terms of their understanding of the causes of PHL. Across the 14 causal variables only the use of old combine technology with respect to harvest loss and the lack of attention from drivers with respect to short haul loss differentiates those that measure PHL from those that don't (Table 5). Thus the findings only weakly support Hypothesis #2, which those that measure PHL think differently about the causes than those who don't measure. There appears to be no difference between measurers and non-measurers among the other 12 causal variables. Also interesting is the lack of consensus of unique causes of loss. Average scores cluster around a 5 (out of 8) with respect to harvest loss and 4 (out of 6) with respect to short haul loss.

The respondents do agree that yes the causal factors are somewhat important. This is not surprising as a lengthy pilot study plus a literature review identified the list of 14 causes. But no one or two single factors stand out either as being unimportant or important.

Table 6 supports the lack of consensus among farmers as to a specific set of causes of loss. The percentage of farmers who answer 1 through 8 for causes of harvest loss appears to be uniformly distributed across all eight Harvest causes and all six Short Haul causes, expect for Bad Weather Conditions and Natural Causes (Table 6). Farmer responses do cluster around these two causes. Farmers who answered 1 for High Operation Speed (first cause on Table 6) believe that this factor is not important, while farmers who have answered 8 for the same factor believe this factor is very important (or the most important).

However, when reclassifying the harvest loss causes variables as being unimportant (scores of 1-4) or important (scores of 5-8) shows distinct clustering as to the causal factors affecting loss (Table 7). Over 70% of the respondents state that attention to maintenance and bad weather cause post-harvest loss (Table 7). While only 60% state that harvest speed is an important factor in harvest loss. Also 60% feel that natural causes from insects and other pests is not an important cause of harvest loss. Over 70% of the respondents identify poor road conditions as causing short-haul loss. Contributing to the causes of short-haul loss are the condition of the truck and the body type of the truck as over 60% of the respondents identify these causes as important. Respondents identify the loading/unloading process as a relatively unimportant cause of short-haul loss.

Multiple regression allows for deeper analysis as to the causes of PHL (Table 8). First the Y intercept of 7.18 represents the level of harvest and short-haul loss of soybeans for farmers in Mato Grosso. The coefficient is significant at the 10% level and it is similar to the findings of previous studies conducted in Brazil. This means that farmers may actually have a proper understanding of the levels of loss, or that such loss levels are common knowledge. Three factors provide some evidence of the prior rather than the latter.  First there is a considerable range of loss estimates across all respondents.  While the average stated harvest loss is 5.68% and the Sort-haul loss is 2.24%, two standard deviations are 12.6% and 5.1%, respectively.  So there appears to be little clustering, which would indicate bias.  Second, on-farm measurement of loss is not unheard of.  A third of farmers do measure loss, so incorporate it into their management plans.  Third, semi-structured interviews both with farmers and management within the corn and soybean association reveal an understanding that loss is an issue, but little experience either measuring or documenting the phenomenon of loss. Thus PHL appears to be a relatively new management issue of concern, albeit mild.

The coefficient Age shows a negative relation with PHL, meaning that the older is the farmer the lower is his or her perception on Postharvest losses. The same result is found in Basavaraja et al (2007) and Begum et al. (2012), and despite little significance in terms of future policies, this might be related to education, where younger farmers are having more education than their parents, and consequently, have access to more information and greater awareness of the problems at the farm level. The coefficient for Education was not significant to confirm this statement, but it was hypothesized to have a positive correlation: the more educated the farmer is, the greater is his or her perception on PHL.

From the three management characteristics selected to analyze PHL, only one was found significant. Farmers who have On-farm Storage perceive to have lower level of postharvest losses, as expected. The coefficient of -2.71 is significant at the 10% level.  This supports Hypothesis # 4 that having on-farm storage reduces PHL. This is an important finding for future policies promoting the installation of storage on farm in Mato Grosso. Problems of access to loans were indicated from the seven-farmer pilot study as the main impediment faced by farmers willing to invest on storage facilities.

The coefficient on those that measure PHL is positive but insignificant with a P-Value of .12.  Thus Hypothesis #1 is not confirmed.  Though insignificant, it is interesting that those that measure tend to state higher rather than lower losses. Do farmers then underestimate their losses because they do not measure loss?

The coefficient for farmers who employ contracting for their harvest operations is positive but not significant at a P-Value of .30. Hypothesis #3 is not proven. It was hypothesized that contracting might lower PHL, but there is no effect on PHL levels among the respondents when employing contractors versus simply relying on employees. Thus substituting professional combine operators appears to have no effect on loss. This is consistent with the weak contracting environment present in Mato Grosso. Contracting has proven to be very prevalent, thus successful in the United States and Argentina, but relatively little used in Mato Grosso. Harvest windows in Mato Grosso when planting earlier and with shorter varieties advance harvest into the rainy season. Adverse weather conditions compress the harvest window and make timeliness of harvest critical. The contractor model may not be sufficiently flexible and mobile to adapt to the weather uncertainty of harvest in humid low latitude regions. Secondly, larger farms require greater levels of equipment. Contractors may be capital constrained, thus less competitive in such environments, compared to farmers owning their own equipment.

Regarding factors directly affecting postharvest losses at the farm level, all the three factors affecting harvesting losses were significant at 5% confidence level. High Harvesting Speed was found to be negatively related to the level of postharvest losses, meaning that farmers who consider that harvesting speed is an important factor affecting harvesting losses perceive lower levels of PHL compared to those farmers who do not consider speed to be an important factor. This result might indicate that these farmers are more aware of the speed problem, thus avoiding High Harvesting Speed.

The same interpretation goes to the factor Operator Attention, where there is a negative and significant coefficient. Farmers who believe that the lack of attention in the adjustment of the combine in the field is an important factor affecting harvesting loss perceive lower PHL. Thus speed and equipment maintenance appear to be important areas of focus for training employees and for equipment manufacturers. The corn and soybean association (Aprosoja) or the farmer's training organization (Senar) might invest in combine operator training, especially in the areas of speed and maintenance, in order to reduce PHL. Similarly, equipment manufacturers might help reduce loss by making operators more aware of loss when operating at high speeds and provide more automated adjustments or indicators of out-of-adjustment to reduce loss. Loss monitors for example, are not used in Mato Grosso. Producers remark that such added technology across a lot of equipment operated by many different employees is not cost effective. Thus the cost of loss mitigation through the use of technology may be higher than the benefits of loss reduction.

The cause Bad Weather Condition was positively and significantly related with the level of post-harvest losses. Farmers who believe that Bad Weather Condition is an important factor affecting PHL perceive a greater level of PHL. The correlation between Bad Weather Conditions and High Harvesting speed is quite low, only 0.07. Similarly the correlation between Bad Weather Conditions versus Operator Attention is also low, 0.20. Farmers control High Harvesting Speed and Operator Attention, but do not control the weather. Farmers who cite "controlled factors" as more important causes that "non-control factors" perceive lower levels of PHL, the difference on the averages for High Harvesting speed is 2.35 (significant at 10%) and for Operator Attention is 1.59 (not significant). Farmers that feel that PHL is a function of uncontrollable factors such as the weather do not actively manage PHL, thus perceive have higher losses, of 3.33 (significant at 1%). Those farmers that identify management as a way to reduce PHL, are more active in PHL reduction, and as a result will incur lower levels of loss.

Finally, as stated above, there is weak consensus as to the causes of short-haul loss. Only one short-haul variable was included in the final model, truck condition. The coefficient is positively associated with higher levels of loss, but insignificant with a P-Value of .12.

## 1.6. CONCLUSION

An implicit question is this research is whether PHL was important to farmers. Clearly the global community cares about PHL, and its reduction. But unexplained is why a farmer accepts controllable loss. Most hypotheses remain unproven. Clearly not proving a null hypothesis can indicate the alternative. Or maybe the theoretical propositions are weak or the sample is sufficiently heterogeneous to cause poor statistical fit. The sample though is fairly homogeneous and reflects fairly well-educated and successful farmers. The lack of power in the model may better indicate a lack of managerial focus or criticality of the PHL to farmers. Might the challenges of quickly harvesting large tracts of land with extensive weather uncertainly, and heavy uses of labor trump attention to 10% PHL? Might the cost of reducing loss further, using current technology, exceed the benefits? Similarly, the weak results of the model might indicate to policy makers and equipment manufacturers that their willingness may be low to accept significant investments in PHL reduction. Low cost investments might be acceptable, but specific capital expenditures or those incurring labor allocations might involve costs that exceed benefits. As grain prices rise, ceteris paribus, interest in reducing PHL might rise. But rising grain prices also provides incentives for farmers to farm more ground and extend their equipment, and there is a wealth effect reducing the marginal value of lost grain. Thus interest in PHL reduction by farmers may not rise as prices rise.

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1.8. TABLES

**Table 1 Sample Comparisons**

| | IBGE Census (2006) | Aprosoja (2012) | Sample (2012) |
|---|---|---|---|
| Number of farms | 3,246 | 108 | 94 |
| Soybean Planted area (ha) | 3,614,465 | 182,662 | 211,273 |
| Average area (ha) | 1,113 | 1,691 | 2,248 |

**Table 2 Summary Statistics of Selected Demographic, Managerial and PHL Variables**

| | |
|---|---|
| Total number of farmers | 94 |
| Number of measurers | 34 |
| Number of non-measurers | 60 |
| Item | **Average** |
| Total loss estimated by farmers (average in %) | 10.37 |
| Harvesting Loss (%) | 5.68 |
| Short-Haul Loss (%) | 2.24 |
| Storage Loss (%) | 2.45 |
| Farmer Characteristics: | |
| 2012 Crop year Soybeans Acreage | 2,247 |
| 2012 Crop year Corn Acreage | 1,097 |
| % of area double-cropped | 49% |
| Age (% of farmers with age of:) | |
| < 40 years old | 50% |
| 41 to 60 years old | 48% |
| > 61 years old | 2% |
| Education (% of farmers with education :) | |
| High School | 34% |
| College graduate | 72% |
| Graduate school | 1% |
| Soybean area (% of farmers with soybean area of: ) | |
| < 500 ha | 14% |
| 500 to 1,000 ha | 26% |
| > 1,001 ha | 61% |
| On-farm storage | 34% |
| Contracting | 31% |
| Farmers Perception of PHL: | |
| Factors affecting PHL | |
| High operation speed | 34% |
| Lack of adjustments at the platform when needed | 36% |
| Bad weather conditions | 57% |
| Bad truck conditions | 62% |

**Table 3 Correlation Coefficients among Dependent Variables - factors affecting harvesting losses**

| | PHL | H_Speed | H_attention | H_maint | H_tech | H_weather | H_natural | H_seed | H_soil |
|---|---|---|---|---|---|---|---|---|---|
| PHL | 1 | | | | | | | | |
| H_Speed | -0.16 | 1 | | | | | | | |
| H_attention | -0.11 | 0.11 | 1 | | | | | | |
| H_maint. | -0.21 | 0.23 | **0.35** | 1 | | | | | |
| H_tech | -0.01 | 0.13 | 0.10 | 0.16 | 1 | | | | |
| H_weather | 0.23 | 0.07 | 0.20 | -0.02 | -0.06 | 1 | | | |
| H_natural | -0.15 | 0.08 | 0.12 | 0.29 | 0.16 | -0.12 | 1 | | |
| H_seed | -0.10 | -0.01 | 0.16 | **0.40** | **0.32** | 0.08 | **0.39** | 1 | |
| H_soil | -0.13 | 0.14 | 0.28 | **0.42** | 0.17 | 0.11 | 0.24 | **0.50** | 1 |

**Table 4 Correlation Coefficients among Dependent Variables - factors affecting short-haul losses**

| | PHL | Sh_truck | Sh_attention | Sh_body | Sh_overload | Sh_road | Sh_loading |
|---|---|---|---|---|---|---|---|
| PHL | 1 | | | | | | |
| Sh_truck | 0.14 | 1 | | | | | |
| Sh_attention | -0.02 | 0.27 | 1 | | | | |
| Sh_body | 0.05 | **0.48** | 0.27 | 1 | | | |
| Sh_overload | -0.09 | 0.27 | 0.16 | **0.42** | 1 | | |
| Sh_road | 0.13 | 0.23 | -0.08 | 0.26 | 0.10 | 1 | |
| Sh_loading | -0.05 | 0.16 | 0.11 | 0.19 | 0.20 | 0.10 | 1 |

**Table 5 Results from T-test of the means for factors affecting PHL**

| Item | Measurers | Non-Measurers | Average | Difference | P-Value | Significance |
|---|---|---|---|---|---|---|
| Harvesting factors (average of 1 to 8 scale) | | | | | | |
| High harvesting speed | 5.44 | 4.95 | 5.13 | 0.49 | 0.34 | |
| Lack of adjustments at the platform when needed | 5.82 | 5.08 | 5.35 | 0.74 | 0.12 | |
| Lack of maintenance | 4.97 | 4.52 | 4.68 | 0.45 | 0.36 | |
| Old technology of the combine | 5.68 | 4.22 | 4.74 | 1.45 | 0.00 | *** |
| Bad weather conditions | 6.00 | 6.00 | 6.00 | 0 | 1.00 | |
| Natural causes (insects, rodents etc) | 3.76 | 3.62 | 3.67 | 0.14 | 0.77 | |
| Bad seed quality | 4.12 | 3.97 | 4.02 | 0.15 | 0.76 | |
| Uneven soil surface | 4.62 | 3.83 | 4.12 | 0.78 | 0.11 | |
| Short-haul (average of scale 1 to 6 scale) | | | | | | |
| Truck conditions | 4.82 | 4.32 | 4.50 | 0.5 | 0.19 | |
| Lack of attention from the truck driver | 4.71 | 4.08 | 4.31 | 0.62 | 0.04 | ** |
| Type of truck body | 5.00 | 4.50 | 4.68 | 0.5 | 0.15 | |
| Overload capacity | 4.53 | 4.18 | 4.31 | 0.34 | 0.29 | |
| Bad road conditions | 4.88 | 4.88 | 4.88 | 0.00 | 0.99 | |
| Loading/unloading process | 3.56 | 3.27 | 3.37 | 0.29 | 0.42 | |

Importance rate is based on a Likert scale (1=not important and 8=very important for harvesting losses and 1=not important and 6=very important for short-haul); Significance: *** <= .01, ** <=.05, *<= .10

**Table 6 Percentage of Respondents answers for factors affecting Harvesting Loss and Short-Haul Loss**

| Item | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|---|
| Harvesting factors | | | | | | | | |
| High operation speed | 11% | 10% | 7% | 7% | 17% | 14% | 10% | 24% |
| Lack of adjustments at the platform when needed | 10% | 6% | 6% | 7% | 15% | 19% | 15% | 21% |
| Lack of maintenance | 13% | 7% | 16% | 9% | 15% | 14% | 12% | 15% |
| Old technology of the combine | 18% | 6% | 10% | 6% | 18% | 10% | 14% | 18% |
| Bad weather conditions | 5% | 6% | 9% | 5% | 5% | 12% | 21% | 36% |
| Natural causes (insects, rodents etc) | 26% | 16% | 12% | 10% | 13% | 10% | 4% | 11% |
| Bad seed quality | 17% | 18% | 10% | 12% | 15% | 13% | 5% | 11% |
| Uneven soil surface | 16% | 16% | 15% | 11% | 11% | 12% | 9% | 12% |
| Short-haul (average of scale 1 to 6) | | | | | | | | |
| Truck conditions | 13% | 5% | 10% | 11% | 15% | 47% | | |
| Lack of attention from the truck driver | 4% | 7% | 13% | 32% | 16% | 28% | | |
| Type of truck body | 7% | 7% | 9% | 11% | 18% | 48% | | |
| Overload capacity | 4% | 13% | 13% | 16% | 27% | 28% | | |
| Bad road conditions | 3% | 9% | 7% | 7% | 24% | 49% | | |
| Loading/unloading process | 20% | 15% | 15% | 19% | 19% | 12% | | |

Importance rate is based on a Likert scale (1=not important and 8=very important for harvesting losses and 1=not important and 6=very important for short-haul)

**Table 7 Percentage of Respondents answers for factors affecting Harvesting Losses and Short-Haul Losses**

| Item | 1-4 | 5-8 | | Significance |
|---|---|---|---|---|
| Harvesting factors (1-8) | | | | |
| High operation speed | 35% | ***65%*** | | **Important** |
| Lack of adjustments at the platform when needed | 29% | **70%** | | **Important** |
| Lack of maintenance | 45% | 56% | | Not Significant |
| Old technology of the combine | 40% | *60%* | | **Important** |
| Bad weather conditions | 25% | **74%** | | **Important** |
| Natural causes (insects, rodents etc.) | ***64%*** | 38% | | **Unimportant** |
| Bad seed quality | 57% | 44% | | Not Significant |
| Uneven soil surface | 58% | 44% | | Not Significant |
| Short-haul (average of scale 1 to 6) | **1-2** | **3-4** | **5-6** | |
| Truck conditions | 18% | 21% | ***62%*** | **Important** |
| Lack of attention from the truck driver | 11% | 45% | 44% | **Moderately Important** |
| Type of truck body | 14% | 20% | ***66%*** | **Important** |
| Overload capacity | 17% | 29% | 55% | **Moderately Important** |
| Bad road conditions | 12% | 14% | **73%** | **Important** |
| Loading/unloading process | ***35%*** | 34% | 31% | **Moderately Unimportant** |

Importance rate is based on a Likert scale (1=not important and 8=very important for harvesting losses and 1=not important and 6=very important for short-haul)

**Table 8 Econometric Results for the OLS Equation**

| | Coefficient | t | P-Value | Significance |
|---|---|---|---|---|
| Intercept | 7.18 | 1.88 | 0.06 | *** |
| Age | -1.29 | -2.00 | 0.04 | ** |
| Education | 0.76 | 0.77 | 0.38 | |
| Acres of soybean planted | 0.00 | -0.22 | 0.82 | |
| Measure PHL? (dummy=1 if yes) | 2.41 | 1.57 | 0.12 | |
| On-farm storage (dummy=1 if yes) | -2.71 | -1.67 | 0.09 | *** |
| Contracting (dummy=1 if yes) | 1.60 | 1.03 | 0.30 | |
| High harvesting speed (dummy=1 if yes) | -3.36 | -2.20 | 0.03 | ** |
| Lack of adjustments at the platform when needed (dummy=1 if yes) | -3.48 | -2.19 | 0.03 | ** |
| Bad weather conditions (dummy=1 if yes) | 4.31 | 2.88 | 0.00 | * |
| Bad truck conditions (dummy=1 if yes) | 2.32 | 1.54 | 0.12 | |
| Significance level | 0.00 | | | |
| Adj R-squared | 0.14 | | | |

Significance: *** <= .01, ** <=.05, *<= .10

1.9. FIGURES

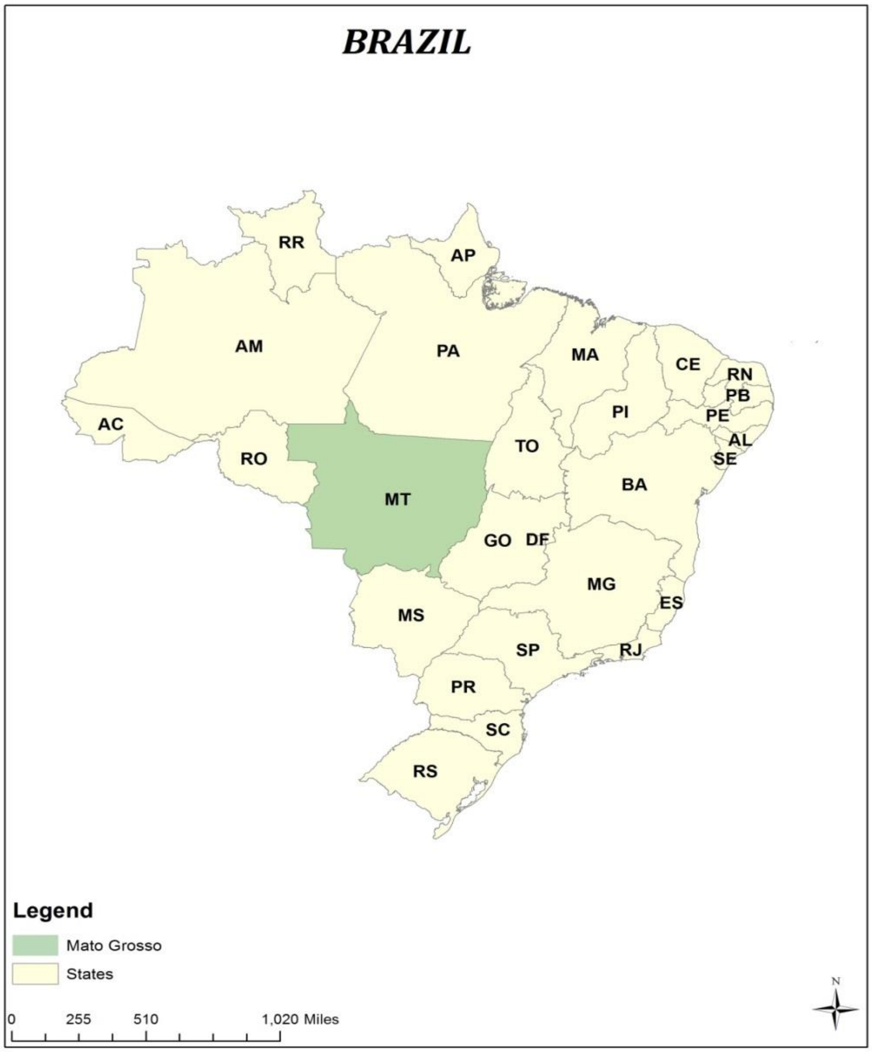


**Figure 1 Map of Brazil**

# CHAPTER 2: UNDERSTANDING FARMER'S DECISION ON ACCEPTING HARVESTING LOSSES TO INCREASE TOTAL GRAIN PRODUCTION

## 2.1. INTRODUCTION

Harvest loss is a function of several causes: bad weather condition, uneven soil, bad seed quality, combine adjustment, carelessness, and high harvesting speed (Vacaro, 1991; Embrapa, 1999; and Pinheiro Neto, 1999). Reducing harvest loss increases yield and profitability substantially (Shay et al, 1993; Vagts, 2003; Kukkarni, 2008; Staton and Harrigan, 2011). The impact of harvest speed on grain losses is unidirectional: higher combine speed increases losses, consequently, farmers have to be more careful and maintain harvesting speed no higher than 7 km/h in order to avoid soybean harvest loss (Mesquita et al, 2001; and Campos et al, 2005). However, no previous research on harvest loss addresses the motivation as to why producers make the decision to drive the combine faster, or the motivations why they are occasionally careless. If farmers are rational profit maximizers, as assumed by Schultz (1964), Norton and Scheifer (1980), and Wallace and Moss (2002), why than producers would accept harvest loss or even increase harvest loss on their property, intentionally?

Results from a pilot study of seven farmers in Brazil, in 2012, suggest that growers increase soybean harvest speed and accept a certain amount of loss to plant maize earlier in the season as a second or succession crop. The double-cropping of soybean-to-maize in Brazil involves adding short planting window maize after advancing the traditional soybeans growing season. The addition of maize production, called "safrinha" (small crop), increases farm profitability and provides agronomic benefits. More recently the rise of corn prices increases the profitability of the safrinha system in Mato Grosso, Brazil (IMEA, 2012). As a consequence, farmers might be rational accepting soybean harvest loss to reach higher farm profitability from jointly producing soybeans and maize. To date there is little literature analyzing the economics of the safrinha model, and no literature addressing the implications for PHL.

Therefore, the objective of this paper is to analyze whether the classic theory of the farm firm as profit maximizing holds such that farmers accept harvest loss when double cropping because the benefits of reducing soybean losses are less than the costs of adversely affecting maize planting. The model also identifies the reasons why farmers make such a decisions and their perceptions regarding soybean loss. The paper is divided into five sections. Section 2 gives an overview of the safrinha production in Brazil. Section 3 discusses the conceptual model of farmer behavior and postharvest loss while Section 4 presents the data and methods. Section 5 discusses the results and Section 6 presents conclusions and implications from the results.

## 2.2. THE SAFRINHA PRODUCTION

The development of the agricultural sector in the Brazilian savannah began in the 1970s as a consequence of federal government programs. These programs included financial incentives and the construction of the first highway crossing the state of Mato Grosso from south to north, the BR-163. Migrants from the south and southeast were encouraged to buy land, expand crop areas and rear cattle in areas surrounding the BR-163. Land prices were fairly low in Mato Grosso compared to the states of Goias and Mato Grosso do Sul (also in the Brazilian savannah) because of its remoteness and difficulty of access. As a consequence, farmers were able to sell smaller plots of land in the south and southeast and buy a considerably larger property in Mato Grosso. This flipping of land essentially at a 10:1 ration of ten hectares in Mato Grosso for every hectare in the southeast lays the foundation for the dominant large scale agricultural model in Mato Grosso. Typical crop farms in Mato Grosso average 2,000 hectares (IMEA, personal communication, June 5, 2013) compared with a typical farm in Southeast Brazil of 308 hectares now (Cepea, 2012), which today characterizes their agricultural production system as medium to large-scale farms, compared to other states in Brazil.

However, it was only at the beginning of this century that the production system as it is today was established. Rise in international demand for soybean, in addition to the depreciation on the Brazilian exchange rate relative to the U.S. dollar, increased the profitability of the soybeans in a monoculture cropping system. Mato Grosso quickly became the country's leading state producing soybean in Brazil. Before 2000, the leading producer of soybean was the southeastern state of Parana. Soybean production in Mato Grosso increased from 0.12 million tons in 1980, to 2.9 mmt in 1990, to 9.8 mmt in 2000, to finally reaching 18.76 mmt in 2010 CONAB (2013). This translates into an annual average growth of 5.4% a year. In 2010, Mato Grosso produced 27% of the national soybean production, followed by the state of Parana, with 20%, and Rio Grande do Sul, with a 15% share.

But the monoculture was rapidly replaced by the double-crop system, where farmers harvest two consecutive commercial crops in the same season (i.e., soybeans and maize). Farmers first started double cropping; to maintain soil moisture during the winter (dry period), break pest cycles, and improve soil quality (Arvor, 2011). This was quite advantageous as tropical soils in their natural state, like those found in Mato Grosso, is nutrient poor, contain very low levels of organic matter, poorly hold moisture, are high in aluminum, and are very acidic (Broch and Ranno, 2011). Soybean cultivation improved soil fertility, but maize as a complement helped break pest cycles, keep ground cover to reduce erosion, and contribute added organic matter to the soil. There were economic benefits as well. The rise in production costs, motivated by the increase in fertilizer prices, led farmers to invest in double cropping in order to improve the cash flow, cover the soil during a dry season, increase the efficiency of fertilizer applications, reduce the costs of controlling weeds and fungi like rust, spread fixed costs associated with land and equipment over two revenue generating enterprises, and occupy labor more fully (Tsunechiro et al, 2006; Silva Neto, 2011).

However, agricultural intensification using the safrinha system is a recent phenomenon driven by the rise in maize prices. In 2009, only 10% of the soybean area was double-cropped with maize, but the area rapidly jumped to 38% in 2011. Net profit from safrinha production reached $672 R per hectare in 2010/11 ($ 305USD), while soybean, the main crop, had net profits of $631 R per hectares net profit in the same year ($ 287 USD) (IMEA, 2013).

The safrinha planting season begins in late January, after the soybean harvest. The window lasts 30 days. Farmers must plant maize no later than February 15th - 25th, depending on location, in Mato Grosso (Fundação MT, 2011). Planting later than March 1 significantly increases the risk of the onset of the dry season negatively affecting corn pollination, which will reduce yield. The earlier farmers harvest soybeans, the more of the maize crop can get planted. Notice how in 2012/2013, for example, 2 million hectares or 69% of the soybean crop was harvested before February 25 (Table 8). This allowed 1.3 million hectares of maize or 92% of the safrinha to be planted within the window.

One practice increasing soybean losses and reducing soybean quality has been an increase use of soybean desiccation of green soybeans to strip the leaves and allow for harvest. Desiccation can advance the soybean harvest by 3 to 7 days, and these days might be very important to the safrinha's yield (Silva Neto, 2011). The desiccant application followed by soybean harvesting and maize planting is more prevalent when weather conditions involve excessive rain. It is a critical time for farmers in terms of operation decisions: soybeans need to be harvested in order to free land to plant the safrinha. But desiccation will affect soybean yield and a delay in safrinha planting affects maize yield. Additionally the tight window and adverse weather conditions also cause farmers to increase combine and transport speeds to complete harvest as quickly as possible. This too will increase post-harvest loss.

This dynamic picture, in addition to the importance that maize has gained in terms of profitability, has affected farmer's decision accepting harvest loss on soybeans to increase total production (soybean and maize).

What makes double-cropping an attractive system only more recently is the continued rise in not just world prices but local prices as well. The rise in local utilization and the development of the agro-industrial complex in Mato Grosso has led to a significant strengthening of the maize basis (Goldsmith, 2009). Consequently, the shortening of the harvesting window for soybeans places Mato Grosso in a unique position to initiate an analysis of harvest loss where there exists an “acceptable” amount of loss in order to increase the total production (soybean and maize) to maximize profit.

## 2.3. FARMER BEHAVIOR AND PHL

Farmers will minimize postharvest losses when they have financial motivations to do so. Food companies have an incentive to reduce losses because they must pay disposal costs (Hodges et al. 2011). Clearly ceteris paribus, reducing loss increases the grain for sale and gross revenue on the farm. Thus, the quantity of grain farmers’ capture by reducing losses plays an important role on farmers’ decision to reduce losses (Mwebaze and Mugisha, 2011). Farmers from Uganda preferred local postharvest reduction methods instead of government improved post-harvest technologies because producers did not know that the benefits surpass the likely cost involved in the process to reduce losses (Mwebaze and Mugisha, 2011).

Part 1 from this study (Farmer’s Perception of Postharvest loss) shows a significant harvest and postharvest soybean loss in Mato Grosso, Brazil. A rational farmer may feel that the benefits from monitoring losses are less than the cost. It also may imply that a rational farmer, once measuring loss, may feel that the benefits of reducing loss are less than the costs to mitigate those losses. Thus, the two testable hypotheses are:

$H_{1:}$ Farmers accept soybean harvest loss because the costs to reduce loss are greater than the benefits

$H_{2:}$ Farmers accept soybean harvest loss because the opportunity cost (maize) is higher than the revenue

The supply and demand model for loss mitigation helps to better understand the economics of PHL mitigation (Figure 2). The horizontal axis reflects PHL level from 0% to 100% that a farmer might choose to mitigate. Clearly, losses are positive, so the equilibrium loss level will fall between 0% and 100%. The left vertical axis reflects the benefits a farmer receives from reducing loss. The grain price might be a simple metric for the benefits a farmer receives by reducing PHL. Farmers receive greater benefits from loss mitigation when grain prices rise, and lower benefits when grain prices fall. The right axis reflects the cost to the farmer for reducing PHL. The slope of the cost mitigation supply curve increases from left to right as each marginal unit of loss is increasingly more costly to mitigate. In this figure, reducing low levels of loss is not overly costly. But reduction of 100% of loss is impossible, but the cost to do so becomes infinite.

In the Figure 2, the farmer chooses to mitigate $L_0$ of the loss, and accepts 100% minus $L_0$ of loss. When grain prices rise from $P_0$ to $P_1$ the farmer puts more effort into loss reduction and accepts less PHL, as depicted by the equilibrium loss reduction level shifting to the right from $L_0$ to $L_{1.}$

But what might cause a shifting of the loss mitigation supply curve causing more or less PHL loss mitigation? The supply curve shifts to the right when the cost per unit of loss mitigation falls (Figure 3). The cost to mitigate $L_0$ levels of loss falls as $S_0$ shifts out and becomes $S_1$. Logically, if the cost per unit of loss mitigation falls from point A to point B, holding all else equal, then the equilibrium of loss mitigation benefits to the costs will occur at point C. Loss mitigation will rise from $L_0$ to $L^1$. The opposite occurs if the cost per unit of loss mitigation were to rise, as shown by $S_2$. Loss mitigation would fall from $L_0$ to $L_2$.

The supply curve of loss mitigation could shift to the right by the introduction of new technology (a sensor), that allows the farmer to mitigate more loss for the same price (point C) or the same amount of loss for less per unit of mitigation (point B).The curve would shift to the left because of rise in labor costs, if loss mitigation is a labor intensive process. The state of Mato Grosso has seen a dramatic rise in labor costs in recent years, as the overall Brazilian economy has expanded. Labor scarcity in the short run leads to the employment of less skilled workers, employees working longer hours, and less attention to lower priority activities. Thus the level of PHL mitigation may fall under conditions of labor scarcity as the labor cost per unit of mitigation would rise.

In the base case, the farmer chooses to mitigate $L_0$ of the loss and accepts 100% minus $L_0$ of loss. What might cause a shifting of the loss mitigation demand curve causing less PHL loss mitigation? The base case compares the benefits of mitigating a unit of loss of a crop (soybeans) with the cost of that mitigation. But the price of the crop (soybeans) may not completely reflect the net benefits to the farmer. Opportunity costs occur when selecting to complete one task and foregoing another activity. The assumption is that time is a fixed resource and two activities may compete for time. One activity generates benefits, while the uncompleted task reflects a lost opportunity.

In the case of Mato Grosso, reducing PHL can compete with the planting of the succession maize crop. Early in the soybean harvest season there is no competition so the net benefits to the farmer from PHL mitigation would be the price of the soybeans, point A (Figure 4). Mitigating soybean PHL will compete with maize production as the harvest season progresses and the window to plant maize begins to close. At point B the maize gain are so low that they completely swamp the benefits to the farmer from mitigating soybean losses. The farmer would attempt to mitigate no PHL at this level of opportunity cost. The curve reflecting the demand for PHL mitigation ($D_0$) shifts downward ($D_1$), reflecting at every point along the original demand curve a complete reduction in value to the farmer due reduced maize production when mitigating soybean loss. The equilibrium loss mitigation level falls from $L_0$ to L2.

Table 10 presents a simulation where the opportunity cost to mitigate soybean harvest loss is the gain on maize yield. Each delay (in days) on maize planting (after the 25th of February) decreases yield by 3.5 bags per ha (Fundação MS, 2013). Suppose a farmer is able to anticipate the maize planting in four days by accepting 10% soybean harvest loss. In this scenario, he is giving up of $ 98 USD from soybeans to have $ 117 USD on maize revenue (gross revenue). Despite being a hypothetical scenario, since weather plays a main role on maize yield, this simulation gives an idea about these trade-off farmers are dealing in the case of double-crop system in low latitude countries.

## 2.4. DATA AND METHOD

A questionnaire was developed based on the information collected from a pilot survey conducted with seven farmers in Mato Grosso in June of 2010. The questionnaire was available through an online survey. A link to access the questionnaire was delivered to an email list of 1,902 farmers from a local soybean association, Aprosoja. Survey participants were asked to share their views on costs and benefits to reduce soybean losses and the importance of the safrinha in terms of financial benefits. The section contained both quantitative (level of postharvest losses) and qualitative answers, which consist of a set of 19 statements. Respondents were asked to identify the degree to which they agreed or disagreed with each statement. (1= strongly agree, 5= strongly disagree).

The qualitative responses were subjected to descriptive analysis procedures. The 1 to 5 Likert-scale responses to the 19 statements about PHL and safrinha were subjected to reliability analysis using Chronbach's alpha, which measurers how closely a set of variables relates to each other as a group. All factors that had an eigenvalue value greater than 1 were constructed using principal components. Then, groups of individual items that had loaded with factor loading scores of 0.6 or greater were tested for reliability. Based upon Chronbach's alpha coefficients, the number of factors was judged to be four. Individual items that loaded into those four factors with a factor loading score greater than 0.5 were examined for common themes and assigned a descriptive name.

The four factors estimated from factor analysis were subsequently used to create four independent variables for a binary logistic regression analysis of farmer's decision on accepting soybean harvesting losses to increase total grain production. Two sets of independent variables were used: 1) weighted factor scores for each of the four factors as computed by principal component analysis plus management and demographic characteristics; and 2) the items that had the highest factor loading scores from each of the four factors plus management and demographic characteristics. The second model serves as a robustness check of the first model.

The logistic model is estimated to explore factors that influence farmer's decision to accept soybean harvest loss to increase total production. The parameters were estimated by using the maximum likelihood (ML) procedure. Summary statistics, β coefficients and p-values, and marginal effects were obtained using STATA.

The dependent variable ACCEPT_PHL is a binary variable where 1 represents farmers that are willing to accept 3%, 5% or more loss on soybean harvest in order to plant maize earlier in the season and reduce the risk to maize yield (Table 11). Farmers, who responded that they are not willing to accept additional soybean harvest loss, were scored with a value of zero.

The following model is used to predict the circumstances on what farmers are more likely to accept soybean harvest losses in order to produce more corn:

$$ACCEPT\_PHL = \beta_0 + \beta_1 Factor1 + \beta_2 Factor2 + \beta_3 Factor3 + \beta_4 Factor4 + \beta_5 On\_Farm\_Storage + \beta_6 Combine + \beta_7 Corn\_price + \beta_8 Risk\_lover + \beta_9 PHL + \beta_{10} Age + \beta_{11} Education + \beta_{12} Double\_crop + \varepsilon$$

Where:

1. *On_farm_storage* is a dummy variable taking value of 1 when there is storage on farm. This variable is hypothesized to be positive related to the dependent variable. Although there is a lack of literature to support this position, our previously understanding is that by having storage, farmers have less loss and consequently are willing to accept a certain amount of loss in order to increase the total production.
2. *PHL* is the level of Postharvest Losses farmers perceive they have in percentage of the total production. This variable is expected to be negative related to the dependent variable. The greater is the level of PHL, the lower is a farmer’s consideration to accept more loss.
3. *Combine* is the soybean area divided by the number of combines. We expect to find that the lower the coefficient is, the lower is the farmer’s consideration in accepting more loss (positive coefficient). The idea is that farmers who have a lower coefficient already invested in combine, so they do not want to accept more loss.

4. *Corn_price* is the price received from the 2011/12 season in Reais per bag of 60 kilograms. We hypothesize a positive coefficient for this independent variable because the greater the price received for corn is, the more the farmer will be willing to accept the loss on soybeans in order to produce more corn.
5. *Risk_lover* is a dummy variable equal to 1 if the producer marked option 3 or 4 for the following options: 1) I am extremely averse to risk; 2) I avoid risk; 3) I take risk after some research; 4) I am a risk lover. It is hypothesized that farmers who consider themselves as a risk lover are more likely to accept losses in order to have more production.
6. *Age* is the age of the respondent divide in 3 categories (<40 years old, 41 to 60 years old, >61 years old). We do not assume any hypothesis for this variable.
7. *Education* is the level education divided in three categories: high school, college and graduate. We do not assume any hypothesis for this variable.
8. *Double-cropping* is the coefficient corn/soybean area in the 2011/12 season in hectares. We argue that farmers who double-crop in a larger area of their farm are expected to accept more loss.

## 2.5. RESULTS

### *Descriptive Statistics*

From an email list of 1,902 farmers, 158 accessed the survey, but responses of some questions were missing and therefore excluded, leaving a total of 94 completed surveys. Soybean planted area reported by the respondents indicate a large-scale production system; the average is 2,247 hectares of soybean area (Table 9). The area double-cropped with corn in the 2011/12 season had an average of 1,097 hectares, nearly 50% of the soybean land. The average level was 30% safrinha in 2011/12 (IMEA, 2012). This information is extremely important for this analysis, which aims to understand the relationship between double-cropping with soybean harvesting losses. The majority respondents were young (50% is less than

40 years old) and well educated farmers. Furthermore, 51% of the producers considered themselves as risk neutral or risk loving.

Most of the respondents (55%) said they would not increase harvesting speed and accept soybean losses to have more corn (Table 3). But still a considerable number of producers would accept 3%, 5% or more soybean losses (45%).

Farmers state that they care about soybean loss, as on a 5 point Likert scale they average a 4.29 (0.68 standard deviation) in response to the question (PHL_2), "*I care about soybean losses during harvesting on my farm*" (Table 12). However, they score considerable lower with a higher standard deviation to the question, "*The manager and the employees from my farm are able to take good decisions and to manage harvesting efficiently;*" (PHL_1) with an average score of 3.85 and 0.9, respectively. A second validation question (PHL_4), "*The operators on my farm take care to avoid soybean harvest loss*," supports the response to PHL_1 as it averages 3.68 with a standard deviation of 0.89.

These results might help explain the 5.68% harvesting loss estimated by the farmers in part 1 of this research, "Farmers' Perception of Post-Harvest Loss". In other words, farmers might think about PHL, but employees are not trained or motivated to reduce harvesting loss. A third validation question, PHL_6, asks if a , "(l) L*ack of training for operators in one important factor affecting PHL*"*; which averages a* 4.14 with a standard deviation of 0.76.

However, their attitudes regarding the importance of the safrinha versus reducing soybean harvesting losses, showed from statements DC_5 (*The cost to reduce harvesting speed and post-harvest losses affects my decision to not prioritize this issue*) and DC_6 (*The financial benefits to reduce losses during harvesting and post-harvesting on my farm are small*) indicate that there exist a divergence of opinion about this topic. The low averages (2.78 for DC_5 and 2.37 for DC_6) are close to a "neutral" answer in a 1-5 Likert-scale. These results triangulate with the 45% and 55% of loss farmers are willing and not willing to accept, respectively.

*Factor Analysis*

The research measures the reliability of the 19 statements using Cronbach's alpha. The computed value for all 19 items combined was 0.58. The 0.7 coefficient is commonly used as an indication of acceptable reliability for the alpha value (Nunnally, 1978; Hair et al, 1998; and George and Mallery, 2003). Bowling (2002) though argues that an alpha greater than 0.5 is acceptable in the case of exploratory research. Such would be the case with respect to this original research on PHL among modern low-latitude farmers.

The items were tested individually, and 8 statements were dropped. All these 8 statements presented an alpha value greater than the combine alpha: 1) *Farmers from my county take care to avoid soybean harvest losses*; 2) *large-scale farms have greater losses because can't manage all the employees efficiently*; 3) *Farmers who have on-farm storage can manage better their time and have less loss*; 4*) Farmers who have on-farm storage have more time to manage and plant the safrinha*; 5) *Access to credit is the main reason why farmers do not invest on storage*; 6) *Corn planted after the ideal windows have high yield risk*; 7) *Soybean yield are greater on areas previously planted with safrinha*; 8*) Postharvest loss reduction is an efficient way to increase food availability.*

The new combine alpha has a value of 0.715, which indicates an acceptable level of reliability. The analysis then employs factor analysis on the remaining 11 statements in order to construct the factors' coefficients. The factor analysis was set so all factors with eigenvalues greater than one were extracted using principal component analysis procedure, and a Varimax Rotation with Kaiser normalization is used to generate the rotated matrix.

The 11 statements generate four factors (Table 14). The coefficients on factor loading represent the correlation between the statement (variable) and the factor. The statements loading in each factor make common sense, so the factors can be titled without difficulty. Factor 1 includes three statements related to the timing of planting the safrinha and is named "*The safrinha affects the management of soybean harvesting*". The second factor loads two positive statements relating to the costs and benefits of reducing soybean losses to increase safrinha production and a third negative statement about the lack of training as a cause of harvesting losses. This last statement presents a negative sign, meaning, it is affecting the factor loading in an opposite direction from the two others. Its value is also low, indicating that this statement does not affect the factor as strongly as the two positive statements. Thus, a good representation of this factor is: "*the cost to reduce loss is high and the financial benefit of reducing loss is low*". The factor is named as "*My demand to reduce loss is weak*". The third factor includes statements related to only harvest loss. The central understanding is that farmers care about harvest loss and they try and prevent harvest loss. It is named "*I care about harvest loss and I try and prevent it in my farm*". The fourth, and last factor, loaded on two statements and denotes a preference for producing more maize relative to preventing greater soybean harvest losses. Thus, it is named "*The benefits of reducing soybean loss are lower than the benefits of the safrinha".*

The Cronbach's alpha for 3 out of 4 factors do not indicate good reliability based upon a commonly used cutoff value of 0.7 (Table 14). Factors 3 and 4 however, two are 0.6, an acceptable coefficient. While factor 2 presents a Chronbach's alpha of 0.52, which, following Bowling (2002) is too low, except in the case of exploratory research.

*Logistic Regression*

The model has moderately good fit as measured by a Hosmer and Lemeshow Chi-Square P-Value test far from zero. Farmers are more likely to accept PHL when producing a safrinha if they have on-farm storage and stated that they are risk loving (Table 15). These results are consistent with the expected sign. These groups are more likely to accept soybean harvest loss compared to individuals that do not have on-farm storage and are risk averse. In terms of marginal effects, farmers who have on-farm storage are 42% more likely to accept an increment of soybean harvest loss. Farmers who consider themselves as risk lovers are 47% more likely to accept more losses compared to those who consider themselves as risk averse.

The coefficient for the estimated level of PHL was also positive and significant at the 10 percent level, and was not consistent with the expected sign. Thus farmers who perceive they have a greater level of post-harvest loss are more likely to accept additional loss. Farmers might be very rational about their post-harvest loss. Thus those that have higher levels of loss, explicitly do so, as they attempt to achieve higher total two-crop gross revenue per hectare.

Factor 2 and 4 are found statically significant at 10% and 1% levels respectively. Factor 2 "*My demand to reduce loss is weak"* was found to be positive related to acceptance of PHL. This coefficient suggests that higher scores for "My demand to reduce loss is weak" increases the probability of accepting soybean harvest loss, which seems logical. In terms of marginal effects, any point increase in Factor 2 increases the change to accept loss by 20%. Factor 4 also shows a positive sign, meaning that higher scores for "*The benefits of reducing loss are lower than the benefits of the safrinha"* increase the probability of accept soybean harvest loss and any point increase in Factor 4 increases the chance to accept loss by 33%.

The results are similar to the weighted factor scores when using the highest loading item from each of the four factors from the factor analysis. This indicates that the model is robust. The model has moderately good fit as measured by a Hosmer and Lemeshow Chi-Square P-Value test far from zero (Table 15). On_farm_storage, Risk_lover, and the level of PHL are positive and significant. For the factors, only DC_6 (*The financial benefits to reduce loss during harvesting and post-harvesting on my farm are small*) and DC_8 (*The economic benefits of double-cropping compensate the costs of soybean harvesting losses*) were found statistically significant. They both have positive signs. Thus producers acknowledge weak incentives to reduce loss, while at the same time appear to have a firm understanding of the tradeoff value from safrinha production. Farmers are more likely to accept soybean harvest losses.

The marginal affects analysis allows for direct comparisons among the drivers of PHL loss acceptance. The most significant variables predicting acceptance of soybean PHL are stating that one is risk loving, and if the farmer has on-farm storage. Less impactful, though significant, are receiving higher prices for maize and stating higher levels of PHL. The demographic variables of age and education are not significant, and surprisingly neither is the level of safrinha production. Thus there is no effect on the willingness to accept soybean PHL when producing more safrinha maize. Previous research showed that larger farmers perceive loss no differently than smaller farmers in our sample. Thus the double-cropped variable may be a proxy for farm size, and not safrinha intensity. A better variable to test the willingness to accept PHL might be the percentage of soybean hectares that undergo safrinha production.

## 2.6. CONCLUSION

Preventing loss and increasing food production are two feasible alternatives to meet the future worldwide demand for food. It is commonly thought that increased food production will result from loss prevention. Our results present a setting, not that unique, where this is not true. Farmers are rational profit maximizers and increasing PHL can be optimal in the case of double-crop systems in low latitude countries, where "time" is a critical variable and weather is uncertain. Safrinha production in Mato Grosso, latitude between 10 and 15 degrees South, planting soybean early so harvest can occur early, places harvest in the middle of the rainy season. Significant rain events are a daily concern, thus harvest is often interrupted and farmers must be very adept at having equipment in the right place at the right time to get the soybean crop out within a small window. Soybean harvest and post-harvest loss is a causality of trying to get a maize crop planted before February 25. Farmers accept soybean harvest loss in Brazil because "*The financial benefits to reduce losses during harvest and post-harvest on their farms are small"* and "*The economic benefits of double-cropping compensate the costs of soybean harvesting losses"*.

The limitation of this study is that we are not able to measure the costs and benefits in numerical terms. Though clearly indicated we cannot definitely prove that farmers who accept soybean loss to produce more corn generate more protein, energy, and oil per hectare of land. Such a measure is essential for important research on the factor productivity of land, especially as agricultural output between 15 degrees North and South shows great potential for expansion in the next 25 years. Thus, future studies should measure the amount of protein, starch, and oil produced on a hectare of land farmers are producing and the monetary cost and benefits when trading off loss for expanded grain production. The present study proves that farmers are rational profit maximizers and trade PHL for grain production but cannot specify the levels of the tradeoff.

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2.8. TABLES

**Table 9 Crop Progress in the center-west of Mato Grosso in Feb 25th**

| | Soybean Harvesting Progress | | Maize Planting Progress | |
|---|---|---|---|---|
| Season | Million hectares | % of total area | Million hectares | % of total area |
| 2008/2009 | 1.096 | 48% | 0.498 | 78% |
| 2009/2010 | 1.542 | 63% | 0.738 | 88% |
| 2010/2011 | 0.732 | 28% | 0.412 | 48% |
| 2011/2012 | 1.681 | 62% | 0.980 | 86% |
| 2012/2013 | 2.074 | 69% | 1.322 | 92% |

Source: IMEA

**Table 10 Categories of Acreage, Age and Education as Reported by Respondents**

| Total number of farmers | 94 |
|---|---|
| Item | Average |
| Acreage | |
| 2012 Crop year Soybeans Acreage | 2,247 |
| 2012 Crop year Corn Acreage | 1,097 |
| % of area double-cropped | 49% |
| Age (% of farmers with age of) | |
| < 40 years old | 50% |
| 41 to 60 years old | 48% |
| > 61 years old | 2% |
| Education (% of farmers with education) | |
| High School | 34% |
| College graduate | 72% |
| Graduate school | 1% |
| Risk Propensity | |
| Risk averse | 49% |
| Risk neutral or lover | 51% |

**Table 11 Opportunity cost on loss reduction**

| Days | Day/Month | Opportunity Cost in bags/ha | Opportunity Cost in US$/ha | Soybean Loss of 10% (US$/ha) |
|---|---|---|---|---|
| 1 | 25-Feb | 3.5 | 29 | 98.12 |
| 2 | 26-Feb | 7.0 | 59 | 98.12 |
| 3 | 27-Feb | 10.5 | 88 | 98.12 |
| 4 | 28-Feb | 14.0 | 117 | 98.12 |
| 5 | 1-Mar | 17.5 | 147 | 98.12 |
| 6 | 2-Mar | 21.0 | 176 | 98.12 |
| 7 | 3-Mar | 24.5 | 206 | 98.12 |
| 8 | 4-Mar | 28.0 | 235 | 98.12 |
| 9 | 5-Mar | 31.5 | 264 | 98.12 |
| 10 | 6-Mar | 35.0 | 294 | 98.12 |
| 11 | 7-Mar | 38.5 | 323 | 98.12 |
| 12 | 8-Mar | 42.0 | 352 | 98.12 |
| 13 | 9-Mar | 45.5 | 382 | 98.12 |
| 14 | 10-Mar | 49.0 | 411 | 98.12 |
| 15 | 11-Mar | 52.5 | 440 | 98.12 |

**Table 12 Responses to Question about Accepting soybean harvest loss**

| **Question**: In a scenario with good prices for soybeans and corn, the soybean harvesting is delayed due to weather. What statement would better represent your management decision? | % of respondents |
|---|---|
| I would increase soybean harvesting speed to plant corn as soon as possible | 6 |
| I would increase speed and take max 3% soybean losses during harvesting | 11 |
| I would increase speed and take max 5% soybean losses during harvesting | 25 |
| I would not increase speed and would take corn yield risk | 51 |

**Table 13 PHL attitude and Perception Individual Questions**

| Variable | Description of variable | Average | STD |
|---|---|---|---|
| *Postharvest Loss statements* | | | |
| PHL_1 | The manager and the employees from my farm are able to take good decisions and to manage harvesting efficiently | 3.85 | 0.90 |
| PHL_2 | I care about soybean losses during harvesting on my farm | 4.29 | 0.68 |
| PHL_3 | Farmers from my region care about soybean losses during harvesting on their farms | 3.59 | 0.85 |
| PHL_4 | The operators on my farm take care to avoid soybean harvest in losses | 3.68 | 0.89 |
| PHL_5 | Large scale-farms have larger losses due to lack of control from the manager | 3.71 | 1.13 |
| PHL_6 | Lack of training for operators in one important factor affecting PHL | 4.14 | 0.76 |
| PHL_7 | Farmers who have on-farm storage can better manage harvesting timing (including machinery speed), and thus | 4.23 | 0.89 |
| PHL_8 | Farmers who have on-farm storage are able to start harvesting earlier and have more time to plant the safrinha | 3.46 | 1.19 |
| PHL_9 | The difficulty to access loans to finance the construction of a storage is the main reason for why most farmers don't have it | 3.83 | 1.15 |
| *Double-Cropping statements* | | | |
| DC_1 | My concern about planting corn until the end of February affects the combine speed during the soybean harvesting | 3.35 | 1.22 |
| DC_2 | I anticipated the soybean desiccation in my farm in order to plant corn before the end of February in my farm | 3.19 | 1.26 |
| DC_3 | Farmers from my region have anticipated the soybean desiccation to plant corn before the end of February | 4.09 | 0.79 |
| DC_4 | Planting corn after the optimum planting window (until February 20th) has high yield risk | 4.09 | 0.86 |
| DC_5 | F_5: The cost to reduce harvesting and post-harvest losses affects my decision to not prioritize this issue | 2.78 | 0.99 |
| DC_6 | F_6: The financial benefits to reduce losses during harvesting and post-harvesting on my farm are small | 2.37 | 0.93 |
| DC_7 | F_7_: Soybean yield is higher in areas previously planted with safrinha | 3.58 | 1.10 |
| DC_8 | F_8: The economic benefits of double-cropping compensate the costs of soybean harvesting losses | 3.13 | 1.00 |
| DC_9 | F_9: The reduction of soybean post-harvest losses is an efficient strategy to increase food availability in the world | 3.53 | 1.01 |
| DC_10 | F_10: I increased the harvesting speed in my farm since I increased the safrinha acreage | 3.22 | 1.08 |

Scale 1 through 5, where 1 is "Strongly Disagree" and 5 is "Strongly Agree"

**Table 14 Factor Loading and Individual Cronbach's alpha**

| Factor number, factor name and associated items | Factor Loading | Cronbach's alpha |
|---|---|---|
| **Factor 1:** *The safrinha has affected the management of soybeans harvesting* | | 0.6954 |
| My concern about planting corn until the end of February affects the combine speed during the soybean harvesting | 0.656 | |
| I anticipated the soybean desiccation in my farm in order to plant corn before the end of February in my farm | 0.7722 | |
| Farmers from my region have anticipated the soybean desiccation to plant corn before the end of February | 0.6737 | |
| **Factor 2:** *My demand to reduce loss is weak* | | 0.5213 |
| Lack of training for operators in one important factor affecting PHL | -0.4495 | |
| The cost to reduce harvesting and post-harvest losses affects my decision to not prioritize this issue | 0.5206 | |
| The financial benefits to reduce losses during harvesting and post-harvesting on my farm are small | 0.7165 | |
| **Factor 3:** *My employees and I care about losses and we avoid it* | | 0.5866 |
| The manager and the employees from my farm are able to take good decisions and to manage harvesting efficiently | 0.4806 | |
| I care about soybean losses during harvesting on my farm | 0.594 | |
| The operators on my farm take care to avoid soybean harvest in losses | 0.6631 | |
| **Factor 4:** *The benefits of reducing loss are lower than the benefits of the safrinha* | | 0.5855 |
| The economic benefits of double-cropping compensate the costs of soybean harvesting losses | 0.6265 | |
| I increased the harvesting speed in my farm since I increased the safrinha acreage | 0.5245 | |

**Table 15 Results from Binary Logistic Regression with Weighted Factor Scores from Factor Analysis**

| | Regression | Marginal Effects |
|---|---|---|
| Factor 1 | 0.207 | 0.051 |
| | (0.542) | (0.542) |
| Factor 2 | **0.832*** | **0.207*** |
| | (0.091) | (0.091) |
| Factor 3 | -0.593 | -0.148 |
| | (0.232) | (0.231) |
| Factor 4 | **1.335***** | **0.333***** |
| | (0.008) | (0.009) |
| On-farm storage (dummy) | **1.833**** | **0.426***** |
| | (0.012) | (0.004) |
| Combine coefficient | -0.002 | -0.0006 |
| | (0.119) | (0.119) |
| Corn price | 0.239 | 0.059 |
| | (0.105) | (0.105) |
| Risk-lover (dummy) | **2.082***** | **0.476***** |
| | (0.005) | (0.001) |
| Postharvest-Losses | **0.065*** | **0.016**** |
| | (0.054) | (0.053) |
| Age | 0.1547 | 0.038 |
| | (0.589) | (0.589) |
| Education | 0.0234 | 0.006 |
| | (0.953) | (0.953) |
| Double-cropped area | -1.227 | -0.306 |
| | (0.363) | (0.363) |
| Constant | **-8.17*** | |
| | (0.08) | |
| Prob chi2 | **0.0002***** | |
| Chi-square[a] | 36.83 | |
| | (0.300) | |

**Table 16 Results from Binary Logistic Regression with the Highest Loading Item from Each of the Four Factors from Factor Analysis**

| | Regression | Marginal Effects |
|---|---|---|
| DC_2 | 0.189 | 0.047 |
| | (0.464) | (0.464) |
| DC_6 | **0.792**** | **0.197**** |
| | (0.043) | (0.043) |
| PHL_4 | 0.122 | 0.03 |
| | (0.725) | (0.726) |
| DC_8 | **0.852***** | **0.212***** |
| | (0.007) | (0.007) |
| On-farm storage (dummy) | **1.523**** | **0.363**** |
| | (0.026) | (0.014) |
| Combine coefficient | -0.001 | -0.0004 |
| | (0.307) | (0.306) |
| Corn price | **0.266*** | **0.066*** |
| | (0.062) | (0.063) |
| Risk-lover (dummy) | **1.581**** | **0.3734***** |
| | (0.019) | (0.009) |
| Postharvest-Loss | **0.084**** | **0.0209**** |
| | (0.018) | (0.017) |
| Age | 0.347 | 0.086 |
| | (0.22) | (0.219) |
| Education | 0.147 | 0.0367 |
| | (0.719) | (0.719) |
| Double-cropped area | -1.232 | -0.306 |
| | (0.357) | (0.356) |
| Constant | **-12.868***** | |
| | (0.004) | |
| Prob chi2 | **0.0003***** | |
| Pseudo R2 | 0.3196 | |
| Chi-square[a] | 36.27 | |
| | (0.413) | |

2.9. FIGURES

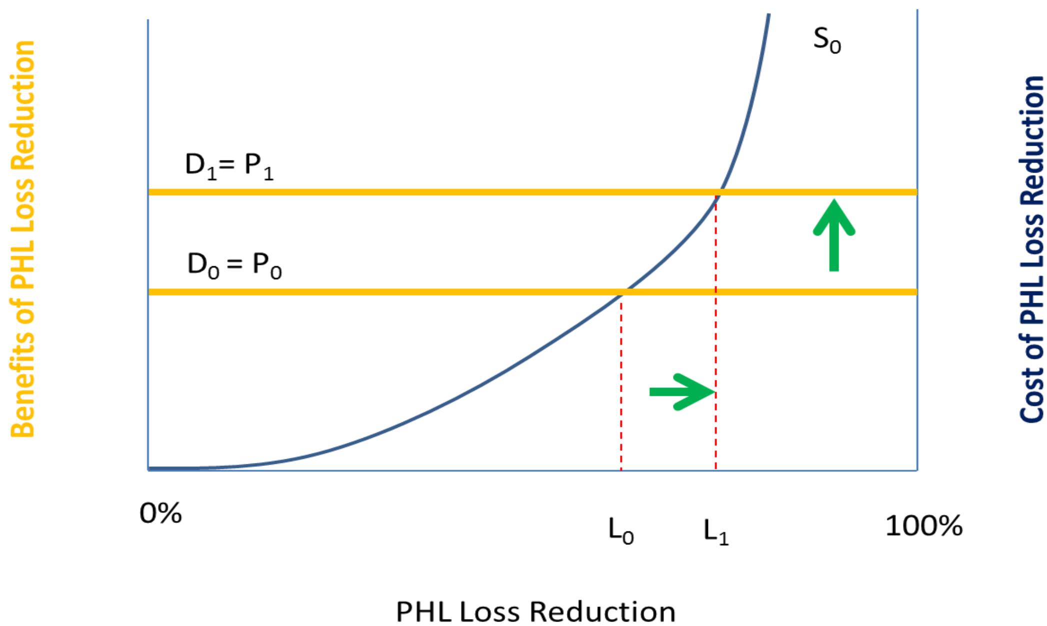



**Figure 2 Model of Farmer Behavior and PHL**

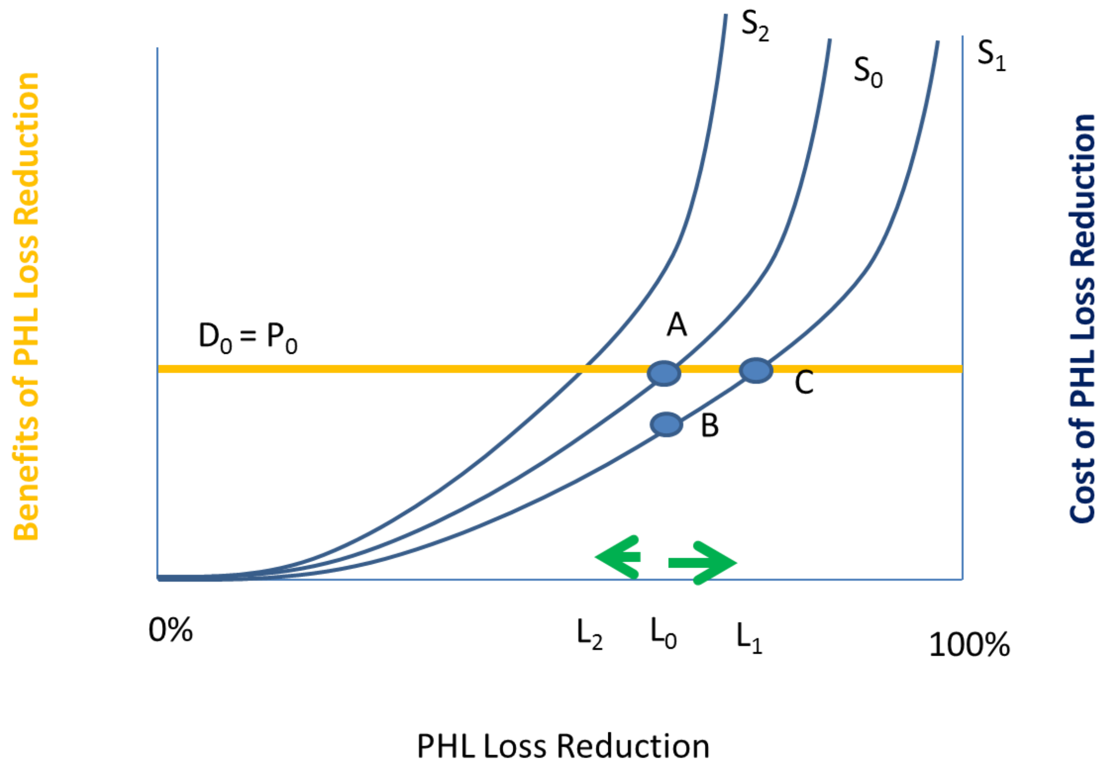
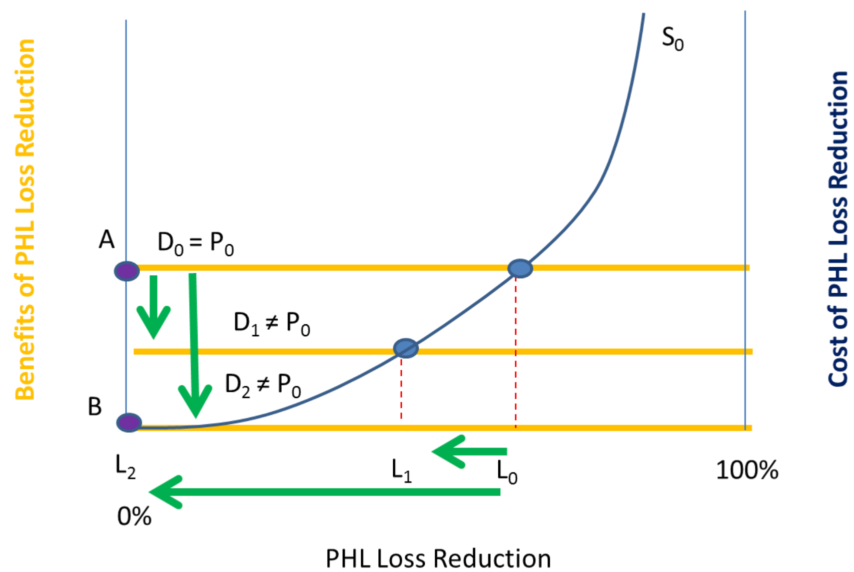



**Figure 3 Shifting the Supply Curve of Loss Mitigation**




Where: D = demand for loss mitigation, P = soybean price,
S = the supply of loss mitigation, L = equilibrium phl loss level

**Figure 4 Changes on the Demand Curve for Loss Mitigation**