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Managerial factors affecting post-harvest loss: the case of Mato Grosso Brazil

ANAMARIA GAUDENCIA MARTINS[1], PETER GOLDSMITH[2] and ALTAIR MOURA[3]

ABSTRACT

Increasing demand for food and rising grain prices makes grain loss and waste reduction a topic of great concern. A fundamental question exists: why would a manager permit losses? Unfortunately, the farm manager's role and understanding of harvest and post-harvest loss (PHL) are not well understood due to a lack of research. We argue that that policy makers and equipment manufacturers need to understand how grain loss reduction fits into the farm manager's 'problem', if efficient levels of loss reduction are to occur. We conduct semi structured interviews and a statewide online survey in Mato Grosso, Brazil to better understand the role of management in harvest and post-harvest loss. The survey results: help fill the important knowledge gap about the managerial component of post-harvest loss; provide insights into loss management among farmers running large modern operations in the fast growing tropical regions of the world; and show and explain the weak motivation to reduce current levels of PHL.

KEYWORDS: post-harvest loss; soybean; maize; tropics; management; Mato Grosso

1. Introduction

Agricultural production needs to increase at least 60% over the next four decades in order to meet the future demand for food (FAO 2009). The projections are grounded on a growing population that is expected to reach more than nine billion people in 2050. Prevention of postharvest losses (PHL) is a key component to meet this demand target (Harvey; 1978; Greeley; 1982; Greeley 1986; and U.N. 2011). Approximately 1/3 of the total annual food production fit for human consumption is lost every year worldwide (U.N., 2011).

We broadly define post-harvest loss as grain lost from harvest up until grain is sold to commercial buyers. More specifically for this research we define three stages of PHL: harvest; short haul; and storage. Harvest often relates to combine related losses short haul involves transport from the field to storage or the market; and storage losses are those losses occurring in on-farm storage.

2. Literature review

To date while there is an abundant literature on harvest and storage loss, there is little research on the manager's role in PHL. We argue that the interface between PHL relevant equipment and management needs to be a vital component of PHL loss reduction policy and private sector strategies. 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 labour inputs. This research fills an important gap in the PHL literature by providing a better understanding of farmer's perceptions of loss. The specific research questions are: what is a farmer's role in loss management and does measuring loss reduce loss.

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. 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 soybean production growth (MAPA, 2012). Located in the Brazilian savannah, 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 loss as a dominant new business model is the large-scale farm that operates in low latitude developing countries.

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[1] Department of Agricultural and Consumer Economics, University of Illinois, USA.
[2] Corresponding author. Department of Agricultural and Consumer Economics at the University of Illinois, USA. Email: pgoldsmi@illinois tel: 217-333-5131.
[3] Department of Rural Economy, Federal University of Vicosa, Brazil.

The small body of literature on the role of management in post-harvest loss centers in Asia and involves small holders. In such cases farming operations are less complex, may involve small scale irrigation, and at times, may be a subsistence activity (Basappa *et al.*, 2007; Begum *et al.*, 2012). Basavaraja *et al.* (2007) determine 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. Therefore we hypothesize the following:

H_o1: Younger farmers incur more loss.
H_o2: Better educated farmers incur less loss.

Soybean harvest losses mount in tropical settings because producers are torn by wanting to harvest early, but conditions may not be ideal and optimal care may not be possible (Roessing *et al*, 1981). Soybean harvesting loss was first estimated at 12% in Brazil in 1973 in the southern Rio Grande do Sul (see RS in Figure 1) (Dall'Agnol *et al.* 1973). Harvest loss in Brazil has been estimated to be 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 though sets the maximum acceptable level of harvest loss at 2.51% (EMBRAPA, 1999).

Magalhães *et al.* (2009) measure the quantitative losses of soybean by varying harvesting speed and machinery type in the state of Mato Grosso do Sul (see MS in Figure 1), and find that the differences in combine operating speed are not statistically significant. They conclude that loss is more a function of poor combine adjustment and maintenance of the grain cleaning system. They conclude that operator training and combine maintenance are important tools to reduce soybean loss. These conclusions are important because of the relatively high volume of labour employed on developing country soybean farms. Likewise, Campos *et al.* (2005) and Ferreira *et al.* (2007) also do not find significant differences in loss by varying combine 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 abruptly increase 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 harvest losses also increase with speed (Mesquita *et al.*, 2002).

There are in fact many causes for soybean harvest losses: uneven soil surface; seed quality; weeds; late

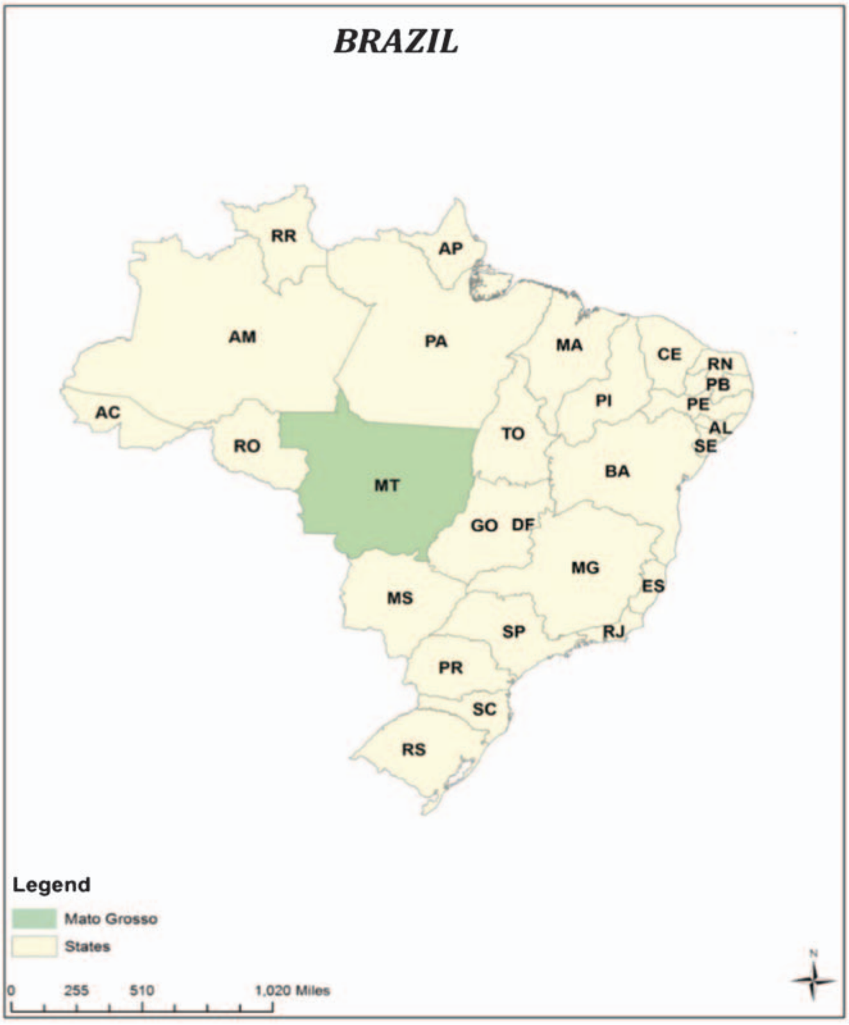

Figure 1: Map of Brazil

harvesting; soybean moisture during harvesting; bad machinery adjustment; 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, 2003). Franz *et al.* (2002) identify obsolete machinery and untrained operators as the main reasons for harvest losses of 3.71%. Therefore, we hypothesize that perceived losses are positively associated with; high harvest speeds, improper adjustment of the combine, poor maintenance, aged equipment, bad weather, pests and disease, poor seed quality, and uneven soil topography.

H_o3: Awareness of high harvest speed as a factor in loss results in lower levels of harvest loss.

H_o4: Awareness of improper adjustment of the combine as a factor in loss results in lower levels of harvest loss.

H_o5: Awareness of poor maintenance of the combine as a factor in loss results in lower levels of harvest loss.

H_o6: Awareness of aged equipment as a factor in loss results in lower levels of harvest loss.

H_o7: Awareness of bad weather as a factor in loss results in higher levels of harvest loss.

H_o8: Awareness of higher levels of pests and disease as a factor in loss results in lower levels of harvest loss.

H_o9: Awareness of poor seed quality as a factor in loss results in lower levels of harvest loss.

H_o10: Awareness of uneven soil topography as a factor in loss results in lower levels of harvest loss.

Identifying the technical causes and levels of harvest loss are difficult because accurate measurement is rare (Greeley, 1982). This is troubling because of the importance of measurement in the management literature (Porter, 2010; Kalkanci, *et al.* 2012) in support of the notion that you can't manage what you don't measure.

The question of measurement 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. Shay *et al.* (1993) emphasize that measuring losses might take only 10 minutes, and this attitude is essential to achieving satisfactory combine operation. But according to Greeley (1982):

"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, 1982, p.53).

Franz *et al.* (2002) provide the only evidence of Brazilian farmers measuring loss. They find that only 10% of Federal District farmers measure soybean loss. There is a lack of literature connecting the measurement of harvest loss by managers with the level of PHL. The lack of research on the importance of loss measurement stands at odds with analogous contexts such as environmental management. The prevention of a 'problem' requires first that farmers are aware in order then to act with environmental problems such as groundwater pollution or land degradation (Napier and Brown, 1993; Elnagheeb *et al*, 1995; Bayard and Jolly, 2007). In terms of postharvest losses, the awareness of the problem can be associated with the measurement of the loss. Therefore we hypothesize that farmers who actively measure harvest loss better understand the drivers of loss and are more willing to act to solve the problem.

H_o11: Farmers who measure loss achieve lower levels of loss.

Researchers in India identify farm labour 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 employ significant amounts of labour because of their size. Typical farms in Mato Grosso are hierarchical in their management as farm owners do not operate equipment, as is the custom in the United States. Thus owners in Mato Grosso choose between contractors and employees, when deciding who should operate equipment in the field. 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 when using contractors, 4.72% for contract harvesting against 2.92% per hectare when using their own machinery. Silva *et al.* (2002) find a similar result. Both studies reflect agency problems whereby contractors are more careless than employees or the owner-operator. Attention to loss and care in operation increases when farmers operate the combine (Campos, 2005).

These findings of higher harvest losses by contractors diverge from a seven-farmer focus group study we conducted in Mato Grosso prior to implementing our statewide survey on PHL. The focus group reveals three modes of combine operation in Mato Grosso, owner operation, contracting, and employees. The first two are rarely used in the large operations of Brazil because owners manage and do not operate equipment. Contractors find it difficult to assemble the capital necessary to provide high quality and timely service to a typical farm owner in Mato Grosso; especially given the scale of operations, large distances, poor network of roads, and weather uncertainty. Unlike harvesting in higher latitude regions, low latitude farmers often engage in succession cropping systems where a second crop is directly planted behind the harvest of the first crop. As a result farmers' demands on equipment, speed and operating flexibility limit the value or role of a contractor in such settings. Thus we hypothesize that though large farm owners may be more aware of PHL, larger farms incur greater losses due to dependence on hired labour, and scale diseconomies from operating a large organization under difficult conditions. We therefore hypothesize that using contractors is associated with lower losses, as the alternative of using less well trained employees would likely result in higher losses.

H_o12: Larger farms incur greater loss than smaller farms.

H_o13: Farmers who actively engage in contract harvesting incur lower PHL.

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. Farmers either move the grain themselves or often hire contract drivers who provide their own trucks. Historically there have been few studies on transportation losses in developing countries (National Academy of Science, 1978; Caneppele et al, 2012). This is especially true for short-haul loss. Short-haul loss is especially difficult to measure because scales are not present in the field to weigh grain prior to departure to storage or a commercial facility. Transportation losses may occur due to poor road conditions, improper truck maintenance, the type of truck body, overloading, inefficient transfer of grain, and negligent or inattentive drivers (Caneppele et al, 2012). These factors are consistent with the factors identified by our focus group farmers, and are hypothesized to be consistent with higher loss levels.

H_o14: Poor truck conditions results in higher levels of post-harvest loss.

H_o15: The lack of attention results in higher levels of post-harvest loss.

H_o16: An improper truck body results in higher levels of harvest post-loss.

H_o17: Awareness of overloading wagons and trucks as a factor in loss results in lower levels of post-harvest loss.

H_o18: Bad road conditions results in higher levels of post-harvest loss.

H_o19: Awareness of poor loading/unloading processes as a factor in loss results in lower levels of post- harvest loss.

On-farm storage serves as a major reducer of harvest loss (Strahan and Page, 2003; Nawi and Chen, 2007). Farmers are able to avoid unfavourable weather by harvesting the first crop earlier and at higher moisture levels (Abawi, 1993). Farmers have a larger window between succession crops when using storage as they can focus on harvesting and planting, and not getting grain to market (Strahan and Page, 2003). Therefore we hypothesize that farms with on-farm storage will incur lower losses.

H_o20: Farms with on-farm storage incur lower PHL.

3. Materials and Methods

We employed a three stage survey process. First, a focus group with 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 focus group we developed and tested a draft online survey instrument in November 2012. A final survey, with follow up, was emailed in December 2012 to 1,902 farmers listed in the database of the Mato Grosso Soybean and Corn Growers Association (Aprosoja).

Farmers in Mato Grosso had never before been surveyed online. They are also sporadic users of email, and do not use the Internet as their main source of information (Aprosoja, 2013). The response rate is low, 8.3% (158 observations with 94 usable), but important given the lack of research in the area, and the high quality of the sample. The sample is not representative though, 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 farmers in the world, and their perceptions about PHL are unknown. They are also the thought leaders for the industry and they operate in the largest and fastest growing corn and soybean state (Mato Grosso) in the world. The survey results have application to other high growth tropical regions such as Africa, other parts of Brazil and Latin America, and Southeast Asia, because respondents operate in a tropical region where expansion is occurring most rapidly.

The survey contains 32 questions divided into three sections. Part one asks farmers general information about the farm. Part two focuses on farmer's perception of PHL and the relationship between soybean harvest loss within a succession crop ('safrinha') production system. Finally the last section includes general questions about the respondent.

Male respondents comprise 97% of the responses, which is consistent with previous work that found women only manage 9% of the farms in Mato Grosso (IBGE, 2006). Regarding age, 50% of the respondents are younger than 40 years old, while 47% are between 40 and 60 years of age (Table 1). These age characteristics match an in-person survey conducted by Aprosoja of their membership, 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 (Aprosoja, 2011). In terms of education, 69% of the respondents have a bachelors or graduate degree. The sample from this survey does not represent the average education level of farmers from Mato Grosso. Numbers from the 2006 census show that only 3% of farmers have bachelors or graduate degrees.

Managerial questions were tested during the focus group study. From the semi-structured interviews, three managerial areas emerged as relevant to PHL: 1) whether farmers 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.

Among the respondents, 36% measure PHL. Despite being a small number in absolute terms, the level of measurement is a lot higher than previous findings where only 10% of the farmers in the Federal District of Brazil measure loss (Franz *et al.* 2002). 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*, 2002) may reflect the low value of the grain compared with a survey of farmers in 2012. The model includes measurement as 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 on their farms.

Table 1: Summary statistics of selected demographic, managerial and PHL variables

Total number of farmers	94
Number of measurers	34
Number of non-measurers	60
Average 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 (%)	
<40 years old	50%
41 to 60 years old	48%
>61 years old	2%
Education (% of farmers)	
High School	34%
College graduate	72%
Graduate school	1%
Soybean area (% of farmers)	
<500 ha	14%
500 to 1,000 ha	26%
>1,001 ha	61%
% of farmers with on-farm storage	34%
% of farmers contract harvesting	31%
Farmers Perception of factors affecting PHL (% of farmers):	
High operation speed	34%
Lack of adjustments at the platform when needed	36%
Bad weather conditions	57%
Bad truck conditions	62%

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. 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 29%.

There is relatively little on-farm storage in Mato Grosso; about 20% (Medeiros and Goldsmith, 2013). Our survey sample is biased towards larger operators who have higher levels of on-farm storage, as 34% of the producers from the sample have storage on their farms.

The survey asks farmers to estimate or state their harvest, short-haul, and storage losses. Special care was taken during the focus group and survey pre-test to clearly define the terms, 'harvest', 'short-haul,' and 'storage.' We test eight causes of harvest loss and six causes for short-haul loss. The respondents ranked causal factors in terms of importance on a scale of 1–8 for harvest loss and 1–6 for short-haul loss. 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 stated levels of post-harvest losses as:

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

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

Correlation analysis identifies low levels of correlation among the 14 hypothesized causal factors of harvest and short-haul loss (Tables 2 and 3). All variables with a correlation above .30 were dropped. Thus we drop maintenance (H_o5), seed quality (H_o9), soil (H_o10), and the body of the truck (H_o16). Then a series of reduced form models were compared in an attempt to balance model performance with analytical scope, as degrees of freedom were a limiting factor due to our small sample. Six additional variables were eliminated without reducing the performance of the model: aged equipment (H_o6); natural causes (H_o8); attention (H_o15); overloading (H_o17); road conditions (H_o18); and loading problems (H_o19). The final multivariate linear regression model contains ten variables, three demographic, three managerial; and four causal.

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

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 measures loss;

Table 2: Correlation coefficients among 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 3: Correlation coefficients among 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

- Contracting is a dummy variable taking value of 1 when the producer outsources part of his/her 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 on-farm loss;
- Adjustment is a dummy variable taking value of 1 when the respondent considers that lack of adjustments as an important factor (survey response of 6, 7 or 8) affecting on-farm loss;
- 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 on-farm loss;
- 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 short-haul loss.

4. Results

The research employs several tests, both parametric and non-parametric, to better understand farmers' perceptions of post-harvest loss. There is moderate consensus as to the causal factors affecting loss as over 70% of the respondents score poor attention to maintenance and bad weather as important causes of post-harvest loss (Table 4). Producers can effect maintenance but have no control over the weather. Interestingly only 60% state that harvest speed is an important factor in harvest loss. This is consistent with the literature, which is mixed with respect to speed being a cause of loss. Also 60% feel that natural causes from insects and other pests are **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, 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.

The Y intercept of 7.18 from the results of the multiple regression model represents the baseline perceived level of harvest and short-haul loss of soybeans for farmers in Mato Grosso (Table 5). The coefficient is significant at the 10% level and it is similar in level to the findings of previous studies conducted in Brazil. Farmers therefore may actually have a proper understanding of the level of loss, or that such loss levels may be 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. The average stated harvest loss is 5.68% and the sort-haul loss is 2.24%, yet the standard deviations are high, 12.6% and 5.1%, respectively. So there does not appear to be common knowledge as to standard loss levels. Second, on-farm measurement by management of loss does occur. A third of farmers do measure loss thus incorporate loss management into their operations.

Third, semi-structured interviews, both with farmers and executives within the corn and soybean association, reveal an understanding that loss is an issue. They note that there is little experience either measuring or documenting the phenomenon of loss. Thus PHL appears to be a relatively new management issue of concern, albeit mild.

Parametrically there is not a statistical difference between those farmers who state that they measure their PHL and those that don't as the coefficient is not significant at the .10 level. Thus our results do not support $H_o 11$ that farmers who actively measure PHL achieve lower levels of loss. The positive sign on the coefficient may imply that those that do not measure may underestimate their loss levels. The non-parametric analysis too does not clearly differentiate between

Table 4: Factors affecting harvest and short-haul Loss

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).

measurers and non-measurers. Analysis across the 14 causal variables shows that only the awareness that the use of old combine technology increases harvest loss, and the lack of attention from drivers leads to high short haul loss differentiates those that measure PHL from those that don't (Table 6). Thus those that measure PHL do not think differently about the causes of loss than those who don't measure.

The coefficient age shows a negative relation with PHL, meaning that the older is the farmer the lower is on-farm loss. This result is consistent with Basavaraja *et al* (2007) and Begum *et al.* (2012). The coefficient though for education was not significant. It was hypothesized that with more education leads to less loss. Our sample is relatively highly educated.

Farmers who have on-farm storage achieve lower post-harvest losses, as expected. The coefficient of −2.71 is significant at the 10% level. This is an important finding for future policies promoting the installation of on-farm storage in Mato Grosso as PHL reduction will be one key benefit. Recent research has indicated a significant shortage of private storage in Mato Grosso (Medeiros and Goldsmith, 2013).

The coefficient for farmers who employ contracting for their harvest operations is positive but not significant. Thus H_o13 is not confirmed; that those that engage in contracting have lower levels of loss. Thus substituting professional combine operators appears to have no effect on loss. The result 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. Implementation of a more professional workforce in the form of specialized contactors will not result in lower loss levels in Mato Grosso. Therefore, focusing on training and improved

Table 5: Estimated determinants of loss

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

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

Table 6: 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	0.00	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	0.50	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	0.50	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 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.

incentive structures for employees would be more effective for reducing PHL.

Awareness of the connection between high harvesting speed and loss is found to be significant at the .05 level and negatively related to the level of postharvest losses. Therefore farmers who consider that harvesting speed is an important factor affecting harvesting losses achieve lower levels of loss compared to those farmers who do not consider speed to be an important factor.

This would appear to confirm H_o3 that farmers that are more aware of the speed problem are able to reduce their losses, and stands contrary to research denying the linkage between speed and loss.

Similarly the awareness of the importance of combine adjustment for reducing loss is significant at the .05 level and the coefficient has a negative sign. This result not only confirms the hypothesis (H_o4) as to the importance of adjustment awareness for reducing loss, but also supports the general idea that producer awareness of the drivers of loss is an effective loss reduction policy approach. Attentiveness to the role of speed and proper combine adjustment seems to help reduce loss, while having farmers actually measure loss appears to be less important. Speed and equipment maintenance appear to be important areas of focus for training employees and for equipment manufacturers.

Bad weather condition is positively and significantly related at the .01 significance level with loss. Farmers who believe that weather is an important factor affecting PHL incur higher levels of loss. The correlation between weather and speed is quite low, only 0.07. Similarly the correlation between weather versus Operator Attention is also low, 0.20. Farmers have responsibility for harvest speed and operator attention, but do not control the weather. Farmers who cite 'controlled factors' as more important causes than 'non-control factors' achieve lower levels of loss. Therefore farmers that identify management as a way to reduce PHL, are more active in PHL reduction, and as a result incur lower levels of loss. So while PHL reduction is clearly not a high priority for managers, it is a management issue and will respond to policy and industry efforts in support of management oriented approaches to loss reduction.

Finally, as stated above, there is weak consensus as to the causes of short-haul loss. The short haul variables perform poorly in the model, thus many were dropped. Truck condition is the only short-haul variable tested. The positive sign is as hypothesized but the coefficient is not statistically significant. The weak results are puzzling as short-haul loss is known and literally quite visible along farm and rural loads. But there is no research on the topic, as admittedly it is difficult to conduct.

5. Discussion

The specific research questions are:

- What is a farmer's role in loss management?
- Does measuring loss reduce loss?

Implicitly though we ask whether PHL is important to farmers. Clearly the global community cares about PHL, and its reduction. But unexplained is why a farmer accepts controllable loss. Addressing the loss acceptance question would benefit from further research.

The sample is fairly homogeneous and reflects a well-educated and successful set of farmers. The lack of power in the model may better indicate a lack of managerial focus or criticality of PHL to farmers. We posit that challenges of quickly harvesting large tracts of land with extensive weather uncertainly, and heavy use of labour trump attention to PHL levels in the 10% range. Clearly not all loss is measurable, i.e. short-haul, thus remains an abstraction. Also not all loss is controllable, i.e. weather, thus some sources of loss are not a domain of management. The cost of reducing loss further, using current technology, may exceed the benefits. Similarly, the weak results of the model might indicate to policy makers and equipment manufacturers that farmer willingness to pay or invest in loss reduction may be weak. Low cost investments might be acceptable, but specific capital expenditures or those incurring additional labour allocations might involve costs that exceed benefits.

About the authors

Dr. Peter Goldsmith is an associate professor in the Department of Agricultural and Consumer Economics at the University of Illinois. He directs the University's Food and Agribusiness program and is the Executive Editor of the *International Food and Agribusiness Management Review*. He also serves as the principal investigator of USAID's new $25m Soybean Innovation Lab, focusing on soybean research and development in developing country settings.

Dr. Altair Dias de Moura is an Associate Professor in the Agricultural Economics Department, Federal University of Viçosa (Brazil). He is an agronomist, with masters in Agricultural Economics and Ph.D. in Agribusiness Management (Lincoln University - New Zealand). He focus on farm and agribusiness management, and specifically addresses questions in value chain coordination and inter-firm relationships, supply chain management, farm business planning, and project management.

Ms. Anamaria Gaudencio Martins is an economist who spent most of her career working with, and for, farmers and supporting the dynamic agribusiness development in Brazil. She received her Master's degree from the University of Illinois in 2013, and immediately joined the agricultural research team at Lanworth/Thomson Reuters in Chicago. Ms. Martins now brings her field expertise to forecast grain supply and demand worldwide.

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