METROLOGICAL UNCERTAINTY IN AGRICULTURE MEASURING EQUIPMENT

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Abstract: It was checked five enterprises from agriculture business in Mato Grosso State assessing the uncertainty in the controls of productivity, humidity and temperature through information from harvesters equipped with productivity sensors supported by GPS, weigh of grain harvest per area, electric humidity control, difference of weight from dry and humid grain and thermometers respectively. The result of this research is a preliminary evaluation of measurement uncertainty and proposes recommendations for calibration and adjustment for that equipment.

Keywords: agriculture, uncertainty, harvester, calibration.

1. INTRODUCTION

Investments in agriculture in Mato Grosso are growing fast according to Aprosoja [1]. Growth of Soybean planting is significant. Harvested in 2010 were 20.6% higher than 2009, with a yield (tons harvested per hectare planted) 12.1% higher, according to IBGE [2]. This not only demonstrates the strong investment in scaling, but also in improving technology to agriculture.

New cultivation techniques, soil care, fertilizers and pesticides has been studied and widely used.

In recent years the investment in agriculture technology also is allied to mechanical technology investments. Nowadays the grain harvesters are provided with sensors to count the grain yield in harvested area and humidity sensor. Coupled with area mapping taken by GPS technology it is possible to assess which area has a higher or lower productivity, allowing the farmer to set specific corrective actions according to the results presented, which is known as agriculture precision.

Soybeans should be stored in warehouses specially prepared for this purpose, avoiding variations in humidity, temperature and contamination by impurities. When the need for bagging soybeans, this should be selected as its size and then must be dry enough to meet commercial standards involving this sector. Thus, humidity control and temperature must be accurate [5] enough to keep the product within the standards.

During the investigation, it was possible to detect that the farms, owners of such technology, has not knowledge and their equipment are not capable of evaluating the accuracy of such measurements [5], i.e. they may be taking incorrect decisions from untrusted data.

In most cases it was noted that farmers acquire the equipment, in this case harvesters, balances and thermometers, and conduct their work in accordance with the conditions in which the machines are, without any care for the assessments the sensors measuring machines quality presents. When these machines come in maintenance, are analyzed and adjusted for mechanical parts such as knives and mats, but it is not observed any maintenance for their ability to accurately measure and the sensors are not calibrated [5].

The objective of this research is to complete an assessment of measurement performed by enterprises from agriculture business and proposes recommendations for calibration and adjustment for the equipment to controlling productivity, humidity and temperature.

2. RESEARCH METHODOLOGY

It was investigated five enterprises form agriculture business located in northern and south of Mato Grosso State intentionally chosen for its size and update of grain harvesting machinery, humidity equipment and temperature control.

This investigation characterization was a case study [3], and has not objectivities of statistics evidences, where the emphasis will be in-depth analysis of complex matters involving the object of research, as well as their interference.

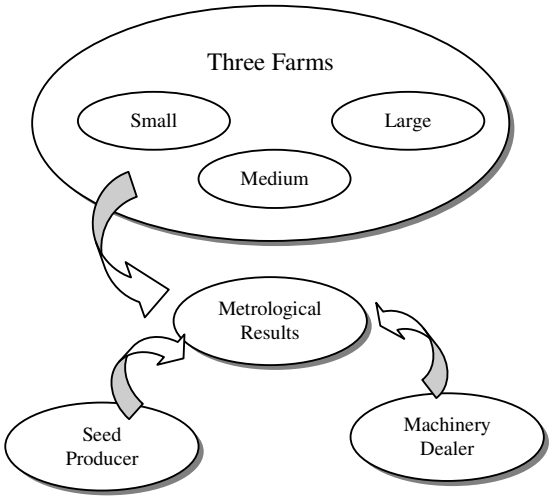
The secondary data [4] will be based on historical productivity measured in tons of grain harvested per hectare and the primary data [4] are those related to evidence taken from the measurements of humidity, temperature and evaluation of the capacity of measurement from the machines.

Considering the hypothesis that the equipment presents measurements errors beyond acceptable, this work is premised establish recommendations for calibration and adjustment for that equipment.

3. MEASUREMENT EVALUATION

The five companies from agriculture business surveyed were selected as follows: three farms producing soybeans, planting, harvest, store and sell; a soybeans seeds producer,

planting, harvest, dry, selected by size, controls, benefits and bags and a farm machinery dealer who sells, makes maintenance and support for farmers



The three farms surveyed plant and harvest grains, and the research was focused on growing and harvesting of soybeans. The farms were selected according to their size, so that research could determine the method of evaluation of productivity, humidity and temperature in different types of farms.

The seeds producer do plant, benefits and packages the grains, where the focus was also soybean seeds. It was chosen because it is a benchmark in the market and indicated by the soybean producers for having metrological equipment that would not be found in any other grain-producing farm.

The dealer of agricultural machinery carries out maintenance on the machines used to harvest soybeans and sensors that have been targets of research. It was chosen because, as will be shown below, the producer does not own technology for adjust and calibration of measuring equipment installed on the harvesters, which is the dealer responsibility.

3.1. Large Size Farm

The first company studied is located in the northern of Mato Grosso State, one of the largest farms producing soybeans in the world. The researched unit has approximately 200,000 hectares of soybeans planted. The farm has state of the art machinery, and the agricultural machinery manufacturer sends their most advanced products for testing at the farm, because their high demands for machines and importance as big world player.

At the visit beginning we were greeted by the farm manager, who explained the whole process, from planting to harvest. The harvester has a sensor that measures the amount of harvested grain. This measurement is collected by a computerized system, and the machine location is controlled by GPS. As the traditional GPS system does not have sufficient accuracy (around 1.0 m) to perform an expected control of productivity (bags per hectare) of the soybean crop the farm has installed a proper system of GPS (satellite) as a great investment to make a location accuracy of about 5.0 cm.

Their purpose of having so accurate localization process is to able to reap the grain with greater use of the platform (front of the harvester that effectively comes into contact and cut the soy plants) which would be impossible by machine hand control, so the harvester moves automatically.

This technological apparatus allows the producer to know how many beans are harvested per hectare, crossing the location information obtained from the GPS and information obtained from the productivity sensor (which assesses how many grains are harvested). In this way the farm can evaluate the productivity (bags per hectare) in each part of the plot (standard size area with planting and harvesting) and then can plan the most appropriate corrections to the ground.

Considering the GPS calibration, the farm manager explained that the company specializes in the system installation makes an assessment in the equipment each season beginning and precedes the necessary calibration and adjustments.

Concerning the productivity sensor, was informed that the machinery is supply from dealer in perfect condition. It is supposes that the sensor is calibrated from the factory but the machine has not sensor calibration certificate.

The machines are sent to maintenance in each beginning of season. As there is a very large amount of agricultural machinery, the supplier installed a workshop within the farm, and there is a trade agreement defining the responsibilities. The farm provides the facilities and the dealer provides the manpower trained and parts to be replaced but the farm manager has no information about calibration and adjustment of productivity sensor.

Grain humidity must be checked to determine whether the crop can be started. If the humidity is very high (above 21%), the grains are likely to crush during the harvest and also there will be a high cost of drying grain to achieve the humidity for sale (14% maximum).

To evaluate the grain humidity in the field the producer own data from the harvester, harvesting a small area and observing the data of the humidity sensor of the machine. The calibration, repair and adjustment of humidity sensors follow the same pattern of productivity sensor: is made by the dealer and not informed to the farm manager.

After harvesting the grain passes through a dryer to achieve the maximum humidity for sale. During drying the humidity is controlled by sampling grain from the silo. This sample is weighed and dried in an oven, and the difference in weight shows the humidity of the grain. The balance is not calibrated.

Once it reaches the right humidity the grain is transported for storage. During storage the grain should be kept to a standard temperature and humidity to not deteriorate, being held from 27 to 35 °C. There is a thermometer in the storage bin to check that temperature. The thermometer is not calibrated.

To sale, the humidity is checked again by difference of weigh humid and dry. The grain must have maximum 14% of humidity, otherwise the grain should being dried again and this generates a high cost. Another possibility is to

negotiate to the buyer a price discount due to excessive humidity.

In summary, from the perspective of metrological evaluation control the large farm has the characteristics described in Table 01

Table 1. Metrological Evaluation - Large Size Farm

Characteristic	Using Equipment	Calibration
Productivity Evaluation	Productivity Sensor	By the harvester dealer
Humidity Control	Humidity Sensor	By the harvester dealer
Temperature Control	Thermometer	Not done

3.2. Medium Size Farm

The second company visited was a medium size farm with approximately 1,000 hectares of planted area located in the southern of Mato Grosso State. The farm has four harvesters older model with approximately 10 years of usage, which do not have computerized systems and only one that despite having a computerized system, was not acquired with the sensors of productivity and humidity.

To evaluate the productivity is harvest a plot and it is performed the weighing of a truck empty and full, and productivity (bags per hectare) is calculated by the amount of soybeans harvested per area. The weighting scale is calibrated annually by IMEQ-MT. Using the more modern machine, there is some confidence in the measurement of planted area, but the owner has no odometer calibration certificate of the harvester or other form of proof of error for measuring the area under cultivation for this evaluation.

The farm has an electronic humidity meter, so a sample prior to harvest of soybeans are removed manually and passed this equipment that is portable. If the humidity is above 21% then the harvest is not performed to avoid excessive losses and extra costs by crushing and by the drying process.

After harvesting the beans pass through the dryer and are stored in silos. There is other electronic humidity measurement equipment in the farm's laboratory. In this case, the equipment, as reported, is more accurate and used to measure the humidity of the grain before the sale. There is a limit of humidity in the trade agreement accepted and therefore the need to take extra care in measuring the humidity before sale. This device has no record of calibration and no other method of measurement errors analysis. The farm's owner affirms to rely on the equipment because historically never had major problems with difference of humidity evaluated by the buyer.

While the beans are stored should be kept in a controlled temperature to avoid getting humidity and may deteriorate. The used thermometer is stuck in the middle of stored grain. Three times a day the temperature is controlled, if it is too low or too high (which can also damage the soybeans) is then turned on a ventilation system, cold or hot, depending on needs.

The thermometer is replaced each new season, because it suffers external damage when loading and unloading of grain in the silo. There is no register of calibration certificate for this thermometer or another way to evaluate their measurement errors.

Table 2. Metrological Evaluation - Medium Size Farm

Characteristic	Using Equipment	Calibration
Productivity Evaluation	Truck weighting	Only balance by IMEQ-MT
Humidity Control	Electronic Humidity Control	Not done
Temperature Control	Thermometer	Not done

3.3. Small Size Farm

The third company investigated was a small farm by the standards of the state of Mato Grosso, with 250 hectares of planted area. We were met by the owner who showed us the entire process, from the seed to harvest and care of equipment and products. There are two harvesters approximately 20 years usage. These machines have neither humidity nor productivity sensors.

To evaluate the productivity is harvest a plot and it is performed the weighing of a truck empty and full, and productivity (bags per hectare) is calculated by the amount of soybeans harvested per area. The weighting scale is calibrated annually by IMEQ-MT. Different of Medium size Farm there are no odometer in the harvester then it is used a normal car to evaluate the crop area that has less confidence then the harvester.

Before the harvest the farmer must make the measurement of humidity from the soybeans planted in order to avoid excessive costs to the drying and also to avoid crushing losses during harvest. This measurement is accomplished by difference of weight of the amount of soybeans harvested by hand and dried in an oven.

However, in practice, the producer is assessing the grain humidity before harvesting by sensory observation (crushing the beans with their fingers) because of their extensive experience developed over 20 years planting soybeans.

After harvesting, the grain passes through a dryer. The owner does not usually assess the humidity during or after the dry grain. It was developed the drying process over the years of work and the evaluation of the humidity is held in a sensory observation.

The grain is stored in a warehouse (instead of a silo) and has no temperature control. The stock turning is high, ie, the grain is not stored too long time to absorb humidity from the air. According to the farm's owner, after the grain is dry, the absorption of humidity is negligible.

The grain buyer is responsible for collecting the material on the farm. The truck is loaded and weighted on the farm. Upon arriving at the warehouse of the buyer, the grain humidity is evaluated by means of differential weighing before and after a sample is dried in an oven. The amount of humidity in excess of 14% is deducted from the amount to be paid to the producer

Asked about the possibility of difference of humidity in the upper region of the truck load (which is more in contact with moist air), the producer said that the setting is performed with a device that collects the grain in the middle of the load at various regions, to obtain a sample more homogeneous from the product.

Table 3. Metrological Evaluation - Small Size Farm

Characteristic	Using Equipment	Calibration
Productivity Evaluation	Truck weighting	Only balance by IMEQ-MT
Humidity Control	difference of weigh humid and dry	Not done
Temperature Control	Not done	Not done

3.4. Seed Producer

The fourth company visited is a farm that produces soybeans that are sold to producers with the purpose of planting. This is one of the largest seed producers in the world, with approximately 200,000 hectares. In the visited unity there are processes of planting, harvesting, drying, processing and packaging of seeds that are sold in bags of 25 Kg

The farm is divided into two areas: production and processing. The first initiates in planting, through harvesting to delivery in the industry and the second begin with the receipt of the seed, through drying, cleaning, sorting, processing, bagging, storage and delivery.

The focus of the visit was the industrialization process of the seed. As explained by the industrial manager the truck that comes from harvesting deposits the grain in a hopper. The beans are transported by conveyor to the drying silos. This unit has 21 silos with a capacity of approximately 125 m^3 each. Unlike the care the producers have on the humidity of the grain in the process of industrialization the humidity will influence all subsequent proceedings in this way humidity control is a very important step for the company.

Thus, the humidity is controlled in each silo drying quite accurately. Every hour an employee does setting the grain in the silo openings those are distributed every 2 m along its height. The beans are collected and investigated its humidity through an electronic humidity device checking. The process is fast, taking less than 10 seconds.

As informed by the manager, there is a counter measurement of humidity held by difference of weight from a sample humid and dry. The weight scale is calibrated. The variation of humidity is observed and differences were considered non-standard are investigated.

The plant manager worked on the measuring verification of the equipment for humidity control. He noted that the results were far ranging and began to distrust the uncertainty of the equipment. Thus, a study conducted as follows: samples collected at different humidity in ranging from 15% to 25% with 2% increase in scale (15%, 17%, etc.). After the measurement performed with the electronic measuring equipment the same sample was measured by weight difference in dry and humidity grain. It was confirmed that there was a discrepancy in measurements. Thus, the equipment was adjusted to the results found by weight difference.

Another alteration observed was the result of humidity throughout the drying process. Sometimes the humidity, which should have a continuous fall during the drying process varied unexpectedly.

By a process of research, industry manager noted that the collection of grain in the silo was not being done correctly. Therefore, invented and installed an automatic system for collecting grains in the silo, using pipes with windows drive by a pneumatic system. This system was 12 months in test to ensure its efficiency, being compared with liming manual. Several adjustments were needed as the window opening time for collection as the inclines of the collection pipe that sits inside the silo.

The plant manager has developed a database for record keeping of humidity in and out of the silo for each batch of harvested grain, objecting actions of corrections in the process, such as adjusting the burners, maintenance and monitoring process costs.

After drying the grains pass through sieves for size selection. This is accomplished in several steps and the refinement of that selection is progressive. Control the size of the screens is performed after the acquisition and maintenance is only performed as the broken crates, with no other verification of loss of ability to select the beans properly. The grain size is an important factor in the process because the planter machine requires an appropriate grain size for your process. In the case of small grains the machine will deposit more than one seed in each hole, in the case of large grains the machine will not be able to drag and the pit will be left without a seed.

Finally, the grains separated by size and clean are directed to the improvement, where they receive a layer of organic material to acquire a spherical shape, correcting variations in shape and also size. This process also protects the grain during the planting process and facilitates germination. It was not possible to follow the process of processing the grain, because it is a trade secret of the company, a leading national market.

The latter process is bagging. There is a weight scale, controlled by IMEQ-MT. Commercial agreements concerning bag weight demands a straight control and monitoring of the weight scale. The seed producer has a standard weight and calibrates the weight scale each one hour. If necessary, adjustments are made and bags are weighted again.

Table 4. Metrological Evaluation - Seeds Producer

Characteristic	Using Equipment	Calibration
Humidity Control	Electronic Humidity Control	difference of weigh humid and dry
Seed Size	Strainer	Not done
Bags weight	Weight Scale	IMEQ-MT Standard Weight

3.5. Farm Machinery Dealer

The fifth company studied was a dealer of agricultural machinery. The aim was to study the details of the process control and calibration of productivity and humidity sensors of the harvesters. The farms surveyed understand that the entire analysis adjustment and calibration of sensors of the harvesters are left to the manufacturer, in this case, the dealer.

In Large farm investigated, despite the maintenance of the machines is held at the farm, manpower and replacing parts are responsibility of dealer. On Medium and Small size farm, these sensors are not used because the machines do not own this technology. In seeds producer the harvest process was not the focus of the research.

We were greeted by the dealer manager and forwarded to the maintenance sector. Who served us was the maintenance supervisor who explained the whole process, from the arrival of the machine, through the process of analysis and maintenance to deliver the machine to the farmer. Most of Big and Medium Size farms send their harvesters to maintenance at dealer as informed.

Asked about the sensors, the supervisor informed us that are factory calibrated, but does not know of the existence of calibration certificates or any accuracy test.

Concerning the maintenance of sensors, he explained that if it does not work it is replaced firstly the reading software that is part of the whole electronic control of the harvester. If keeps lack of functioning, then it is replaced the machine sensor.

The productivity sensor is located on the grain passage from the platform (front of the machine that pulls the soybeans plants) for the machine bean container. The supervisor did not know the accuracy of the equipment.

4. CONCLUSION

The summary results of evaluations of this case study and metrological recommendations are below.

4.1. Productivity

Evaluation: productivity sensor installed in harvesters has no control of uncertainty. The method of weighing the plot does not analyze the productivity in each area, preventing the taking of corrective actions most suitable soil and has not accuracy of measurement of crop area.

Recommendations: the manufacturer shall require to dealer to evaluating the uncertainty of productivity sensor in the purchase and maintenance carried out after the machine, which usually occurs before a new harvest. In the method of weighing of grain harvested per plot will continue to be used because many producers can not invest in more modern equipment, however, it is recommended to measure the perimeter with a controlled instrument.

4.2. Humidity

Evaluation: Humidity sensor installed in harvesters has no control of uncertainty. The control method of difference weight of dry and wet grain is the most accurate, since the weight scale used is calibrated, however, this method takes a long time leading producer to not use it. The electronic humidity meter has assessment of uncertainty provided by the manufacturer.

Recommendations: the producer should require the humidity sensor uncertainty measurement evaluation from the dealer in the purchase and after maintenance. In the control method of difference weight of dry and wet grain must be careful to control the measurement uncertainty of the scale. The electronic control of humidity can be calibrated by comparison with the weight difference method of wet and dry grain that is more accurate.

4.3. Temperature

Evaluation: The temperature is a very important characteristic not only to keep the humidity in the grain, but also because of his integrity. Case studies have shown that in most cases there is no care in control of uncertainties in temperature measurement.

Recommendations: To use a calibrated thermometer and check the measurement uncertainties before each new crop or substitution of the silo contents.

4.4. General Conclusion

There is not much knowledge about metrology controlling systems applied to farm machinery. In most cases investigated, evaluation and adjustment of measuring instruments used to support decisions related to farming is done by the manufacturer before selling and was not found another way to adjust or control these instruments measurement during their use.

It is interesting to note that respondents understand the importance of metrological controls for the outcome of their business, however, has they have no knowledge or technological capabilities that help them to discern about the mistakes may be made by measurements taken incorrectly.

Agricultural productivity data involving government actions are linked in data analysis and producers who do not have the right tools of measurement.

Although no statistical evidence, this study may serve as a warning to more focused actions in the agricultural industry in the expansion of knowledge and control of metrological instruments involved in this significant sector of Brazil's economy.

4.5. Research Continuation

As a suggestion, the continuation of this research can be performed by auditing harvester factory process to check the calibration of the sensors during installation.

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