THE ADM INSTITUTE FOR THE PREVENTION OF POSTHARVEST LOSS

Periodic Report

About this issue:

°The ADM Institute at the University of Illinois in partnership with InnovoSoy has released projections on post-harvest loss of rice in India in 2030.

°University of Illinois engineers study PHL to identify gaps in existing PHL research and ways to reduce PHL.

°Elevated levels of carbon dioxide (CO^2) in storage bins contribute to PHL. A team of UI engineers are developing a low-cost laser-powered fiber optic sensor designed to measure levels of CO^2 in grain storage bins.

Inside this issue:

Postharvest Loss in 3D

The ADM Institute for the Prevention of Post-harvest Loss has commissioned InnovoSoy to combine animation and visualization to document and visualize trends in PHL.

InnovoSoy: Cutting Edge, Powerful Data Visualization

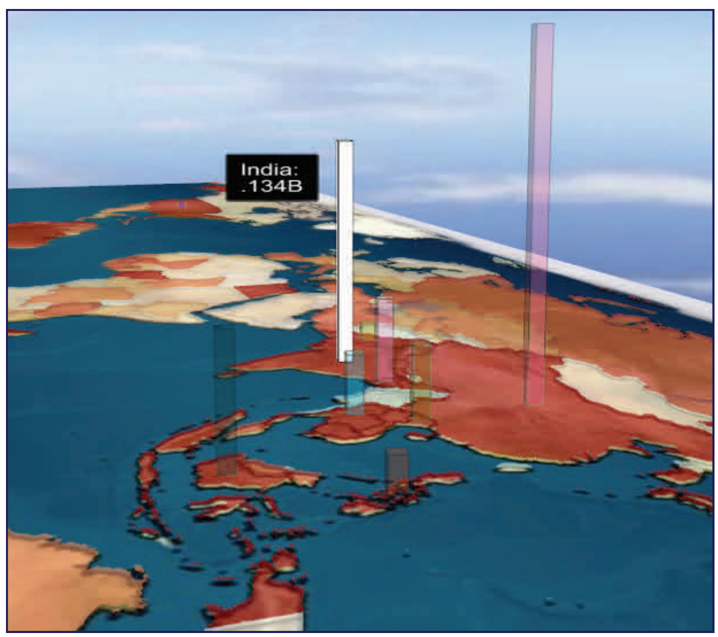
InnovoSoy uses innovative technology to display data three - dimensionally. Using econometric and visualization tools, the company's proprietary software (Global 3D Loss) analyzes data and forecasts trends in PHL. The resulting visual aid rivals video game graphics while presenting content rich, analytic and predictive data.

InnovoSoy's technology is designed to explore and examine the relationships between production and consumption worldwide, income elasticities for different commodities cross regions, growth trends and net changes in production and consumption, and more.

Global 3D Loss and Postharvest Loss

This technology has great implications for PHL. Looking at future trends for rice in India, for example, we can anticipate the future dynamics of PHL.

In 2009, India was the second largest producer of rice in the world (see image below). Rice consumption is culturally very important to many segments of the Indian populace.



India was the second leading producer of rice in 2009. (source: InnovoSoy)

Postharvest Loss in 3D (continued)

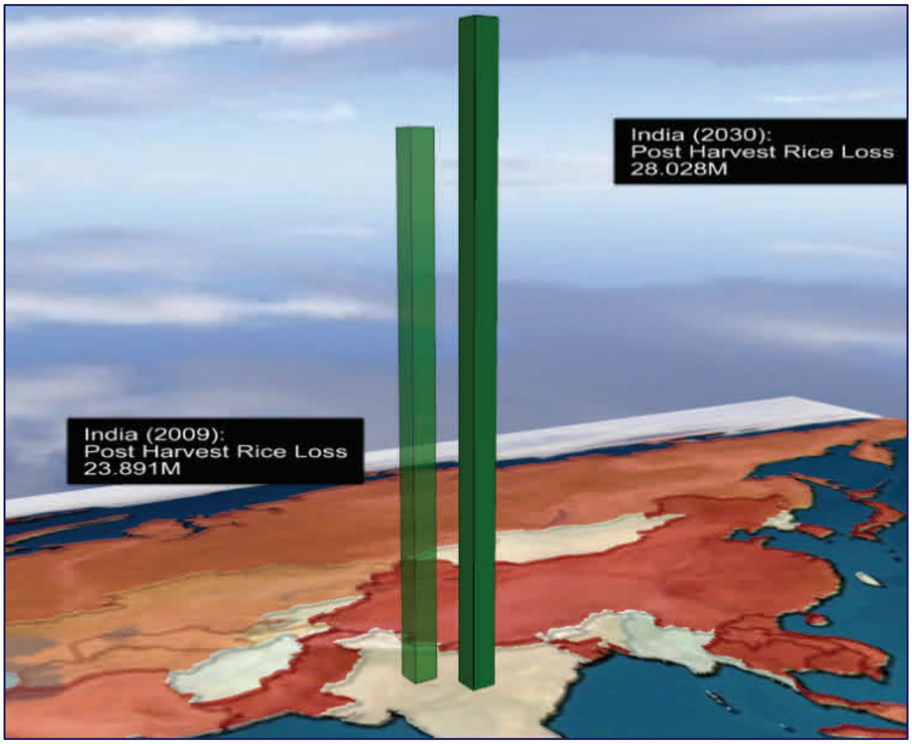
Using the Global Loss 3D Tool, we can anticipate the future dynamics of PHL. In India, PHL of rice is expected to rise from 24 million metric tons in 2009 to 28 million metric tons by 2030.

How large is 28 million metric tons? In 2030, the Philippines' ***entire*** production of rice is estimated to reach 28 million metric tons. Thus, India's expected loss in 2030 is equivalent to all the rice estimated to be produced in the Philippines.

Indeed, the total loss expected in India alone exceeds the total production of rice in 75 countries around the world. These include agriculturally important nations such as Argentina, Spain and Mexico.

But opportunity is embedded in finding solutions to these problems. Effective steps to reduce PHL can materially expand available food supplies. For example, if the expected 2030 losses of India's rice production were cut in half, those reduced losses would exceed the total expected production of rice in the United States and in Japan.

The ADM Institute is committed to finding ways to solve this growing problem. The Institute has already committed $2.5 million to innovative research projects that systematically address loss of staple crops in India and Brazil. To maximize effectiveness, these projects will engage leading universities, NGOs, and the private sector in India and Brazil. Collaboratively, we can convert loss to available food and contribute to developing more sustainable food systems in the world.



Projected PHL for 2030 compared to PHL in India in 2009 (source: InnovoSoy)

About InnovoSoy

InnovoSoy was founded in 2009 at the University of Illinois. Dedicated to developing powerful and easy-to-use data visualization applications, InnovoSoy provides users with practical and cost-effective solutions to understand complex and dynamic datasets. Dr. Peter Goldsmith is president of InnovoSoy and associate professor of agribusiness management at the University of Illinois. Dr. Goldsmith has also received funding from the ADM Institute to study PHL in tropical regions.

Dr. Peter Goldsmith, president of InnovoSoy and Associate professor of Agribusiness at the University of Illinois (source: InnovoSoy)

Engineering Sustainable Solutions to Postharvest Loss

An interdisciplinary team led by Civil and Environmental Engineering Associate Professor Ximing Cai and comprised of students from Construction Management, Transportation, Construction Materials, and Hydrology and Hydraulic Engineering recently completed a literature review summarizing the concept of PHL, identifying current techniques to reduce PHL, and highlighting important gaps in existing PHL research.

The concept of PHL is summarized by the engineering team in terms of decrease in quantity by weight as well as the reduction in product quality from harvest to consumption. The team found that existing literature tends to emphasize quantitative loss in the context of developing countries; while loss due to product quality, which affects nutritive/ caloric composition, acceptability to the consumer, and the edibility of a product, tends to be more prevalent in developed countries.

Stages of the supply chain identified in existing research on PHL indicate the potential for staggering levels of loss. The following table outlines recently published information on loss estimates for the Asia Pacific Region.

Internal and external factors leading to PHL are highlighted in the literature review.

Table 1

Percentage loss in post-harvest supply chain, Asia Pacific Region

Harvesting	5-8 percent
Storing operation	15-20 percent
Storage	5-10 percent
Transport	10-12 percent
i.e. a theoretical total	35-50 percent

(Source: APO & FAO 2006)

Broad areas encompassing internal factors are included in Table 1. Specific internal factors include handling at harvest; drying and transport; storage; primary processing (cleaning, classification, dehulling, pounding, grinding, packaging, soaking, winnowing, drying, sieving, milling); secondary processing (mixing, cooking, frying, molding, cutting, extrusion); product evaluation and quality control; packaging; marketing and distribution; and consumer and post-consumer waste and disposal of food.

External factors identified in the literature include environmental factors such as climatic conditions (wind, humidity, rainfall and temperature) that contribute to loss by in-field falling as well as damage from mold and fungus, pests such as insects and rodents which contribute not only to quantity loss but also to quality loss through contamination. Other external factors include consumer intolerance of substandard foods, and socio-economic factors such as urbanization and increasing household affluence, which leads to a reduction of farm labor force and an increase in consumption of perishable commodities such as meat and produce by urban consumers.

High impact measures to reduce PHL are summarized in the literature review with a focus on those most important to developing countries. Examples of these measures include considerably greater investment in formal markets to improve infrastructure and the capacity of agro-food supply chains, and a shift to the use of indigenous crops that are more suited to the local climate.

Implementing sustainable solutions through the entire food supply chain, as highlighted in the research, is crucial to the realization of a meaningful reduction in PHL. This will require large-scale investment in agriculture infrastructure, technology skills and knowledge, storage, transport, and distribution. A consideration of socio-economic factors, such as changes in demand in developing countries from a market based on starchy foods to one that depends more on meat and perishable produce, is also important to the sustainable reduction of PHL.

An integrated, sustainable, and resilient supply chain emerged as a critical missing component in the overall reduction of PHL over the course of the literature review process. Though biological and environmental factors, which contribute to PHL, are well understood and several technologies have been developed to reduce loss, the team discovered that other factors have inhibited progress. As current research indicates, inadequate marketing systems and transportation facilities, governmental regulation and legislation, unavailability of tools and equipment, lack of information, and poor maintenance of facilities and warehouses have hindered attempts to apply available knowledge and technology in the prevention of PHL.

Areas in which further research is needed include the benefits of pre-cooling technology and its effect on PHL; how improvements to the supply chain, such as on-farm technologies, central storage, vehicles and transport in Brazil, Russia, India and China would affect PHL; and additional comprehensive studies on PHL loss for a single commodity supply chain or for the supply chain in a single country.

Important research areas and related questions highlighted by the team include:

- ***Strategic supply chain design:*** How do we increase the reliability of supply chain design considering probabilistic characteristics of

Engineering Sustainable Solutions to Post-Harvest Loss (continued)

external factors such as adverse weather conditions, storage/processing facility failures, insect pests, and transportation infrastructure failure?

- ***Harvest:*** How can farmers better predict optimal harvest time?
- ***Handling:*** How can contamination and damage be reduced in processing?
- ***Storage*****:** How can storage structures better withstand negative environmental effects, and how can bio-deterioration in storage be reduced?
- ***Transportation*****:** What is the optimum transportation method and network to reduce post-harvest loss while minimizing cost of technologies?

Civil and Environmental Engineering Literature Review Team Pictured L-R: Yun Bai, Moatassem Abdullah, and Michelle Miro. Not pictured: John Michel, Ahmed Abdelmohsen, Ximing Cai

Monitoring Carbon Dioxide in Storage

A team of graduate students working under the direction of Steven Eckhoff, Professor of Agricultural and Biological Engineering, and Lynford Goddard, Assistant Professor of Electrical and Computer Engineering, are developing a low-cost laser-powered fiber optic sensor designed to measure levels of carbon dioxide (CO^2) in grain storage bins.

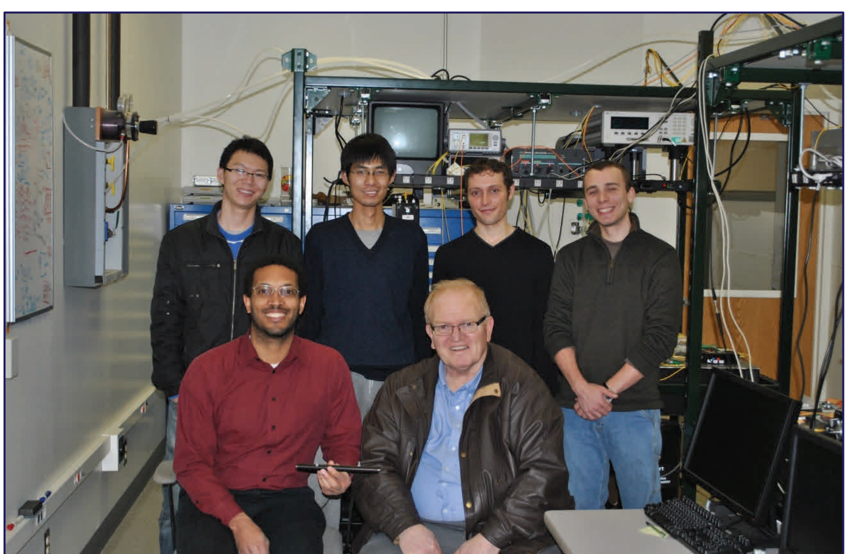
The presence of elevated CO^2 levels in grain storage facilities is commonly the result of respiration by insects and microbial life forms such as mold and fungus, which can cause significant loss in grain weight and quality. The presence of fungus can also lead to the generation of mycotoxins, toxic metabolites which cause serious health problems in consumers.

The common approach to monitoring grain in storage for the presence of insects and microbial life is the use of thermal cables in order to detect increases in temperature, which results from insect and microbial respiration. However, this method is limited by the low thermal diffusivity of bulk grain.

Temperature measurement alone is not sufficient for effectively detecting insect and microbe respiration due to infestation, which is a major problem in tropical regions. Recent research has found that monitoring the head space of a bin with a CO_2 sensor can lead to earlier detection of microbial or insect degradation of the grain. However, the system only gives an average concentration that is complicated by convective mass transfer in the head space. Ideally, a sensor system would give a spatial indication of where deterioration is occurring.

In order to determine the accuracy of imbedded CO^2 sensors relative to thermal sensors, the engineering team conducted tests with commercially available battery operated wireless CO^2 sensors in a mock storage bin of 0.3 meters in diameter and 3.4 meters in height. The storage bin was filled with eight bushels of corn (448 pounds), and sensors were placed in the center of the bin at depths of 1.2 and 2.4 meters as well as at the bottom and the top of the bin.

A known concentration of CO^2 was injected into the center of the bin at a height of 0.6 meters, and a thermal-resistance was placed at the same location to generate heat. CO^2 readings were collected wirelessly, and thermal couples were installed to monitor temperature changes in the grain storage bin.



Back Row L-R: Haibo Huang, Renjie Zhou, Ben Griffin, and Steve McKeown. Front Row L-R: Lynford Goddard, Steven Eckhoff. Not pictured: Bussaba Amnueypornsakul.

Monitoring Carbon Dioxide in Storage (continued)

The results of this study confirmed that CO^2 measurements were more effective than thermal sensing in indirectly detecting spoilage.

While wireless CO^2 monitoring systems are commercially available, the high cost of these devices prohibits smallholder and marginal farmers from investing in such technology. In addition, the transmission range of currently available CO^2 monitoring systems installed inside the grain bin may restrict their usage to surface or near-surface measurements.

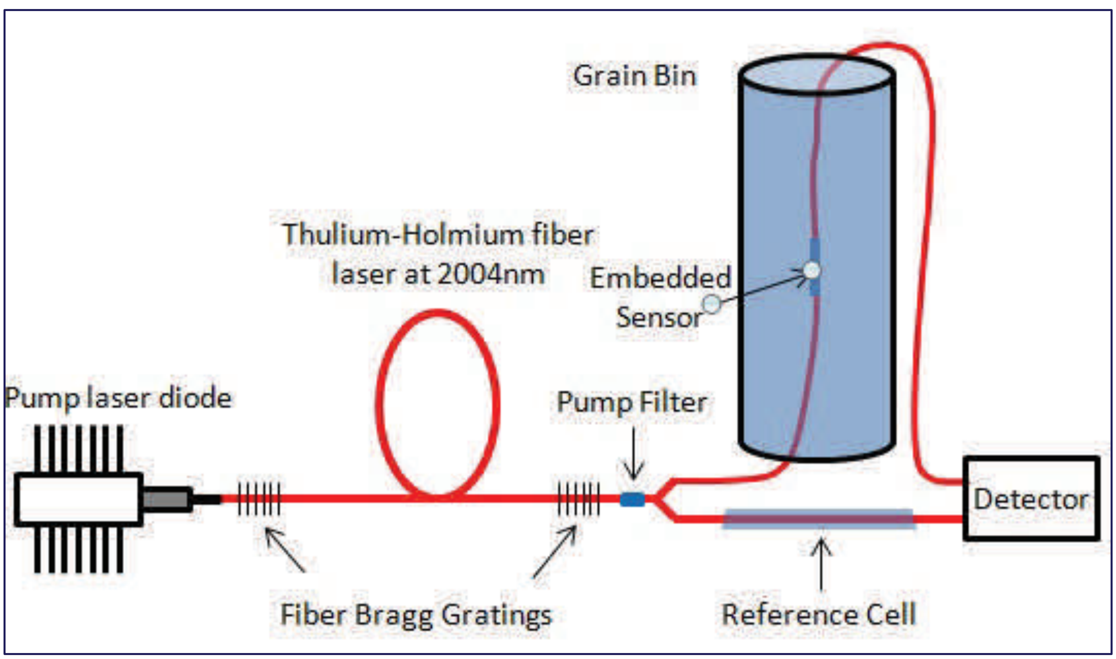
The experiment outlined above will be repeated with a laser-based fiber optic CO^2 sensor developed by the Illinois engineering team to determine how accurately it measures CO^2 levels in comparison with commercially available devices.

This new sensor, which is nine inches in length with a diameter of nine millimeters, is constructed with two internal lenses and a fiber cable adapter on each end. The sensor is pulled to various locations inside the grain bin using the fiber tether, providing a spatial indication of where deterioration is occurring. This sensor is designed to sweep through the light absorption range of CO^2 in order to more accurately detect concentration and diffusion.

A separate reference cell filled with CO^2 is placed outside the bin and allows the operator to determine when the laser reaches an intensity level at which light will be absorbed by CO^2.

The research team's objective is to develop low-cost embedded sensors that can map out regions of insect or microbial activity inside grain bins by quantifying the local concentration of CO^2. It will be possible to collocate these CO^2 sensors with temperature sensors in most applications. Microbial and insect respiration can be monitored via changes in CO^2 concentration over time and location.

Expected outcomes from development of the CO^2 sensor include providing a lower cost option for smallholder and marginal farmers, reducing PHL due to insect and microbe infestation, and reducing health risk to consumers from mycotoxins produced by fungus.



Graphic of the device created by the team of graduate students working under the direction of Steven Eckhoff, Professor of Agricultural and Biological Engineering, and Lynford Goddard, Assistant Professor of Electrical and Computer Engineering.

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The ADM Institute for the Prevention of Postharvest Loss is located at the University of Illinois at Urbana-Champaign. Dr. Steven Sonka serves as Director of the Institute, and oversees the research, education and outreach activities of the Institute.

Founded in January 2011, the ADM Institute for the Prevention of Postharvest Loss will serve as an international information and technology hub for evaluating, creating and disseminating economically viable technologies, practices and systems that reduce postharvest loss in staple crops such as corn, wheat, and oilseeds.

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