Integrated Crop Supply Chain Planning for Minimum Post-Harvest Loss

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We propose an integrated research project that will investigate optimal engineering solutions and infrastructure investment requirement to minimize the post-harvest loss (PHL) in both crop quantity and quality. We will model a large scale crop supply system including harvesting, handling, storage, processing, transportation and distribution in markets, considering multiple factors such as extreme weather (e.g., severe storms, floods, droughts, heat waves, frost incidence), microclimate (e.g., temperature gradients, humidity), facilities and equipment, resource availability (e.g. energy, water, labor) and socioeconomic conditions (e.g., demographic shifts, demand variations). The specific objectives are to (a) develop detailed and encompassing multi-echelon supply chain design modeling tools of entire crop logistics systems with focus on the components and processes with potential PHL, which will integrate information technology (e.g., bio-sensing), complex physical processes (e.g., storage, deterioration), and socioeconomic factors (e.g., stakeholders' preferences) into logistics system operations; (b) develop resilient supply chains to minimize PHL subject to stochastic and dynamic/seasonal variations; (c) examine options for flexible design of the supply chain structure to reduce PHL through cost-effective and reliable mechanisms (e.g., onsite pre-processing of crops). We propose two specific research tasks:

Task 1: Examine the risks associated with physical, environmental and social factors, and assess the economic benefits and costs of technical options. To minimize PHL in both crop quantity and quality, we need to understand the impacts of various physical, environmental and social factors and the uncertainties to explore various technical options to reduce PHL at all supply chain stages. Specific examples include: 1) To address the impact of climate change, which alters the hydroclimatic variability and may cause more frequent extreme events (e.g., more heat waves, intense precipitation, prolonged droughts); such changes may induce significant uncertainty in chemical and biological losses (e.g. insects, fungi, moulds). 2) To reduce the likelihood of bio-degradation by exploring alternative storage structures that prevent the ingress of moisture, insects, pests and other contaminants, or mitigate insect attack by accurate and precise sensing of in-situ insect activities. 3) To mitigate PHL by enhancing the grain movements in conveyance systems, or preprocessing crops (e.g., by grinding and drying) into dense dry matter (e.g., pellets) for convenient storage and transportation. We will investigate the economic trade-offs between the various technical options, the situations under which an option will become viable, and the optimal location and timing of such procedures. In particular, extra energy input and investment requirement in facilities and equipment under all these options will be assessed. The results will be incorporated into the comprehensive supply chain design model to determine the best engineering solution via Task 2.

Task 2: Determine the multi-echelon supply chain design to reduce PHL, including the optimal infrastructure investment (e.g., size and location of storage space) and strategic operation rules (e.g., harvesting/storage/collection/transportation), under stochastic and dynamic/seasonal demand. Supply chain design starts with farmers, who decide how to store the harvested crops temporarily, given their geographical locations and the existing transportation network. The system will help farmers to consolidate harvested crops to a local storage area (if one exists), pre-process and transport them. More importantly, the supply chain design will be related to strategic decisions regarding the choices of technologies to be used, the selection of warehouse/preprocessing locations, the design for distribution systems as well as the assignment of farms to warehouses, warehouses to crop processing plants, or plants to markets. Moreover, the uncertainties in all stages of the whole system that can increase PHL, such as randomness of supply and demand, fluctuations in production and transportation capacities, need to be considered in the strategic multi-echelon supply chain design models so the resulting supply chain can be robust and resilient. Note that the planning and design based on the assessment of multiple factors will mitigate the risks of PHL. However, reliable supply chains will also need to absorb unexpected risks through optimally designed “back-up” plans and enhance the expected supply chain performance despite internal or external hazards. In addition, some social factors, such as the different (if not conflicting) objectives of stakeholders (e.g., government, industry, farmers), should also be taken into consideration when optimizing the overall supply chain system.

We will apply the modeling tools to India and Brazil through existing research collaboration and contacts. A key outcome of this project will be a comprehensive framework to explore optimal engineering solutions and infrastructure investment requirement for large scale crop supply systems that minimize PHL while considering other relevant objectives such as satisfying market demands. Results from this research will provide guidance for realistic adoption of crop processing and development technologies. More importantly, the project outcomes will provide decision makers and analysts with a scientific and methodological basis to analyze the implications of various decisions under various uncertain scenarios.