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Title
Decision support tools to guide assessment and adoption of postharvest technologies and to ensure food security.

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Research Updates/Outputs:
Science-based postharvest technologies exist that could help food value chains reduce postharvest losses. However, the increased and sustained adoption of such technologies remains challenging despite indications that value chain actors could substantially benefit from them. While many factors contribute to the limited adoption of science-based postharvest technologies, effective promotion within a value chain has increasingly become a key method used by several agricultural program managers, and extension experts to increase adoption. At the same time promoting postharvest technologies in high-income and low-income countries often requires comparing multiple technologies alternatives before selecting the technology that optimizes the potential adopters' preferences. To this end, decision support tools are important for evidence-based decision-making in agriculture to promote technology for increased adoption. Hence in this dissertation research, two decision support tools were developed to: (1) guide agricultural program managers in sub-Saharan Africa rank mango, maize, and tomato postharvest technologies based on multiple criteria and identify the best alternative to be promoted for adoption; and (2) assist extension experts and sweet potato growers in North Carolina, USA, assess the economic viability of operating Unmanned Aerial Vehicles (UAVs) to quantify sweet potatoes inadvertently left in the field after harvest.

The Rockefeller Foundation YieldWise Initiative (YWI) was used as a case study to develop the first decision support tool. In a first attempt to understand and summarize the YWI data, multiple postharvest technologies were compared in the mango value chain in Kenya. Results indicated that plastic crates used to transport or store mangos post-harvest and fruit fly traps used to attract and kill fruit flies pre-harvest were statistically significant ($p < 0.05$) in reducing PHL at the point of sale. Subsequently, a postharvest losses (PHL) dashboard was developed, allowing the user to compare PHL associated with different technologies in the maize value chain in Tanzania and the tomato value chain in Nigeria.

A second study to further learn from the YWI data used the Random Forest model to rank critical maize, mango, and tomato PHL drivers. The study then predicted maize, mango, and tomato PHL as a function of two variables: the levels of the most critical drivers of PHL and various numbers of farmers at each level. Results indicate that the most critical drivers of PHL consisted mainly of pre-harvest and harvest variables in the field. Most importantly, results further revealed that changes in the number of smallholder farmers at a given level impact PHL, although in a relatively small way. Hence, the Random Forest predictive model confirmed that increasing adoption impacts PHL. The PHL online dashboard was further expanded because of this study to allow users to explore the relationship between several critical drivers, the predicted PHL of each crop, and a desired number of smallholder farmers, in addition to comparing PHL reducing technologies.

Drawing from the YWI data analysis results, a decision support tool was developed to guide agricultural program managers in ranking various postharvest technology alternatives before selecting the best technology to promote for adoption. Surveys were conducted in the value chains of mango in Kenya, maize in Tanzania, and tomato in Nigeria. Six hundred participants comprised of technology suppliers, smallholder farmers, crop buyers, and policymakers were interviewed in each value chain. The literature identified six postharvest technology adoption measures: postharvest loss per year, purchasing price, yearly operation cost, lifespan, availability, and ease of adoption. Participants were then asked to rank the adoption measures in order of importance. Postharvest technologies commonly used by individual smallholder farmers in Kenya, Tanzania, and Nigeria were identified. The decision support tool employed a Multi-Attribute Utility Theory (MAUT) approach to let users rank pre-established and user-defined postharvest technologies based on composite utility value that heeds the preferences of all key value chain actors. Results from analyzing the survey data and the output of the decision support tool indicated that promoting the adoption of postharvest technologies in SSA by using a single measure, such as PHL or cost minimization alone, can be misleading to a program manager. Instead, identifying the best technology to be promoted for adoption should be based on a composite utility (CU) that encompasses multiple adoption measures. Hence, the plastic crate (13-15 kg) used to transport mangos after harvest is, on average, 90% of an ideal alternative compared to fruit fly traps and polypropylene bags. Hermetic bags (100 kg) used for storage and preventing insect grain damage without insecticide is, on average, 89% of an ideal technology in the maize value chain, approximately twice the average CU of polypropylene bags (100 kg) used for maize storage. In the tomato value chain, a plastic crate (13-15 kg) used to transport tomatoes after harvest has the highest CU for the technology supplier and the tomato buyer. On the other hand, the raffia basket (50 kg) has a slightly higher CU than the plastic crate for the smallholder farmer and the policymaker. Interestingly, conflicting value chain actors' preferences observed in the tomato value chain make identifying a technology that will optimize all value chain actors' preferences difficult.

A second decision support system was developed to assess the techno-economic viability of using drone imaging to quantify sweet potatoes left in the field after harvest. A DJI M600 drone with two mounted cameras, one with an RGB sensor and the other with an NIR filter, was used to evaluate the cost of quantifying sweet potatoes left in the field after harvest compared to using a field technician. Results indicated that the average cost of quantifying sweet potatoes left in one field of 13 acres (5.3 ha) using a UAV is 27 times lower than the average cost of using a field technician to collect the same quantity of information. As the number of fields surveyed increases, the difference between the UAV measurement costs and the field technician measurement cost increases linearly. Hence, the UAV measurement cost was predicted to be 67 times lower versus the field technician measurement cost for 10 fields. The net economic benefits from the recovered sweet potatoes quantified using a drone were predicted to be only slightly (4%) higher than those quantified by a field technician. However, the amount and quality of data collected by a drone and data availability for real-time analysis are substantially greater and favor its use over a field technician. This study also resulted in a decision support tool that allows the user to define or modify the independent variables provided in the Techno-Economic Analysis (TEA) and quantify the effect on the dependent variables.

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Deliverables

Oral Presentations

- Chikez, H.; Maier, D.; Sonka S.; and Olafsson, S. Decision support tools to guide assessment and adoption of postharvest technologies and to ensure food security. Ph.D. defense, Ames, Iowa, April 07, 2023.

Publications

- Chikez, H. 2023. Decision support tools to guide assessment and adoption of postharvest technologies and to ensure food security. Unpublished Ph.D. Dissertation, Iowa State University, Ames, Iowa.
- Chikez, H.; Maier, D.; Olafsson, S.; and Sonka, S. Identifying Critical Drivers of Mango, Tomato, and Maize Postharvest Losses (PHL) in Low-Income Countries and Predicting Their Impact. Agriculture 2023, 13(10), 1912. https://doi.org/10.3390/agriculture13101912

Online Dashboards

- Identifying and comparing critical drivers of mango, tomato, and maize postharvest losses (PHL) and predicting their impact: https://phldashboard.shinyapps.io/phldashboard/
- Multi-criteria decision support system to rank postharvest technologies based on Multi-Attribute Utility Theory (MAUT) adoption measures and numerous value chain actors' preferences: https://phldashboard.shinyapps.io/MDCA/
- Techno-economic analysis (TEA) of remote sensing image-based technologies to quantify sweet potatoes left in the field in North Carolina, USA: https://phldashboard.shinyapps.io/TEASP/