The FarmTabs program lets farmers input their GAP audit results, compare historical results and make improvements before future audits. Farmers previously had to record their safety records on paper logs as part of the GAP requirements, leading to errors and delays.

Photos courtesy of the authors

Ensuring food safety from farm to fork through industrial engineering

Record-keeping application devised to streamline tracking of produce

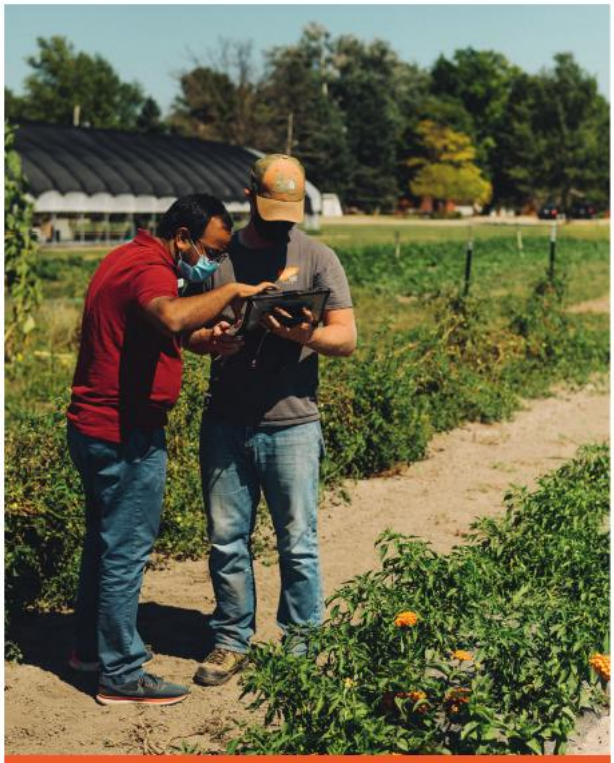
By Anuj Mittal, Claire Zabel and Jason Grimm

Salmonella. E. coli. Cryptosporidium. As anyone who has experienced it will attest, foodborne illness is no joke. Fresh produce is especially high risk because it is often consumed raw. Fruit and vegetable growers have a vital role in supplying secure and safe produce, especially those selling to institutions such as schools, grocers and wholesalers.

In 2011, the Food Safety Modernization Act (FSMA) was written to transition food safety in the U.S. from a reactive to preventive approach. With the introduction of FSMA regulations, today there is an increased awareness of food safety on farms. While farms implement the mandatory FSMA regulations, some farmers are auditing their own food safety policies through the Good Agricultural Practices (GAP) certification program of the U.S. Department of Agriculture (USDA). This voluntary food safety verification system helps build trust between producers and their customers.

GAP are best practices for growing, harvesting, packing, storing and transporting produce to minimize the risk of microbial contamination associated with these products. Many retailers in the U.S., such as supermarket chains, school systems and restaurants, are requiring a third-party GAP audit. Food safety is important to growers not only from a liability perspective but also as an incentive to attract and retain buyers. GAP certification helps farmers improve the marketability of their produce and diversify their customer outlets.

The case study described in this article demonstrates industrial engineering principles applied to improve the record-keeping



Authors Anuj Mittal (left) and Jason Grimm work on the Grow: Johnson County farm to enter harvested crops details in FarmTabs, the open-source application to help farmers streamline record-keeping to comply with food safety standards.

process at a vegetable farm in Iowa by developing a low cost and open source tool called FarmTabs and its benefits for enhancing overall farm business efficiency.

GAP certification requirements

GAP certification requires producers to create a food safety plan for their operation. This plan encompasses employee training, maintaining clean facilities and equipment, using clean potable water at every stage of production and handling and product traceability. Traceability documentation is critical in the event of recall due to contamination, enabling produce to be traced from its field of origin to the customer. Once the source of contamination is known, the producer should be able to use its records to identify every customer potentially affected and recall all products that were contaminated.

To accomplish this, traceability records must be specific and exist on the farm as well as properly labeled on packaging that goes out to customers. At a minimum, labels should include the farm name, product name, harvest and pack date, and an identification code indicating in which field the product was grown.

To enable specific recall capability, it is up to farmers to choose an appropriate "lot size" for their operation that balances recall effectiveness with management time. Lots, with each assigned a unique number, could be as large as the entire annual harvest of a particular crop or as small as one field's harvest from one day. There is no standard for field size, so they can vary dramatically within a farming operation as well as between farms. For traceability purposes, farmers should be able to perform a recall based on the commodity or product – for example, recalling all the radishes – the field from which a crop was harvested, harvest date, harvest crew, packing date and sell date.

These options enable targeted recall depending on the type and source of potential contamination. A field recall could occur if the soil or water in the field was found to be contaminated. A harvest date, packing date or sell date recall could address a situation of contaminated containers or water used for washing or spoiled produce. A recall by harvest crew could address a situation where a crew member was sick or injured while working with produce.

Farmers agree on the importance of food safety but feel overburdened by the record-keeping requirements associated with traceability. Beginning farmers especially find record-keeping for GAP audit purposes to be difficult. Even after food safety training in compliance with FSMA is completed by small farmers, the costs of implementing some corrective measures are prohibitive and thus can prevent them from expanding their operations within the local economy.

Additionally, the food safety record-keeping required by FSMA asks farmers to add daily management tasks to their already busy schedules. This suggests the need for efficient, effective and streamlined digital record management tools that are accessible to beginning small farmers so they are able to interpret and utilize their data to make smart in-season decisions.

Case study with Iowa farms' nonprofit

The issues surrounding traceability records were observed firsthand for Grow: Johnson County, a GAP-certified vegetable farm operated by Iowa Valley RC&D. Iowa Valley is a nonprofit with the mission of strengthening local food systems, leading collaborative placemaking projects and bringing technical assistance to rural communities. The Grow project involves growing vegetables on 4 acres of land located at the Johnson County Historic Poor Farm in Iowa City, Iowa. All of the food grown at the farm is donated to local food pantries, homeless shelters, after-school programs, free meal sites, home-delivered meals and refugee and immigrant support centers.

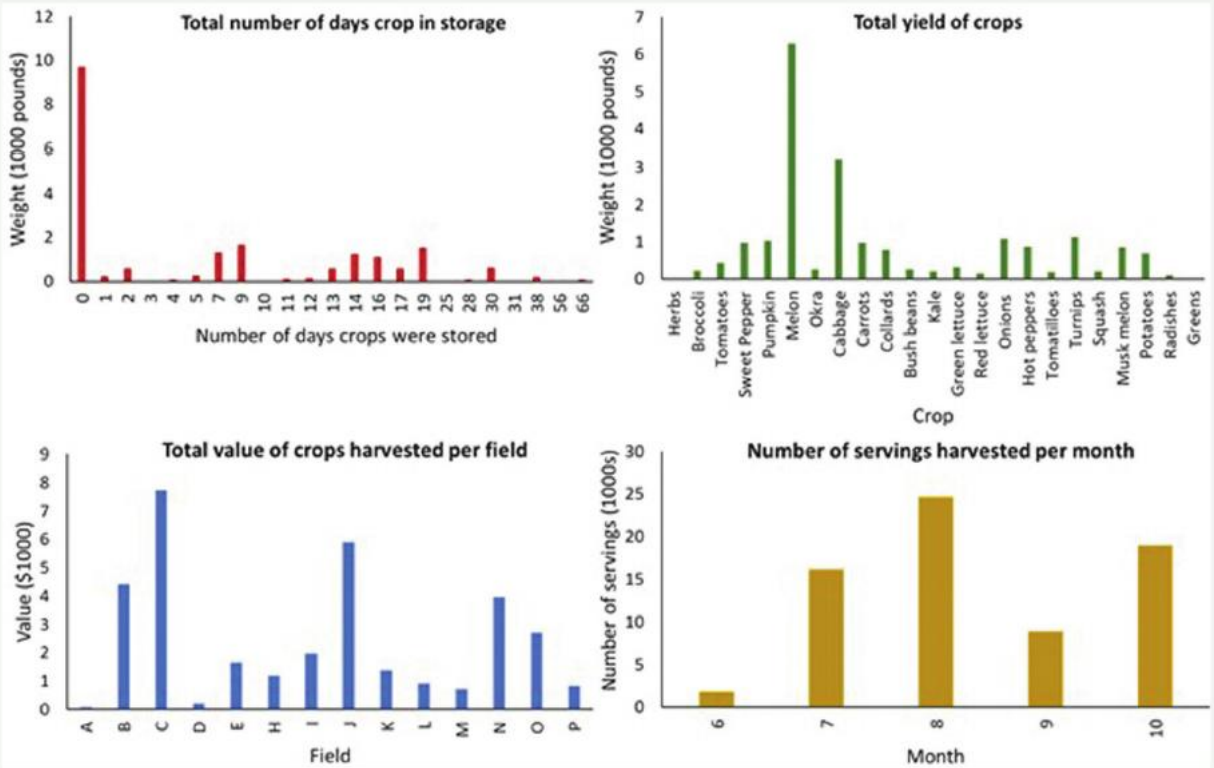
In April 2018, a food safety plan was put in place for the farm to minimize contamination and the spread of diseases. The plan includes detailed policies and standard operating procedures related to harvesting, packing and distribution of fruits and vegetables produced at the farm. It follows USDA GAP and Food Safety Modernization Act standards.

In September 2018, USDA inspectors audited the Grow program and the farm received the GAP certification. However, Grow staff thought it would be important to adopt more robust and real time record-keeping methods store data digitally for efficient product recall purposes and establish a more resilient system than paper logs. Quick access to data also will shorten

FIGURE 1

Harvesting data

A snapshot of the analysis performed by FarmTabs from the data collected at the Grow farm in 2019 include various crop data to help farmers compare and plan.



the amount of time to conduct recalls and remove contaminated products from the market, ultimately reducing the number of illnesses.

This article describes how DMAIC, a Six Sigma approach to process improvement, has been used to improve the Grow recordkeeping process. DMAIC is a data-driven method used extensively by industrial engineers to improve processes with applications in both manufacturing and service industries. The first phase in DMAIC includes defining the problem.

DEFINE

At Grow, the food safety record-keeping required by the GAP guidelines was all done by hand on paper logs. Each time a crop was harvested, information had to be recorded multiple times on separate sheets of paper: harvest log, pack log and delivery log. First, it needed to be recorded on a harvest log detailing the crop name, lot number, date of harvest and Julian date, any specific notes related to harvesting (such as deer activity being observed in the field and the area avoided during harvest) and the initials of the person responsible for the harvest. A hand-written note card was made with the same details for each container where the harvested crop is stored.

Once the crop was ready to be packed, the harvest details were again added in the pack log using the information written in the labels in the previous step, along with other details such as weight of packed crop, pack date and pack initials. Hand-written packaging labels were also created with information such as harvest date, pack date and crop name to allow customers to report the crop details in case of any contamination for recall purposes.

Finally, as the customers pick up the products, the details of crop name, harvest and pack date, and lot number had to be entered again in the printed delivery log. In addition to other information, such as weight of each crop, the person responsible for making deliveries must document the cleanliness of the delivery vehicle by initialing the delivery log. In case of a product recall, information needs to be accessed from the harvest, pack and delivery paper logs to be able to identify the root cause of the problem.

MEASURE

In the measure phase, the process of record-keeping was observed from beginning to end that included:

Lack of standardized work process. The process of data recording was often inconsistent with different people using multiple methods. There was no standard instruction document

in place that would enable different staff members to perform data entry in a consistent manner as per the GAP certification requirements. For example, delivery log details entered upon a customer's arrival must record the initials of the driver acknowledging the delivery vehicle is clean. However, many times delivery logs were entered without initials recorded for the delivery order.

The Iowa Valley RC&D team involved in the development of FarmTabs – from left, Jake Kundert, Anuj Mittal, Jason Grimm and Michi Lopez – meet at the Grow: Johnson County nonprofit farm's 4-acre site in Iowa City, Iowa.

Maintaining paper logs. The process of record-keeping required several separate paper trails that must be maintained at a physical location for one year, per the GAP audit requirements. Other challenges include the availability of proper supplies at the farm (such as printed harvest and pack logs), and dirt and moisture on the farm spoiling the paper logs. These inexpensive solutions have value but are prone to error, easily lost (like papers flying away in the wind) and only offer benefit once this handwritten information is transferred into a more usable digital format.

Excessive time consumption. The method of collecting and recording data using clipboards with printed logs and handwritten checklists required a large amount of time to collect, record and transfer into a digital interface. Based on the time study conducted, for 20 bins of products harvested, it took around 10 minutes to conduct the data entry in the harvest log and write labels for each of the 20 bins. The Grow: Johnson County project staff had to spend around five hours each week on recordkeeping.

ANALYZE

An analysis was conducted on the data recorded on the paper logs and the following observations were made:

Transcribing errors. There were inconsistencies in transcribing information involved in this process. For example, names were written differently many times for the same crop and the Julian date was incorrectly calculated based on the harvest date. Sometimes staff or volunteers working on the farm would forget to write things down or switch the order of information in the lot numbers, such as write field name in place of the bed number. The current process is also prone to manual errors. Specifically, since the same information on the harvest log needs to be written in the pack and delivery log again separately, it created more chances for human error.

Absence of an inventory management system. Another issue that was observed was the lack of a method to identify how much produce is available at a point in time in stock for donation. All the information in the harvest logs and pack logs had to be converted electronically and a calculation had to be done each time to identify the current inventory. Alternatively, recounting the stock of each crop had to be done manually at the pack shed.

Absence of data for future decision-making. In the two years since this paper-based method of record-keeping was adopted, none of it had been transferred into a digital format. On paper, data that could guide future decision-making was difficult to analyze and largely unavailable until it could be transferred to a digital format. For example, data on the amount of each crop harvested from a particular lot number would be useful to understand land productivity or assess the yield effects of a pest problem. Additionally, data of the total amounts of crops that were donated or sold could aid in future crop planning. To access this data for improved decision-making would require extra time that farmers often do not have, and the process of transferring data from messy log sheets introduces other opportunities for errors in record-keeping.

IMPROVE

In this phase, the Iowa Valley RC&D team developed an Excel-based software using Visual Basic for Applications, formally named FarmTabs, to improve the data keeping process for their

vegetable farming operation at Grow: Johnson County. FarmTabs is a customizable decision support tool that tracks inventory and allows producers to use data to improve food safety and efficiency, as in necessary crop planning based on historical sales data. With a small amount of initial setup, FarmTabs tracks food from farm to fork by assigning unique numeric identifiers to each "lot" of produce at harvest (Harvest ID) and packing (Pack ID), and generates standard packing labels containing required GAP information by default. Each unique identifier connects produce items to information on from which field it was harvested, harvest and packing dates, and all crew handling the item.

Using FarmTabs for record-keeping eliminates the vulnerabilities associated with a paper system by standardizing data entered and minimizing redundancy. Instead of writing separately in three logs, crop information needs to only be entered one time in the harvest log. This entry establishes a Harvest ID that is then entered into the pack log as it contains all the details about that specific crops harvest data. This same information is created in the form of a Pack ID that is entered on the delivery log.

In place of handwritten labels for each container of product, FarmTabs allows the printing of labels preloaded with the required information. Data entry errors can still occur in the system but FarmTabs reduces the number of opportunities for those errors. Standardized content and the formatting of data saves time, improves ease of training of new employees working on the farm and provides digital accessibility to the data for later analysis and future decision-making. Using FarmTabs the staff at the Grow farm reduced the time spent on recording keeping each week from five hours to one hour.

CONTROL

A revised safety plan has been developed for the Grow farm detailing traceability and recall procedures using FarmTabs. The farm's unique codes for each field have been entered into FarmTabs, establishing the drop-down menus in the digital logs. In addition, procedures to perform a mock audit at the farm using FarmTabs have been documented, which is a requirement during an actual GAP audit.

FarmTabs also allows farmers to input their GAP audit results. The USDA audit consists of 154 questions worth 4 points each. A farm being audited has to score at least 80% to qualify for GAP certification. When multiple audits are recorded by the farmers, FarmTabs allows them to compare historical audit results and make improvements before future audits. By looking at these records, a farm's food safety manager can get an idea on where to improve.

For example, Grow lost points in the first audit for not documenting that its delivery vehicle was clean and functional before generating a pickup order. Therefore, this was incorporated in FarmTabs by generating a dialogue box, which asks for confirmation regarding delivery vehicle cleanliness and functionality from the farm manager and the initials of the delivery driver before the pick-up order can be confirmed.

While the historical audit data is undoubtedly useful to an individual farmer, there is valuable potential for more systematic aggregation of individual farm data at the institutional level that would allow food safety professionals at the state level, such as the Iowa Food Safety Professionals Network, to track trends on GAP audit results. FarmTabs enables data aggregation from multiple farms who are using it for their record-keeping. This will ultimately enable more focused and directed technical assistance and education efforts to help farmers secure GAP certification.

Learn more about The Grow project

Grow: Johnson County is a GAP-certified vegetable farm operated by Iowa Valley RC&D, a nonprofit with the mission of strengthening local food systems, leading collaborative placemaking projects, and bringing technical assistance to rural communities. All of the food grown on the 4-acre site in Iowa City, Iowa, is donated to local food pantries, homeless shelters, after-school programs, free meal sites, home-delivered meals, and refugee and immigrant support centers.

To learn more about the program, visit *www.growjohnsoncounty.org*. To access the FarmTabs open source platform when available early in 2021 and its system requirements, visit *iowavalleyrcd.org/farmtabs*.

The Grow: Johnson County farm staff and volunteers pose with a tractor and potato harvesting equipment.

Ongoing efforts to help farmers

As a technical service provider, Iowa Valley RC&D performs mock audits for other farmers to aid them in preparing for their GAP certification. During these mock audits, Iowa Valley staff began noticing that other farmers were also struggling with record-keeping in the same ways as the Grow: Johnson County staff. Many farmers were using handwritten processes to maintain different logs and masking tape to generate labels. However, as farms grow, they need a more robust system to deal with

Iowa Valley RC&D's Food Systems Director Jake Kundert works in the Grow: Johnson County greenhouse with produce ready for distribution. All of the farm's food is donated to local food pantries, homeless shelters, after-school programs, free meal sites, home-delivered meals, and refugee and immigrant support centers.

inefficiencies and inaccuracies that result from a paper system.

With ever-changing weather conditions during growing seasons and the need to be flexible, farmers are finding ways to make smart in-season decisions. Quality data is more important than ever and, with proper interpretation, offers farmers a way to be agile and confident as they adjust and change their approach. There are, of course, already many data solutions available for farms but they require expensive subscriptions or are not designed with food safety record-keeping in mind. Commercial farm management software solutions available in the market require upwards of $600 annually for subscriptions and setup fees, not including the long hours for the farmer who must set up and manage the program.

Iowa Valley RC&D recognizes an opportunity to serve its mission to support farmers. Using grant funding secured from Iowa Department of Agriculture and Land Stewardship and the USDA, it is developing a version of FarmTabs that is more generalized to be usable by commercial farms. FarmTabs will be open-source and freely available with no initial or recurring costs to farmers. Because it is Microsoft Excel-based, the program can be used on any computer with or without internet access. Iowa Valley RC&D intends to release FarmTabs to the public by winter 2021. A written user guide listing step-by-step procedures a farm has to follow for using FarmTabs along with video demonstrations will also be available to download.

The most recent version of FarmTabs has features aimed at improving business decision-making and workflow efficiency. The program can quickly generate accurate invoices and alert the user when they are trying to sell beyond their inventory. From the data, FarmTabs can generate end-of-season summary reports and graphs which could improve future farm planning.

Figure 1 (Page 30) shows the graphs generated by FarmTabs from data recorded by the Grow farm in 2019. With FarmTabs, farmers can be confident of meeting GAP traceability requirements, save precious time and reduce errors. Farming is already hard work and this tool should help alleviate some of the stress of record-keeping. Once released to the public, it is the hope that feedback and data from users can be used to help improve future versions of FarmTabs.

This case study illustrates one way industrial engineering can be applied to the critical work of food production agriculture. Farmers need efficient and elegant solutions to improve agricultural management systems. Improving efficiency and performance serves the health of the community and farmers' well-being.

Collaboration between academic institutions, nonprofits and the local agricultural community could provide an effective way to serve these needs. Universities, through research and project collaborations, can provide much-needed, low-cost technological skills and solutions and offer continued support as operations evolve. Collaboration on this front can specifically help bring participating students much closer to their community and provide an understanding of the challenges faced by small-scale farmers while catering to their specific needs. ❖

Anuj Mittal is a faculty member in the Industrial Engineering Technology Department at the School of Engineering at Dunwoody College of Technology. He holds a bachelor's degree in electrical engineering from University of Delhi, India, and a master's degree and Ph.D. in industrial engineering from Iowa State University. His research interests include developing quantitative methodologies to study sustainable supply chains. He is an IISE member and member of the Sustainable Development Division's board of directors. Contact him at anujm.dce@gmail.com

Claire Zabel is the food and farm specialist at Iowa Valley Resource Conservation & Development. She holds a bachelor's degree in communication studies from the University of Iowa and is currently pursuing her master's degree in agronomy at Iowa State University. Contact her at claire@ivrcd.org

Jason Grimm is the deputy director at Iowa Valley Resource Conservation & Development. He works with Iowa farmers and businesses as a value chain coordinator connecting producers to each other and to viable markets, and cultivates relationships within the food system. He manages his own farm business marketing specialty crops across Iowa. Contact him at jason@ivrcd.org.