The assessment of a site-specific yield determination and field-level tracking system for Iceberg lettuce production in the desert southwest

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Abstract

Field packing into cardboard cartons is the current method for the handling and later transport of all leafy vegetables, including Iceberg lettuce. Consumer demand for increasing amounts of minimally processed fresh produce can run the risk of being contaminated by pathogens which can, in some cases, make consumers seriously ill. Should an unfortunate issue involving field food safety arise, the ability to trace a contaminant back to a specific field location is critical to the rapid and effective understanding, management and control of the event. Viewed broadly, U.S. food producers have developed an enormous capacity to track the flow of food along the supply chain, though individual systems vary. Some traceability systems are deep, tracking food from the retailer back to the farm, while others extend back only to a key point in the production process. In the fresh produce industry, the development of trace-back systems has been greatly influenced by the characteristics of the product, the harvesting infrastructure, and the current technology. Yet, the ability to georeference cut and packed lettuce back to a precise field location is still in its infancy. In this light, there is no current system which has the capability to trace carton-level packed Iceberg to an exact field location. Using RFID and integrated GPS technologies, we demonstrate the first field level, georeferenced carton tracking system to the leafy green industry. The system is highlighted with the seamless traceability of produce from the retail shelf back to precise grower protocols, field locations, crop vigor status, field worker identification and weather conditions during growth and subsequent harvest. As the system will incorporate carton level GPS links, precise lettuce yield determinations can be made within a field and later integrated into other precision management strategies.

Fig. 1. Sequence of lettuce harvesting and transport operations. A, field packing; B, palletizing; C, cooling; and D, transport to final destination.

Introduction

During lettuce harvesting and production processes, the crop typically undergoes various growing and handling stages. Field packing into cardboard cartons is the

current method for the handling and later transport of all leafy vegetables, including Iceberg lettuce. As shown in figure 1, lettuce is selected in the field for maturity and quality, and then cut, trimmed, packed in cardboard cartons or crates, transported to cooling facilities, cooled, put into temporary cold storage prior to loading or loaded directly, and transported to market. Field packing generally typically provides greater marketable yields because of reduced mechanical damage. And, for Iceberg and other lettuces, field efficiency, postharvest quality, and enhanced productivity necessitate the boxing and identification of quality attributes early in the supply chain, either in the field or packinghouse.

As lettuce handling and growing processes begin at the field level, concern has increased significantly in recent times with greater awareness for issues involving food security and safety. And, should an unfortunate issue involving field-level food safety arise, the ability to rapidly trace a contaminant back to a specific field location is critical to the rapid and effective understanding, management and control of the event. To date, this problem is mainly unsolved in the lettuce industry and this work represents a first attempt in providing a solution for carton traceability back to the field.

Research Methods and Results

System Hardware Development

In this report, we present the design, prototype, and testing of a system for the seamless and wireless tracking of lettuce from harvest to the final point in the supply chain process. A detailed overview of the system is provided in Figure 2. Briefly, a remote electronic carton tracking and field management system includes a field unit that energizes carton fixed, radio frequency identification (RFID) inlays with global positioning coordinates and key field information. Georeferenced harvest data is transported wirelessly to a base unit for archiving or additional data manipulation.

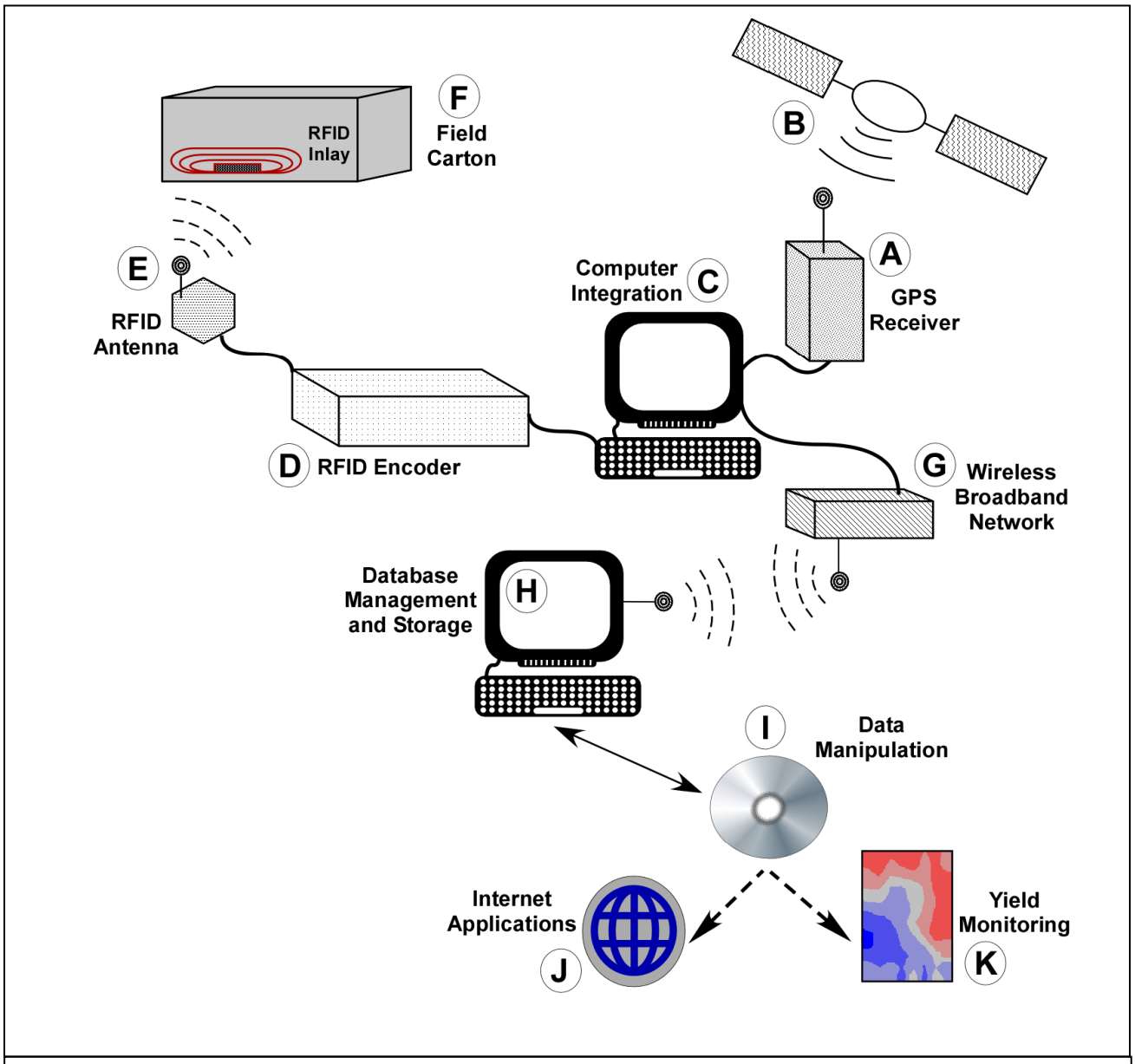

Fig. 2. Conceptual overview of lettuce carton tracking system. For details and description, see text.

As shown in figure 2, a sub-inch global positioning satellite receiver (Trimble Navigation Limited) (A) collects microwave signals from the GPS satellite network (B) that communicates geocoordinates to a field computer (C). Computer Radio Frequency Identification (RFID) integration software (Warren Point Communications Limited) (C) transiently links captured geocoordinates, user inputted field records, crop information and day of harvest information into a format recognized by RFID encoding hardware (D), with remote antenna (Sirit Inc.) (E). An energized ratio frequency signal, containing specific crop and geocoordinate data, is wirelessly transmitted from RFID encoder/antenna devices to RFID inlays attached to field cartons (F). The remote field computer (C) serves as a server and

field history data storage device prior to data delivery from the field to a local area network via a wireless mobile broadband interface (Verizon Communications, Inc.) (G).

Georeferenced crop harvest and field data, administered by RFID computer software (Warren Point Communications Limited) (C), is instantly processed and uplinked from the field to a local area network via a wireless remote broadband connection (G). Individual carton and field history data is wirelessly received for data management and storage (H) or for later manipulation (I) to be made immediately available to internet users via network servers (J) or used later in harvest yield operations (K).

Field Testing

The system was field tested with a grower/cooperator in the spring of 2009 on 3 head lettuce fields in Yuma County. The field tests consisted of prelabeling 5000 field cartons with RFID tags (Generation 2, Sirit, Inc.) and integrating them into the harvesting operation. Figure 3 provides a summary of system field testing. Although the equipment used to construct the lettuce carton tracking system is currently available and used in similar inventory management, the integration of real-time GPS into RFID technologies makes this approach unique. Prior to initiating the field tests, pertinent field attributes and key information was entered and stored into the system database to be transferred to individual RFID labels on the cartons. Field attributes consisted of shipper/grower, crop harvested and pack, names of harvest crew members, weather conditions at harvest, and

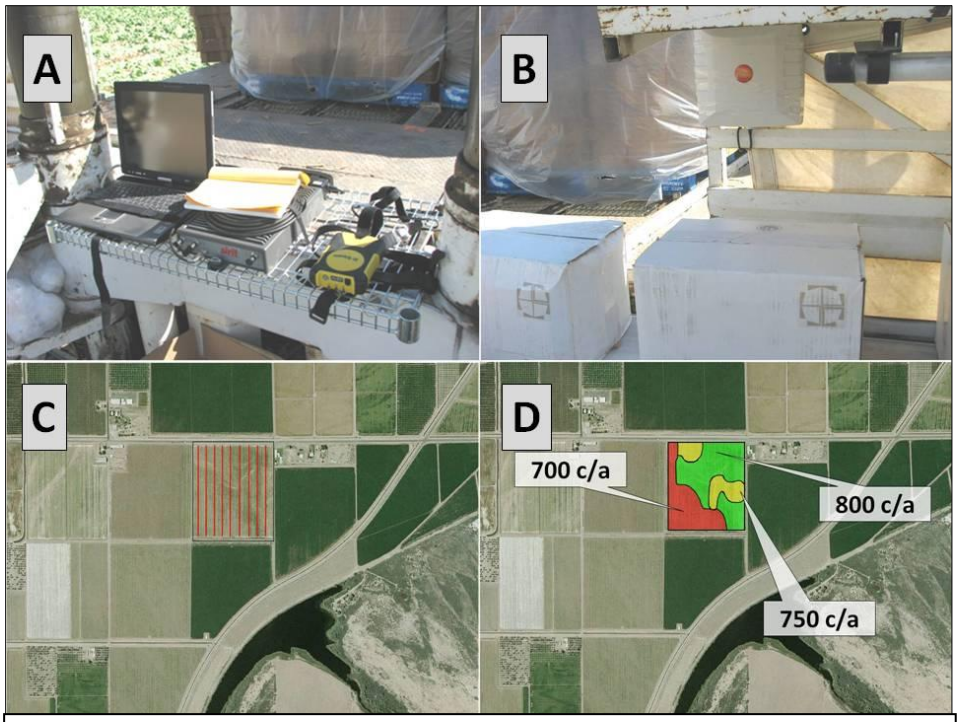

Fig. 3. Field testing of RFID Lettuce Traceback system. A, computer, wireless aircard (not shown), GPS receiver and RFID encoder installation. B, RFID antenna and label attached to lettuce carton. C, georeferenced harvest passes (red lines) within a field test. D, lettuce yield map produced from georeferenced lettuce cartons.

selected growing parameters. Essentially, the system was fixed mounted within a lettuce harvest aide (fig. 3A) with the antenna attached to the wings of the unit and hardwired to the RFID encoder (fig. 3B). Field crews filled prelabeled lettuce cartons whose RFID labels were scanned as they passed within 1 foot of the RFID antenna. At the time of interrogation by the RFID antenna, a GPS location and current time was also instantaneously encoded into the RFID tag. The system operated as designed during the 18 hours of testing. Field cartons were successfully scanned at a rate of 95% during each of the field trials. Figure 3C displays several harvest passes during 1 noted field trial. A real-time Lettuce Carton Traceback website (Fig. 4) was created which displayed actual carton harvest data and mapping to within 5 minutes of actual harvest.

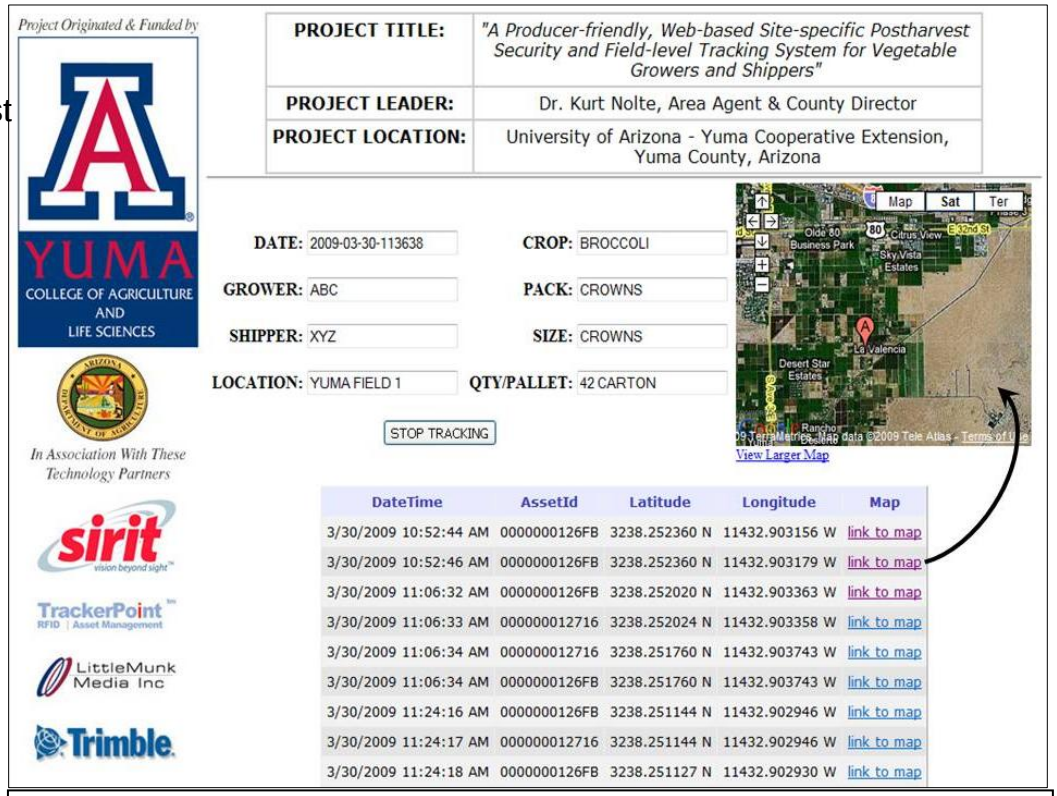

Fig. 4. Lettuce carton traceback web interface. The web site was developed specifically for the lettuce carton traceback system and serves as a point of contact for data collection and distribution for system users. The data integrates real-time individual lettuce carton harvest status and provides a map which displays harvest locations.

Georeferenced field cartons were also used to provided for the first site-specific yield evaluation of produce within the industry (fig. 3D). In 1 of the 3 fields evaluated, lettuce yields varied from 700 to over 1,000 cartons per acre.

Conclusions and Future Work

The lettuce carton traceback system shows great potential for tracking many crops harvested into cartons. The system integrates field level attributes and GPS coordinates into each carton while improving food security and efficiency of the agricultural supply chain. This system has the ability to: 1) trace back, with visualization tools, the entire transportation/movement of lettuce from

the end use/processor to storage, road transport back to the field of harvest and point of origin, 2) query the data base for information/location of lettuce with specific attributes or characteristics, 3) link to other spatial and non-spatial database for identifying other attribute information associated with the lettuce, and finally, 4) identifying alternative sources of food and export sales of lettuce if potential contamination or agro-bio-terrorism events occur. Additional work is underway to further develop and test the various components of the system. Work is also needed to further evaluate the economic feasibility of the technology

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