Full-scale precision livestock farming demonstration systems

R. Burns[1,*], S. Hawkins[1], J. Rhinehart[2], Y. Zhao[2], L. Eckelkamp[2], H. Gan[1], T. Tabler[2] and T. Rowan[2]
[1]*Biosystems Engineering and Soil Science Department, University of Tennessee, Knoxville, TN 37996, USA*
[2]*Animal Science Department, University of Tennessee, Knoxville, TN 37996, USA*
[*]Corresponding author: Robert Burns, rburns@utk.edu

Abstract

For over 100 years, Extension educators have used field demonstrations to provide farmers with the needed information to consider the implementation of new practices. Demonstration facilities provide a unique opportunity for hands-on learning, troubleshooting, and applied research opportunities. University research stations and cooperating private farms have proven to be excellent settings for field demonstrations of animal management, new crop varieties, herbicides, pesticides and tillage practices. Specialized equipment, data privacy, ownership concerns, and overall investment level have been obstacles to initiating full-scale Precision Livestock Farming demonstrations on both university and private farms. To address this challenge, Tennessee AgResearch is equipping selected research and education centers to support the applied research and demonstration of beef, broiler and dairy Precision Livestock Farming systems. This paper reports on the establishment of full-scale beef and broiler Precision Livestock Farming units at the Middle Tennessee AgResearch and Education Center in central Tennessee, and at a full-scale dairy operation at the Little River Animal and Environment Unit in eastern Tennessee. Details about the establishment of pasture-based beef facilities, four commercial broiler houses, and two robotic milking systems that will be used to support Precision Livestock Farming system demonstrations are provided. These new and updated Precision Livestock Farming research facilities will provide producers with the opportunity to see the potential impact of Precision Livestock Farming across a variety of animal species and management styles. Additionally, these facilities will allow training of producers, industry members, Extension personnel, teachers, and researchers.

Keywords: precision livestock farming, full-scale, beef, dairy, broiler

Introduction

This paper reports on the equipping of two University of Tennessee Research and Education Centers to conduct long-term, full-scale Precision Livestock Farming research for beef, dairy and broiler production. Infrastructure and equipment are being added at both The Middle Tennessee Research and Education Center (MTREC) near Spring Hill, Tennessee and at the Little River Animal and Environment Unit (LRAEU) near Maryville, Tennessee to support PLF research and demonstrations. Fifteen, 1.2 hectare beef cattle paddocks, and four commercial scale broiler grow-out facilities are currently being established at the Hickman Precision Agriculture Technology Unit at MTREC and two robotic milkers have been installed at LRAEU dairy to support this initiative.

Materials and methods

Beef precision livestock farming facility

Fifteen 1.2 hectare beef paddocks with electrical power and internet connectivity are being established at MTREC to support beef cattle PLF research. Figure 1 shows the placement of these paddocks in blue, as well as the planned cattle handling facility outlined in red. Electrical power and internet connectivity are two of the main limitations to conducting Precision Livestock Farming (PLF) research and demonstrations on forage-based cattle production systems. Establishing paddocks with both power and internet connectivity

enables operation of a variety of PLF-related equipment. The yellow pins shown on Figure 1 indicate the planned location of power and internet connectivity to be used with PLF equipment at the paddocks.

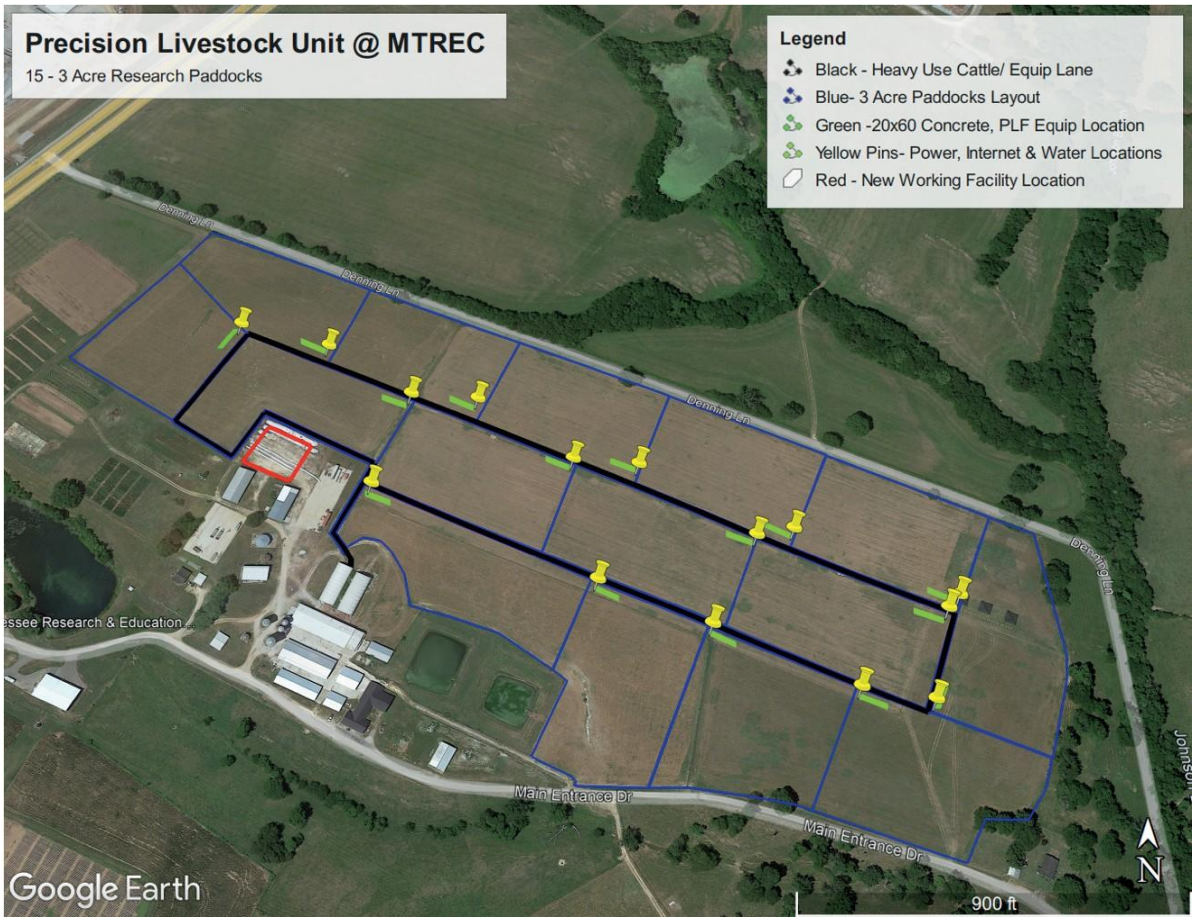

Figure 1: PLF beef research paddock layout at MTREC

Equipment for measuring feed intake, water intake, animal mass and greenhouse gas emissions will be placed in each paddock. This equipment includes C-Lock Inc. SmartScales for remote bodyweight capture and C-Lock Inc. SmartFeed Pros for precise measurement of individual feed supplementation. The SmartScale systems have been augmented with water flow meters to provide individual animal water intake as well as camera systems to collect data for animal welfare and health assessments. The camera system installed on selected SmartScale systems will be used to monitor cattle respiration, drinking behavior, and body condition. Additionally, C-Lock GreenFeed Pasture Systems are being installed to measure individual animal GHG emissions.

All cattle at the MTREC facility will be tagged with electronic identification (EID) tags that utilize devices that use radio frequency identification (RIFD) technology to connect measurements to individual animals. Woven wire fencing will be used to separate the paddocks and solar-powered automatic gates will allow robots to travel between paddocks. Each paddock will contain a shade structure with solar panels mounted to provide solar-generated power for sensors as a power back-up to hard-wired electrical power. Installation of the paddocks is expected to be completed in 2023.

Commercial broiler houses

Four commercial size broiler facilities are in the process of being planned and built at the MTREC facility. In order to conduct broiler PLF research and demonstrations in facilities that represent current commercial broiler production, the houses will be 16.7 meters wide by 182.9 meters long and will be stocked at approximately 30,000 birds per house for around five flocks of birds per year.

Figure 2: Broiler house layout at MTREC

While these houses are being constructed similar to current commercial broiler production houses, accommodations are being made to allow for the instrumentation of the houses. This will allow for monitoring of daily feed and water intake, average bird weight in each house, and cooling water use by both cool cell and sprinkler systems. Heating fuel and electrical power use for each house will also be collected continuously. Instrumentation will be installed that enables continuous monitoring of temperature, humidity, and ammonia. Instrumentation will also continuously monitor ventilation and cool cell fans/air flow rates as well as the position of ventilation inlets. Consideration will be given to alternative energy sources such as solar and geothermal energy. Currently, these alternative energy sources are somewhat cost prohibitive to the poultry industry; however, they may offer potential benefits in the future. At least one house will have an attached "viewing room" that will allow monitoring of bird behavior and activity without entering the house and disturbing the birds. Lighting is a critical welfare component in the poultry industry today. In the past, lighting has always been in the ceiling, however, will investigate gradient-style lighting systems where the lights are mounted to the feed lines to more precisely target specific areas of the house with bright and dim lighting to allow the birds to choose the type of lighting environment they wish to be in. Litter production volume will be accurately determined and the amount produced will be used to precisely fertilize fields and pastures at MTREC in Spring Hill and Lewisburg with the assistance of litter and soil analyses to match the exact amount of litter application to the needs of the crop. An onsite litter storage shed will hold the litter from the broiler houses until the appropriate time to fertilize fields and pastures and

keep the litter dry and out of the weather to prevent leaching and runoff. Rotary drum composting, the latest addition to mortality composting, will be used for daily mortality disposal. Integrator input and partnership will be vital throughout the planning, design and construction phase and key to success of research capabilities and data collection during flock grow outs. More advanced PLF equipment planned to be installed will include a rail mounted robotic systems that contains visual and thermal imaging cameras. A top-view camera system that was developed by University of Tennessee researchers will be installed to monitor the animal-based measures (ABMs), including bird activity and behavior (Nasiri et al., 2022, Yang et al., 2023). This rail system has been installed and is currently being tested in a partner commercial broiler house in Bradley County, TN. A top-view system has been developed and tested in another partner commercial broiler house. Image processing algorithms for monitoring bird activity have been developed, and algorithms for behavioural ABMs are currently being developed. Collaboration with the farm's integrator will allow for testing such experimental systems as feed line lighting systems and next generation poultry house controller designs as well was alterative water provision and disinfection systems. Integrator production data on each flock will strengthen the bird weight, feed, water, and energy use data and enhance the PLF capabilities of the unit. A separate building at the site will include shower-in and shower-out access, office space, a conference room, a wet lab, a dry lab, and storage space. A separate building will be constructed to store farm equipment, litter, and mortality composter. Broiler house construction is expected to be completed in 2025.

Robotic milker addition at dairy facility

Two Lely Astronaut A5 milking robots have been installed at the LRAEU dairy barn at the location shown in Figure 3. The red square indicates the half of the barn that will be managed using automated milking systems (AMS). The yellow square indicates the location of the AMS within the barn. These two AMS will support dairy PLF research and demonstrations at the facility. Each AMS can milk up to 60 cows approximately 3 times per day (total of 120 cows; up to 360 individual milkings per day).

Figure 3: Little River Animal and Environmental Unit dairy facility.

The AMS will collect real-time data including body weight, milk yield, milk constituents, and milk quality. In addition to the data collected by the robotic milkers themselves, cameras will be installed on the milkers in order to capture images to be used in PLF projects. The camera system includes visual and thermal cameras used to monitor the animal-based measures (ABS) such as udder skin surface temperature and infections caused by flies. Wearable PLF neck collars will also be used to identify AMS cows and collect neck activity (au/d), eating time (min/d), rumination time (min/d), and estrus detection. Figure 4. shows the current AMS construction at LRAUE including travel lanes, AMS locations, and a Lely Astronaut A5 milking robot ready for installation.

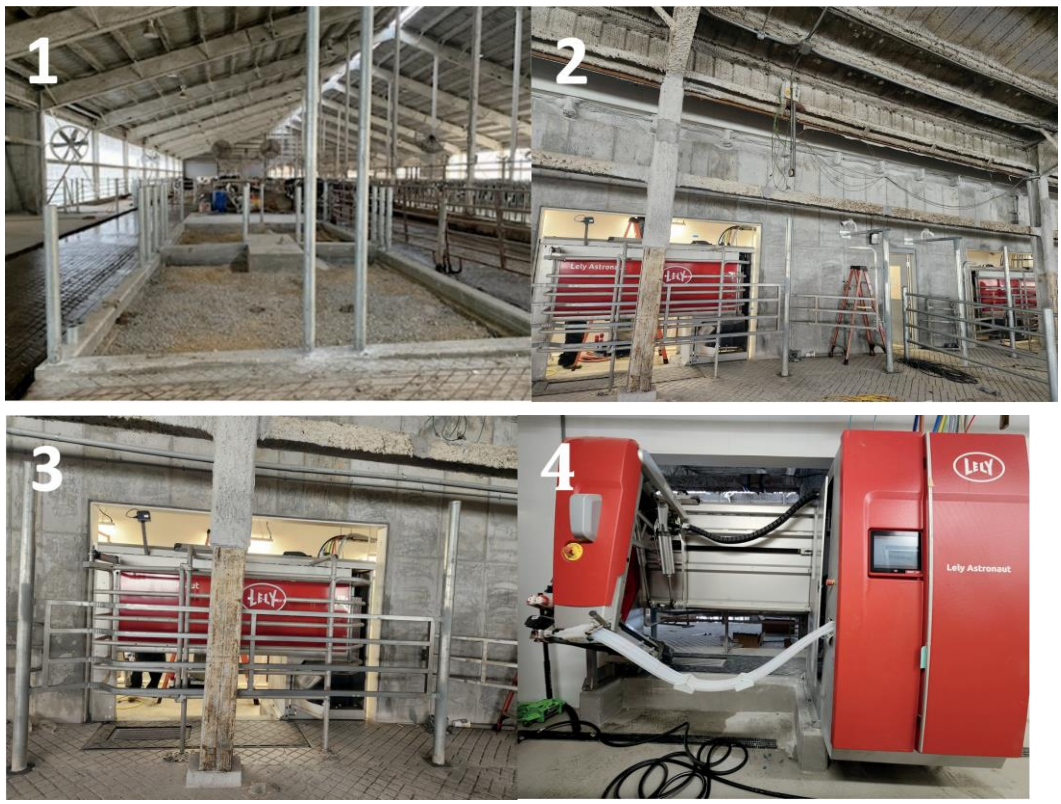

Figure 4: AMS travel lanes (1), AMS locations (2), and Lely Astronaut A5 units (3: front; 4: back).

The AMS installation is expected to be complete in Spring 2023. Projects will include ideal AMS transition strategy (n = 105 cows), labor impact, and economic impact. The transition strategy study will focus on pre-training cows assigned to one of the two AMS. These cows will be intentionally introduced to the AMS by walking through the fully open AMS on the way to the conventional parlor for milking (twice daily on days –5 to –3 with d 0 being the day of AMS start-up). On d –2 to –1, cows will also be brough to the AMS once and go through a training setting on the AMS. The training setting will open the entrance gate, provide a small amount of grain, and engage the robotic milking arm (spin and make sounds, but not go under the cow). On the day of start-up (d 0), cows will have heart rate monitors attached before entering the AMS for the first milking. Thermal imaging cameras will be used to take semi-continuous pictures of the cow's eye during milking. Heart rate variability and eye temperature change will be analyzed for signs of stress between the pre-training and control groups through the first, second, and third milking they experience. Continuous video recording will be taken and analyzed for cow's willingness to enter the AMS and exit velocity from the AMS. Data from cows on pretraining and control groups will be collected until they dry off or are culled from

the herd. Data will be analyzed for differences across milk production, milk components, milking visits, feed intake, and somatic cell count. Outcomes will include the ideal training method for cows transitioning to AMS.

A stochastic simulation model was created (Spring 2023) to assess the economic impact of investing in AMS including: total AMS number (1 to 12); construction cost (new, retrofit, or barn addition); changes in milk yield, feed cost, and labor associated with AMS; and loan rate and length. Data for stochastic simulations is based on Tennessee dairy farms captured through the Dairy Gauge program (UT Dairy and MANAGE programs collaboration).

Partnership with dairy PLF companies is being pursued to develop a short course for students, dairy producers, and industry personnel hosted at LRAEU to train the current and future workforce and customer population in PLF use and potential. In January 2023, the first cooperative meeting with Kaeb Sales was held at LRAEU dairy attracting 15 attendees. Future AMS studies will include AMS performance compared to the conventionally managed parlor (double 8 parrabone parlor with rapid exit with Boumatic milking system) at both 2x and 3x milkings.

Results and discussion

The planning, construction and acquisition of the beef, broiler and dairy PLF system infrastructure and equipment has been initiated for all of the systems described in this paper. Table 1 provides the projected completion date and estimated total budget for each facility.

Table 1: Estimated completion date and investment for UT AgResearch PLF projects

Project	Location	Projected Completion Date	Estimated Investment
PLF beef paddocks/equipment	MTREC	Fall 2023	$1.0 million
Broiler houses	MTREC	Spring 2025	$4.0 million
Robotic milkers	LRAEU	Spring 2023	$2.8 million

The PLF broiler houses are large enough expenditure that they are required to follow all state of Tennessee Building Commission regulations. As such a planning committee for the PLF broiler houses has been established to help guide the process. Committee meetings have included the MTREC director as well as partner poultry producers. Details of planning, including siting, structures, house size, equipment, utility supplies, and the collaborative broiler integrator relationship are considered by this committee.

Conclusions

The University of Tennessee AgResearch is currently investing $7.8 million in infrastructure and equipment to support full-scale PLF research and Extension outreach efforts. Famer surveys have indicated that an important potential limitation to the field adoption of PLF systems by farmers stems from a lack of system validation of many commercially available systems (Schillings et al., 2021). These full-scale PLF research sites being established by UT AgResearch will provide for the opportunity to validate and demonstrate currently available PLF systems as well as conduct new research into the development of new systems.

Acknowledgments

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