Greener Pastures: A Pasture Sanitation CPS for Environmental Enhancement and Animal Monitoring

I. Adams*, R. Wright+, L. Kroeger+, J. Hammond+, N.A. Kotey+, D. Fuka+, E. Feuerbacher+, Z. Easton+, G. Lee*, R. Quinn* & R. White+

*Case Western Reserve University; +Virginia Tech

BACKGROUND

- Non-point source runoff from livestock housed in pasture environments is thought to contribute significantly to emissions of N and P into surface waters.
- These emissions cause significant water quality and human health challenges, therefore their mitigation is of utmost importance
- Due to the diffuse nature of non-point source emissions they are particularly challenging to mitigate, thus presenting great application space for CPS investigation

CPS CONTEXT

A CPS focused on pasture manure management must:

- Accurately sense manure locations
- Model and monitor soil moisture conditions and hydrologically sensitive areas
- Autonomously pickup and redistribute manure
- Maintain stability and control in rugged environments
- Be safe around animals and designed in such a manner so as not to interfere with animal wellbeing

CPS RELEVENCE
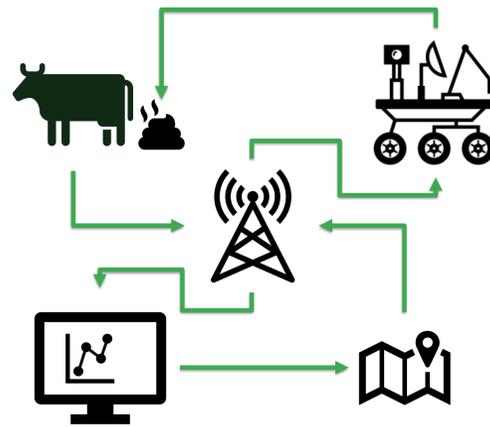
The needs of pasture management CPS generalize to other fields through:

- Algorithm development for multimodal, geospatial sensing applications
- Real-time integration of complex modeling systems with sensor data through LoRa networks
- Autonomous vehicle control, communications, actuation, and interfacing with sentient and reactive beings

PROGRESS & FINDINGS

Figure 1. Spectral sensing, which can be mounted on the robotic vehicle, shows great promise in predicting the chemical composition of forages. Dry matter, organic matter, neutral detergent fiber, acid detergent fiber, and crude protein were all predicted with high accuracy from the spectral data.
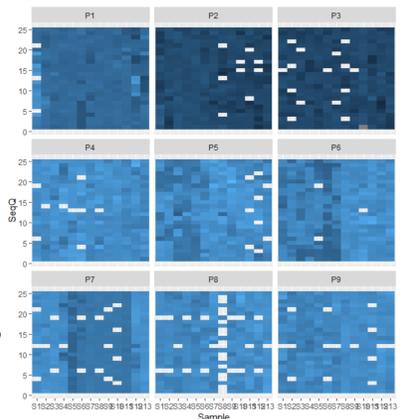
Figure 2. Animal-robot interactions can be optimized for low-stress handling. Use of familiar vehicles, integrating measurement of physiological responses, and optimizing vehicle routes to minimize direct interaction with animal all likely contribute to support improved animal wellbeing within cyberphysical sentient systems.

Figure 3. Conceptual figure showing saturated area dynamics as storm progresses from t0 to t4. Shaded area represents moisture saturated runoff contributing areas or areas with highest runoff propensity according to the VSA concept. Inset figures show a prototypical hydrograph over a precipitation (P) event. Watershed discharge (Q) is assumed to be proportional to the saturated area extent in the contributing area and the effective P over an event.
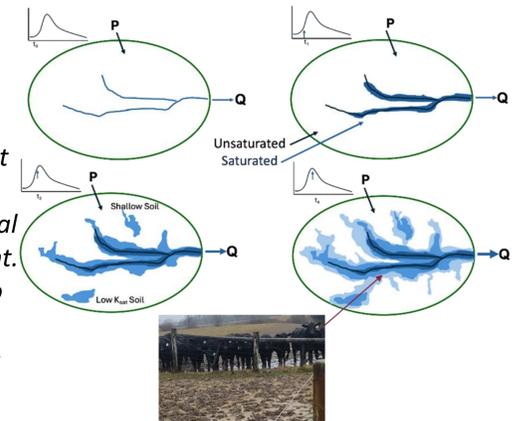
BROADENING PARTICIPATION

Study team includes 2 female faculty and 7 female graduate students, 5 from underrepresented minority populations.
In summer 2024, many of these students will contribute to a high school workshop on CPS.

EDUCATION & OUTREACH

Project findings have been extended to the community through conference presentations, papers, and workshops.
The project data is being incorporated into an undergraduate course on precision technology for Spring 2024.

QUANTIFYING IMPACTS

Economic Growth. Project findings have been communicated to 2 start-up companies for potential collaboration.
Workforce Outcomes. At least 6 graduate students and 20 undergraduates have been exposed to the project.
Scientific Knowledge. Work has resulted in 1 published paper, 2 submitted and 2 in-draft.