Giuseppe Pellizzi Prize

CLUB OF BOLOGNA

ROBOTIC FARMING ON MARGINAL, HIGHLY SLOPED LANDS

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Chetan Badgujar

Department of Biosystem Engineering and Soil Science, The University of Tennessee, Knoxville, Tennessee, United States

✉: chetanmb@utk.edu ☎: +1 785 473 8191

1 Introduction

- **Global food crisis**: around 9+ billion people to feed by 2050.
- **Opportunity:** approximately 116,000km^2 area on 12 Great Plains states are currently under 6°to 25° steep slopes, hills & uneven-terrain, that is unsafe to cultivate with conventional large farm equipment's.
- Land expansion to sloped marginal land can boost beef & grain production in Great Plains region.
- **Overall vision:** to design a fleet of small autonomous ground vehicles (AGV) to perform basic agricultural operation on highly sloped terrain.
- **Objectives:** however, the successful operation of the proposed AGV fleet on sloping terrain is mainly dependent on multiple components, targeting the following objectives:
  1) Experimental investigation on traction, mobility, and energy usage of tracked AGV on a sloped soil bin.
  2) Developing data-driven predictive behavior models of AGV on continuously sloping terrain field.
  3) Design, fabrication and experimental investigation of robotic grain drill prototype.
- **Specification of AGV:**
  - Dimensions: 1.10m×0.64m
  - Weight: 110 kg.
  - Smart-Battery system: 52 Ah & 22.2 Volts.
  - Micro-controller: NI-MyRio (National Instruments, Austin, TX, US)
  - Sensors: Current-voltage, track encoders, load cell, GPS and other for navigation purposes

Fig 1: AGV used in study.

2 Methods

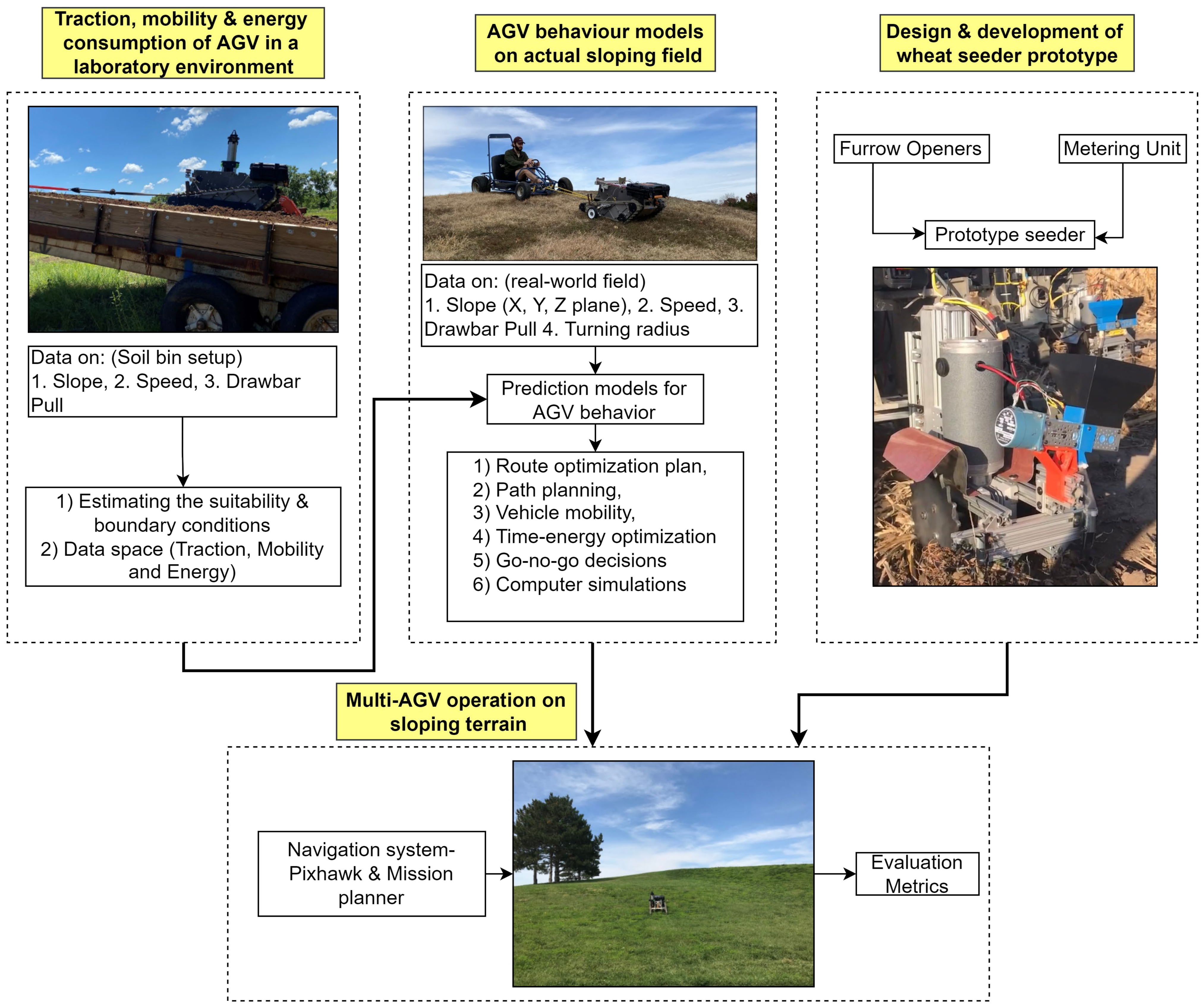

Fig 2: Component of AGV fleet performing on marginal, highly sloped land.

3 Traction Testing

Ramped-drawbar pull test (DPT) was conducted on sloped soil bin to quantify the AGV's available reserve power and help establish its performance curves[1].

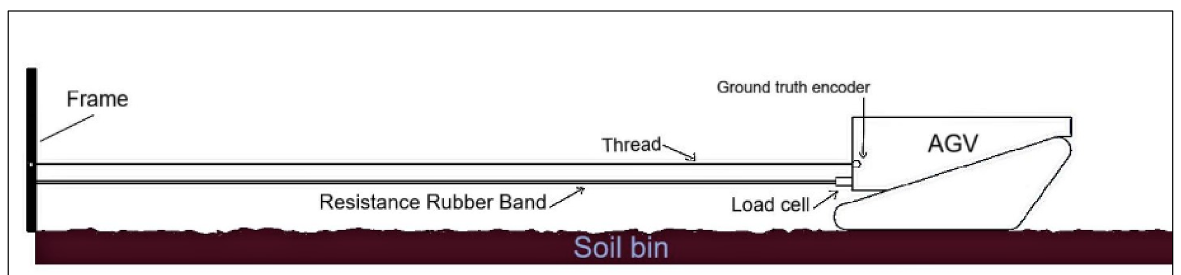

Fig 3: A conceptual drawing of drawbar pull test experimental setup.

Predictor			Response
Slope, °	Speed, (m/min)	Drawbar pull, N	
0 (S_0) 10 Uphill (S_{10U}) & Downhill (S_{10D}) 18 Uphill (S_{18U}) & Downhill (S_{18D})	1.0 2.0 3.0 4.0 5.0	Variable Pull, 0-1500 N	Power efficiency, η Travel Reduction, s Power Number, PN Energy Consumption Rate, ECR

Table 1: Experimental variables used in the study.

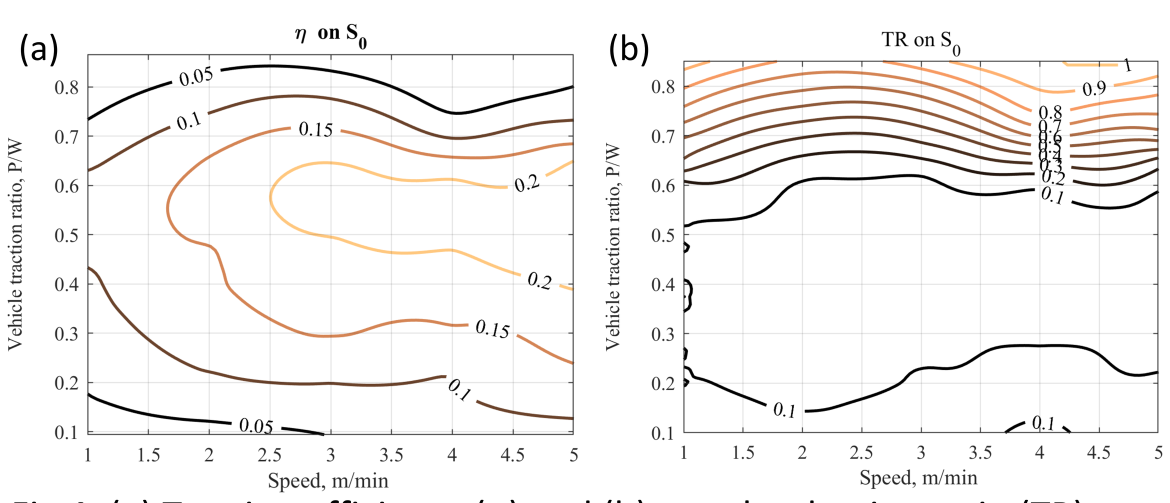

Fig 4: (a) Traction efficiency (η) and (b) travel reduction ratio (TR), as a function of AGV speed and traction ratio on flat surface.

4 Vehicle mobility models

An artificial intelligence based predictive vehicle behavior models were developed from limited sensor data[2,3,5].

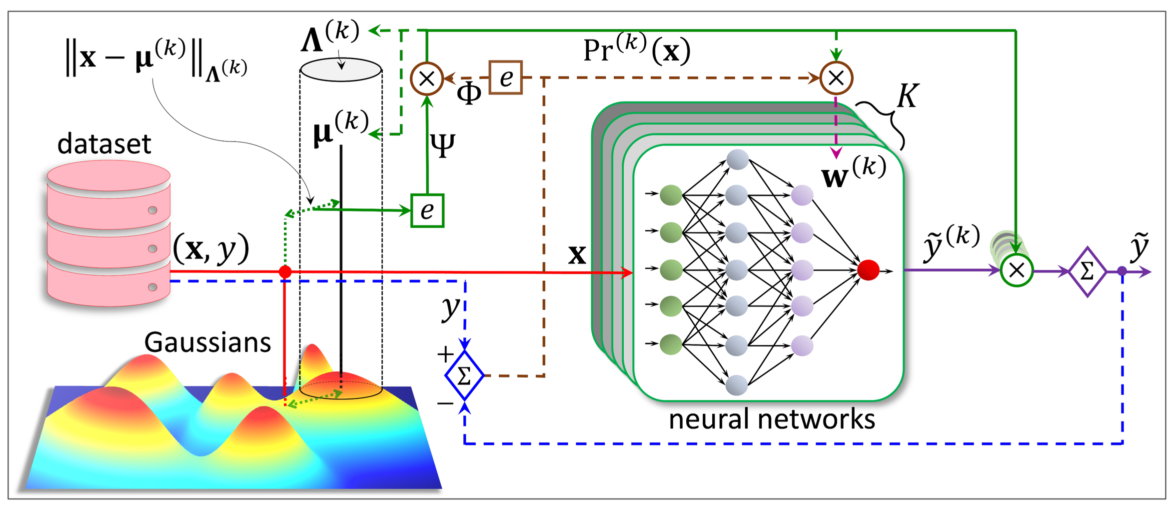

Fig 5: Schematic of proposed model, showing dataset, mixture of gaussians and deep neural networks.

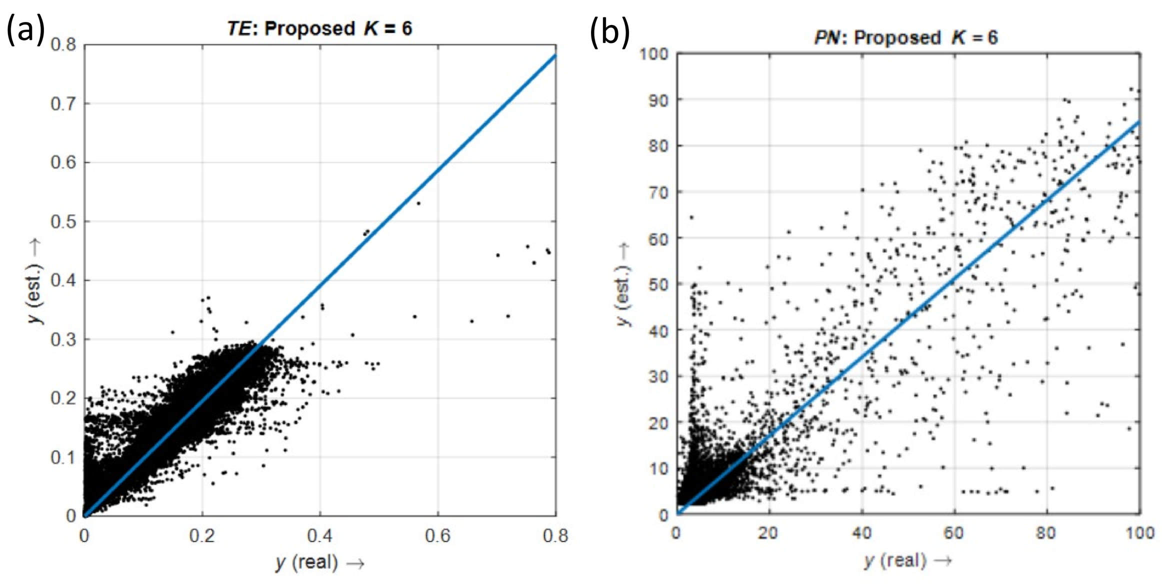

Fig 6: Scatter plots of best out of 20 trails of the proposed approach for (a) traction efficiency, TE and (b) power number, PN.

5 Grain drill prototype

Auger type metering unit was designed, fabricated and tested against auger speed, slope and vibration levels[4].

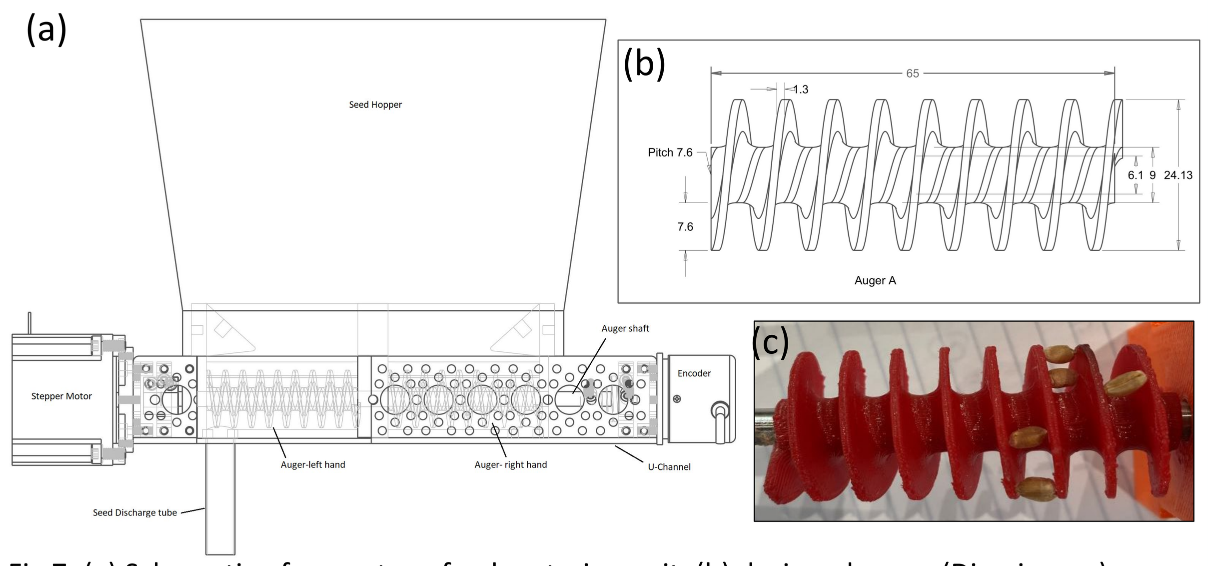

Fig 7: (a) Schematic of auger type feed metering unit, (b) designed auger (Dim. in mm) as per ASABE standard , (c) observed seed blockage on small pitch auger.

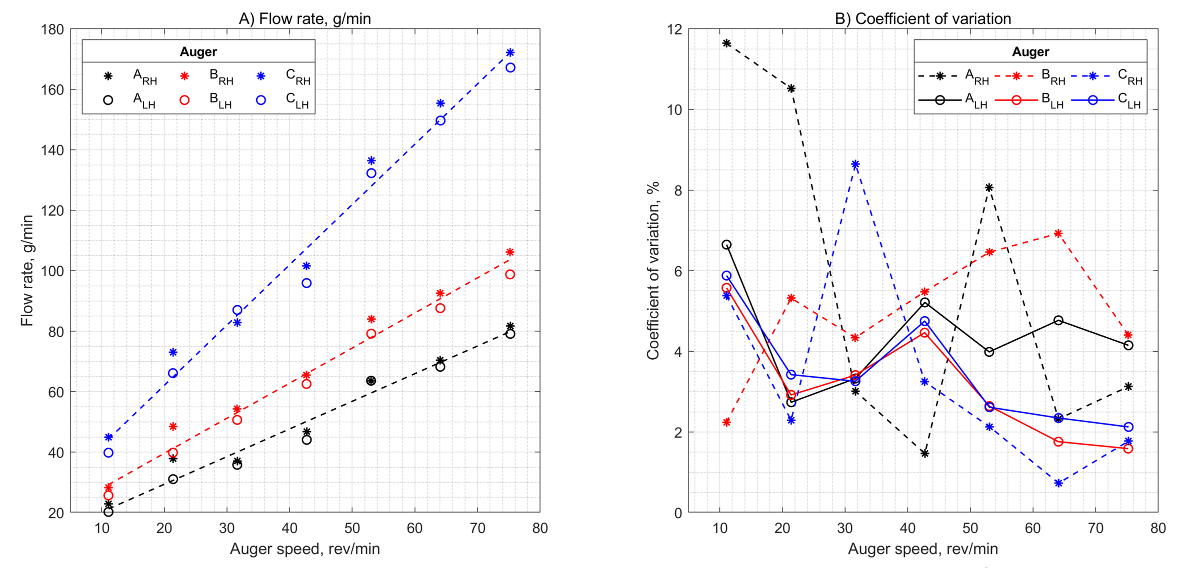

Fig 8: Influence of auger speed (rpm) on: (a) auger flow rate (g/min) and (b) coefficient of variation on three augers types (A, B & C) varying in pitch.

6 Final Remarks

- *Vehicle testing module* explored the suitability and established the boundary conditions of small size ground vehicles for a high slope farming operation.
- Results found that the AGV can successfully operate on slopes up to 18°, so high sloped terrain or hills could be farmed with the proposed AGV system.
- *Vehicle behavior component* explored the capabilities of machine learning algorithms to simulate the AGV's behavior on sloping terrain.
- Predictive models can empower the AGV system operation in a dynamic agricultural environment by assisting in vehicle control variables optimization, and decision making.
- *Grain drill prototype system* established the experimental relationship between flow rate, auger speed, slope and vibration, to control the seed rate on varying terrain.
- This study delivers a bulk feed mechanism for wheat drilling, which can be easily scaled and adopted by small autonomous vehicles or mobile robots.
- *Overall, the study explores the potential of automation and applied robotics to solve the emerging challenges in our food production systems.*

Reference:

1. Badgujar, Chetan, Flippo, D., Brokesh, E., & Welch, S. (2022). Experimental Investigation on Traction, Mobility & Energy usage of the Tracked Autonomous Ground Vehicle on a Sloped Soil Bin. Journal of the ASABE. https://doi.org/10.13031/ja.14860
2. Badgujar, Chetan, Flippo, D., & Welch, S. (2022). Artificial neural network to predict traction performance of autonomous ground vehicle on a sloped soil bin and uncertainty analysis. Computers and Electronics in Agriculture, 196. https://doi.org/10.1016/j.compag.2022.106867
3. Badgujar, Chetan, Das, S., Flippo, D., Martinez, D., & Welch, S. (2023). Deep neural network to predict the autonomous ground vehicle behavior on sloping terrain. Journal of Field Robotics. https://doi.org/10.1002/rob.22163
4. Badgujar, Chetan, Hui, W., Flippo, D., & Brokesh, E. (2022). Design, fabrication, and experimental investigation of screw auger type feed mechanism for a robotic wheat drill. Journal of ASABE. https://doi.org/10.13031/ja.15199
5. Martinez-Figueora, D., Das, S., Badgujar, Chetan, Flippo, D., & Welch, S. J. (2022). A Distributed Approach for Robotic Coverage Path Planning Under Steep Slope Terrain Conditions. 2022 IEEE SSCI. https://doi.org/10.1109/SSCI51031.2022.10022252