Applications of Precision Livestock Farming within the Beef Industry

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Kentucky Beef Production-Pasture

- #1 Beef Producer East of the Mississippi
- 32,000 producers with ~2.1 million cow/calf pair
  - Average 27 head/farm
- Rule of thumb is 2 acres per cow/calf pair
- Background 600 lbs → 800 lbs over the summer

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Producer Challenges

- Most producer's primary income source is off the farm
- Time to monitor cattle is limited
  - Especially in the winter months
- Average age of farmers has been steadily increasing
  - 57 years as of 2022

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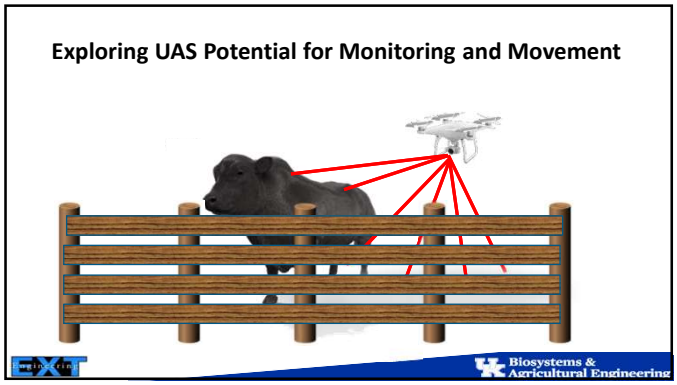
Exploring UAS Potential for Monitoring and Movement
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MUD!!

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Alternative: NRCS Projects

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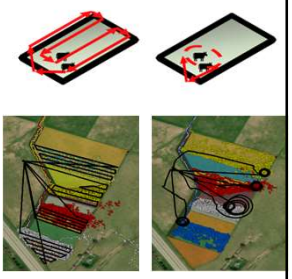
Cattle Response to UAS

- Two different flight treatments on heifers (2 heifers/pasture)
  a) 25-30 ft above ground level (AGL) grid over field (simulate pasture monitoring/influence of lower altitude)
  b) 25-30 ft AGL circular flight around cow (cow evaluation)
- Flight Characteristics
  - Five minutes of flight per pasture
  - Average speed 2.3 m/s (5 mph)
- Behavioral/physiological response to UAV
  - Cow location
    - Land Air Sea® trackers
  - Cow heart rate
    - Polar® H10
    - Polar® Equine electrode set



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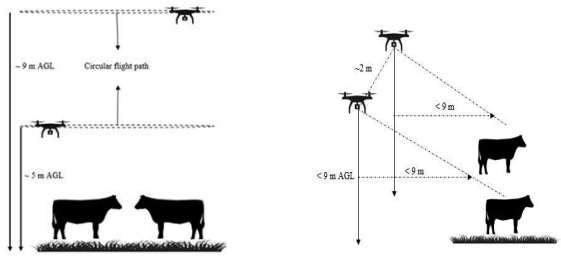
Cattle Response to Multiple UAS



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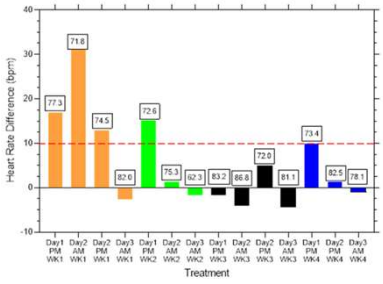
Circular Pattern Heart Rate @ ~9 m



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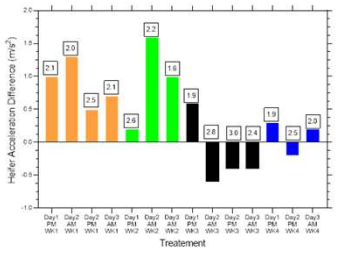
Circular Pattern Movement Rate @ ~9 m



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Item	Circular Pattern Flights			Approach Style Flights		
	Preflight [b]	UAV Flight [c]	P-value	Preflight [b]	UAV Flight [c]	P-value
Heart Rate (bpm) [d]						
Week 1	77.6 ± 3.4	92.7 ± 3.4	0.002	84.3 ± 3.3	97.5 ± 3.3	0.008
Week 2	70.9 ± 4.5	74.3 ± 4.6	0.514	83.6 ± 3.5	85.7 ± 3.5	0.577
Week 3	84.2 ± 3.3	80.6 ± 3.3	0.358	82.7 ± 3.4	91.2 ± 3.4	0.036
Week 4	78.1 ± 3.9	80.9 ± 3.9	0.550	77.4 ± 3.9	81.6 ± 4	0.377
Acceleration (m/s^2) [c]						
Week 1	2.1 ± 0.18	3 ± 0.18	<.0001	2.1 ± 0.18	2.8 ± 0.18	0.002
Week 2	2.1 ± 0.21	3.1 ± 0.21	<.0001	2.3 ± 0.2	2.8 ± 0.2	0.054
Week 3	2.3 ± 0.2	2.3 ± 0.2	0.984	2.4 ± 0.18	2.8 ± 0.18	0.043
Week 4	2.1 ± 0.23	2.2 ± 0.23	0.748	2 ± 0.19	2.4 ± 0.19	0.090

Least square mean of heifer HR and acceleration within weeks ± SEM
[b] Preflight, 30 minutes prior to all UAV flights
[c] UAV Flight, Four (4) minute of UAV flight in pasture
[d] bpm, beats per minute.

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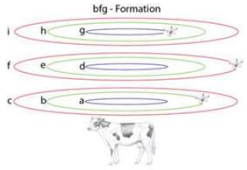
Photogrammetry Using a Drone Test

- a = 10ft (altitude) X 10ft (radius)
- b = 10ft (altitude) X 20ft (radius)
- c = 10ft (altitude) X 30ft (radius)
- d = 20ft (altitude) X 10ft (radius)
- e = 20ft (altitude) X 20ft (radius)
- f = 20ft (altitude) X 30ft (radius)
- g = 30ft (altitude) X 10ft (radius)
- h = 30ft (altitude) X 20ft (radius)
- i = 30ft (altitude) X 30ft (radius)



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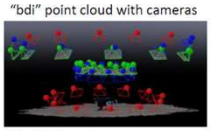
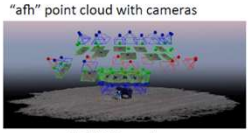
Drone with Multiple Targets

"bdi" point cloud with cameras



"afh" point cloud with cameras



"bdi" 3D mesh

"afh" 3D mesh

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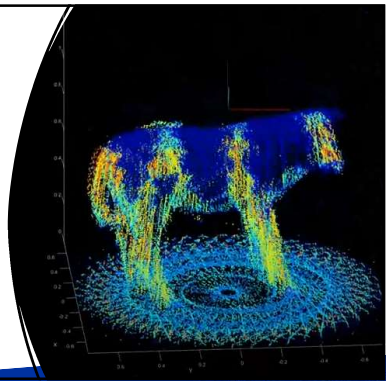
LIDAR-Light Detection and Ranging

- Velodyne
- https://www.youtube.com/watch?v=RGkFAidZBTA



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Monitoring of Cattle

- Cowmanager
- Eating, ruminating, activity, heat
- Each solar unit is ~$2,500

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How much forage is in the field??

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2017 UK Study

- 25 Acre Field
  - Twenty 1 m^3 quadrats
  - Weekly measurements across entire season
- Phantom 4 Pro
  - Standard camera system-20 MP (30 frames/sec, 4k UHD)
  - 30 ft Above Ground Level (AGL) 30-40 ft radius
- Post-processing
  - Pix4d

(Dvorak, et al. 2021).

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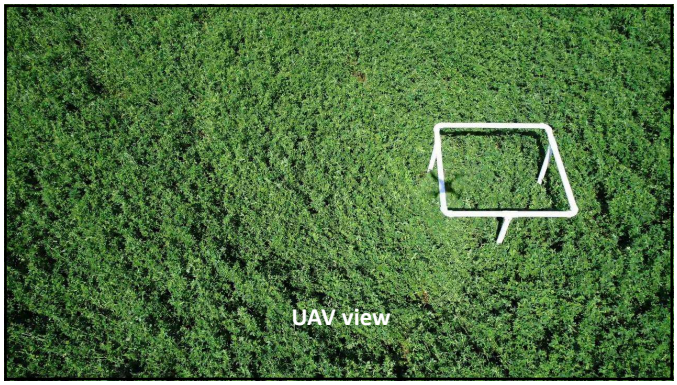

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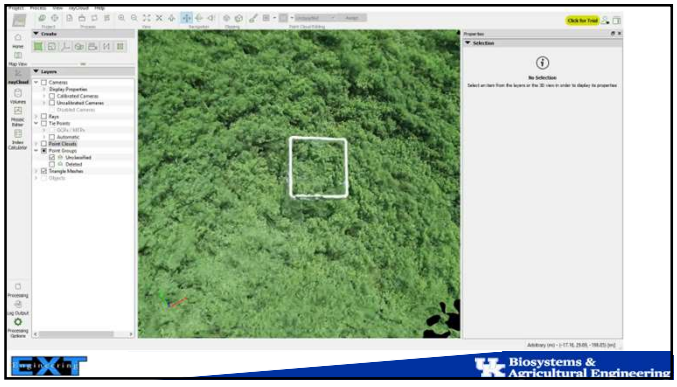

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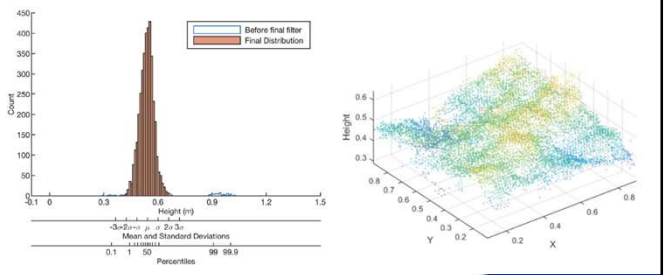
After Filtering



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Machine Learning

- Regression trees, support vector machines, tree ensembles, Gaussian random processes (GRP), and linear regressions
- 10-fold cross validation
- Variables
  1. Mean canopy height
  2. Standard deviation in canopy height
  3. Maturity
  4. Weed pressure
  5. Disease pressure
  6. Pest pressure

Table 2. Weed pressure evaluation scale.

Value	Weed Pressure
0	<5% weeds present
1	5% to 20% weeds
2	20% to 40% weeds
3	40% to 60% weeds
4	60% to 80% weeds
5	>80% weeds present

Table 3. Insect and disease damage scale.

Value	Insect/Disease Pressure
0	<5% insect/disease damage present
1	5% to 20% insect/disease damage
2	20% to 40% insect/disease damage
3	40% to 60% insect/disease damage
4	60% to 80% insect/disease damage
5	>80% insect/disease damage

Table 4. Maturity stage evaluation (adapted from Kalu and Fick, 1981).

Value	Stage	Description
0	Early vegetative	<15 cm tall; no buds, flowers, or seed pods
1	Mid vegetative	15-30 cm tall; no buds, flowers, or seed pods
2	Late vegetative	>30 cm tall; no buds, flowers, or seed pods
3	Early bud	1-2 nodes with buds; no flowers or seed pods
4	Late bud	≥3 nodes with buds; no flowers or seed pods
5	Early flowering	Minimum of 1 open flower on main stem; no seedpods
6	Late flowering	Minimum of 1 open flower on main and axillary stems; no seedpods
7	Early seed pod	Green seedpods on main stem
8	Late seed pod	Green seedpods on main and axillary stems
9	Mature seed pod	Nodes have mostly brown mature seedpods

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Yield and Quality Results

Model	Neutral Detergent Fiber	Acid Detergent Fiber	Crude Protein	Yield	Yield RMSE (lbs/acre)
Two variables	0.62	0.63	0.62	0.63	712
Three variables	0.72	0.76	0.72	0.69	654
Six variables	0.78	0.81	0.79	0.81	532

GPR with rational quadratic kernel function

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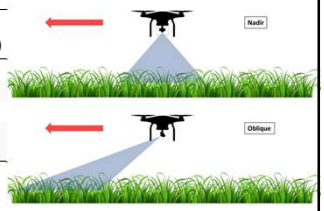
2019 KY Flight Parameters

Phantom 4 Pro	1 (164–90°)	2 (164–75°)	3 (98–90°)
Elevation (ft)	164	164	98
Speed (mph)	12.7	12.7	7.4
Gimbal Angle [a]	−90.0°	−75.0°	−90.0°
Resolution (cm px⁻¹)	1.4	2.2	0.8



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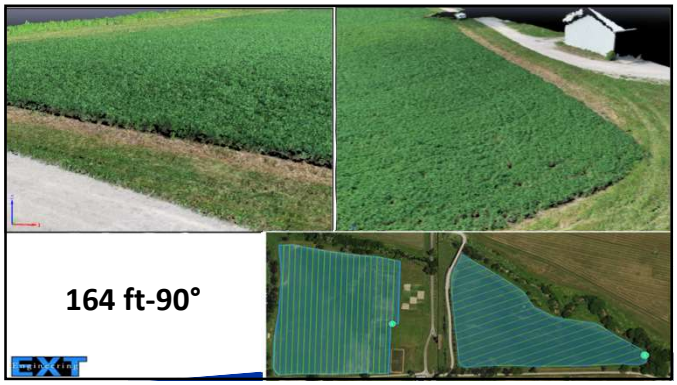

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Results

Flight Parameters (Height (ft3800) - Gimbal Angle)	3-Variable Model RMSE (lbs/acre)[a]	3-Variable Model R^2	2-Variable Model RMSE (lbs/acre)[a]	2-Variable Model R^2	Average (Both) RMSE (lbs/acre)[a]	Average (Both) R^2
Quadrat Only	809	0.71	732	0.6	770	0.65
98–90°	695	0.68	800	0.3	747	0.49
164–90°	932	0.55	861	0.35	896	0.45
164–75°	437	0.87	315	0.84	376	0.85
Combined	1158	0.53	1207	0.47	1182	0.5
Average	807	0.67	783	0.51	794	0.59

[a] Maximum Yield was 3390 lbs/acre

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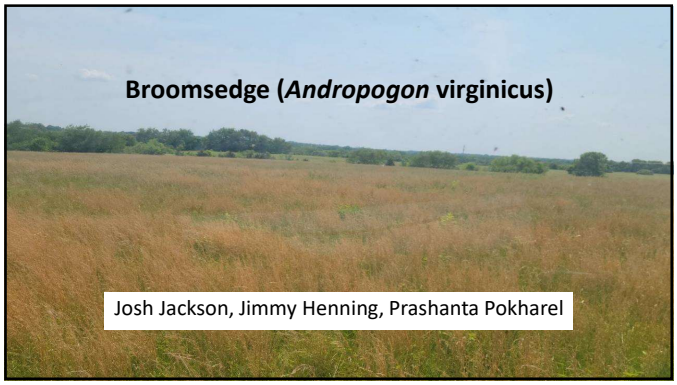

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Background

- A native perennial warm season C4 grass-southeast, east, midwest
- Weed (pastures or hay fields)
  - Livestock
    - Low palatability & digestibility
- Soil fertility indicator
  - P, K, pH < 6.4
- Overgrazing
  - Patches

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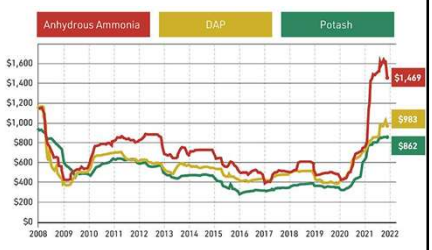
The Challenge

- Cost of fertilizer
- Low input management
  - Hay fields
  - Pastures



https://www.thedailyscoop.com/news/retail-business/3-strategies-manage-around-high-fertilizer-prices
USDA AMS

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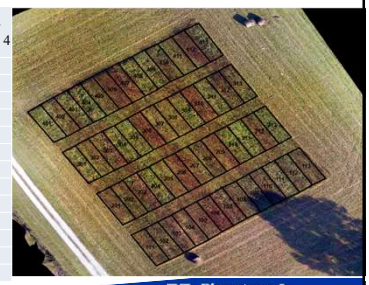
Fertilizer Treatments

Fertilizer Treatment N,P_2O_2,K_2O	Plot-Range 1	Plot-Range 2	Plot-Range 3	Plot-Range 4
0-0-0	101	206	306	407
0-0-180	102	212	307	412
0-0-360	103	201	302	402
0-40-0	104	209	310	406
0-40-180	105	207	312	411
0-40-360	106	202	308	405
180-0-0	107	208	311	408
180-0-180	108	204	304	401
180-0-360	109	210	305	404
180-40-0	110	203	303	413
180-40-180	111	213	309	409
180-40-360	112	211	301	403
38-38-38	113	205	313	410



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Management

- Hay field for over 10 years
- Fertilized annually with 200 lbs/acre Triple-19 (19-19-19) (N-P-K)
- Soil test
  - pH = 6.2, Phosphorous (P) = 72 lbs/acre, and Potassium (K) = 57 lbs/acre
- Tall fescue nutrient removal (lbs/3.5 tons of production)
  - 130 lbs N, 42 lbs P_2O_5, and 189 lbs K_2O

Category	Test Result: P	Test Result: K	Hay K_2O Needed
Very High		>420	0
High	>60	321-420 301-320	30 40
Medium	46 – 60 41 – 45 37 – 40 33 – 36 28 - 32	267 – 300 240 – 266 213 – 239 187 - 212	50 60 70 80
Low	23 – 27 19 – 22 14 – 18 9 – 13	159 – 186 132 – 158 104 - 131	90 100 110
Very Low	<9	<104	120

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Flight Characteristics

- Flights conducted in Powell County
- October, 2018-2020
- Harvested 3x per year
- DJI Phantom 4 V2
  - Standard Camera 1-inch 20 MP CMOS
  - 50 ft AGL with 80% front/side overlap
  - 0.4 in/px
  - Stitched using DroneDeploy

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Visual Index for Standard Images (red-green-blue)

- Green leaf index (GLI)
  - $GLI = \left(\frac{2Green-Red-Blue}{2Green+Red+Blue}\right)$
- Visible atmospherically resistant index (VARI)
  - $Vari = \left(\frac{(Green-Red)}{(Green+Red-Blu\ )}\right)$

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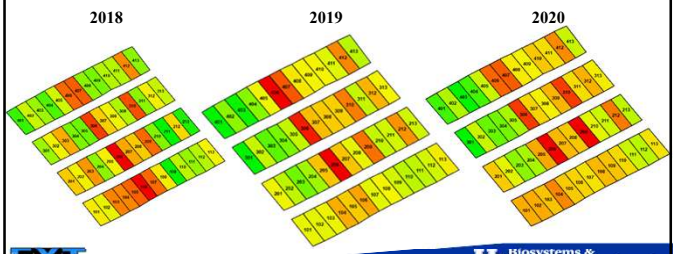
Visible Atmospherically Resistant Index (VARI)



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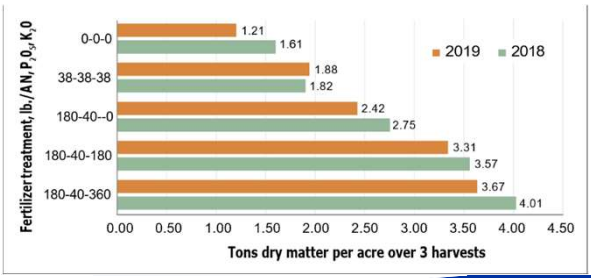
Effect of Potassium (K_2O) on Mixed Grass Hay Yield



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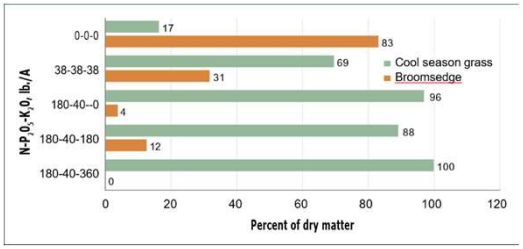
Botanical Composition Nov. 2019



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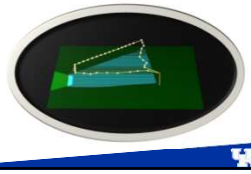
UAS Fence Line Monitoring

- ~7,300 ft is the breakeven distance compared to walking
- ~7.5 MPH is the breakeven UAS speed



Duration (Minutes)	Distance of Fence Line Inspected (feet) Walking at 3.1 MPH	UAS Flight at 7.5 MPH
1	270	Preflight Prepa-
2	540	ration
3	810	
4	1080	660
5	1350	1320
6	1620	1980
7	1890	2640
8	2160	3300
9	2430	3960
10	2700	4620
11	2970	5280
12	3240	5940
13	3510	6600
14	3780	7260
15	4050	Postflight Prepa-
16	4320	ration
17	4590	Video Analysis
18	4860	
19	5130	
20	5400	
21	5670	
22	5940	
23	6210	
24	6480	
25	6750	
26	7020	
27	7290	

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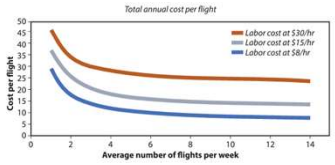
UAS Cost

- UKY- AEN-160 Decision Aid for Estimating the Cost of Using a Drone in Production Agriculture
- $1-2 per acre for standard flights
  - $1,800/year post-processing software
  - $2,600 drone and other equipment
  - $600 insurance
  - ~52 flights per year & 50 acre/flight



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