Using of GNSS and Field Data to Evaluate Working Performance of Mechanical Sugarcane Harvesters

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ASEAN IVO Forum 2017 Nov. 23, 2017
Bandar Seri Begawan, Brunei Darussalam

Sugarcane Production

- Thailand is a major sugarcane producer of the world
  - >1.4 M Ha
  - >100 M tons
    - Sugar
    - Ethanol & biomass fuel (<1%)

Sugarcane Harvesters

$$\text{Efficiency} = \frac{\text{Actual Capacity}}{\text{Theoretical Maximum Capacity}}$$

$$\text{Field Efficiency} = \frac{\text{Total Area / Actual Time}}{\text{Row Spacing} \times \text{Optimum Speed}}$$

$$\text{Time Efficiency} = \frac{\text{Time with no loss}}{\text{Total Time}} = \frac{\text{Active Time}}{\text{Total Time}}$$

FACTORS AFFECTING FIELD EFFICIENCY

Machine maneuverability

Field shape & size

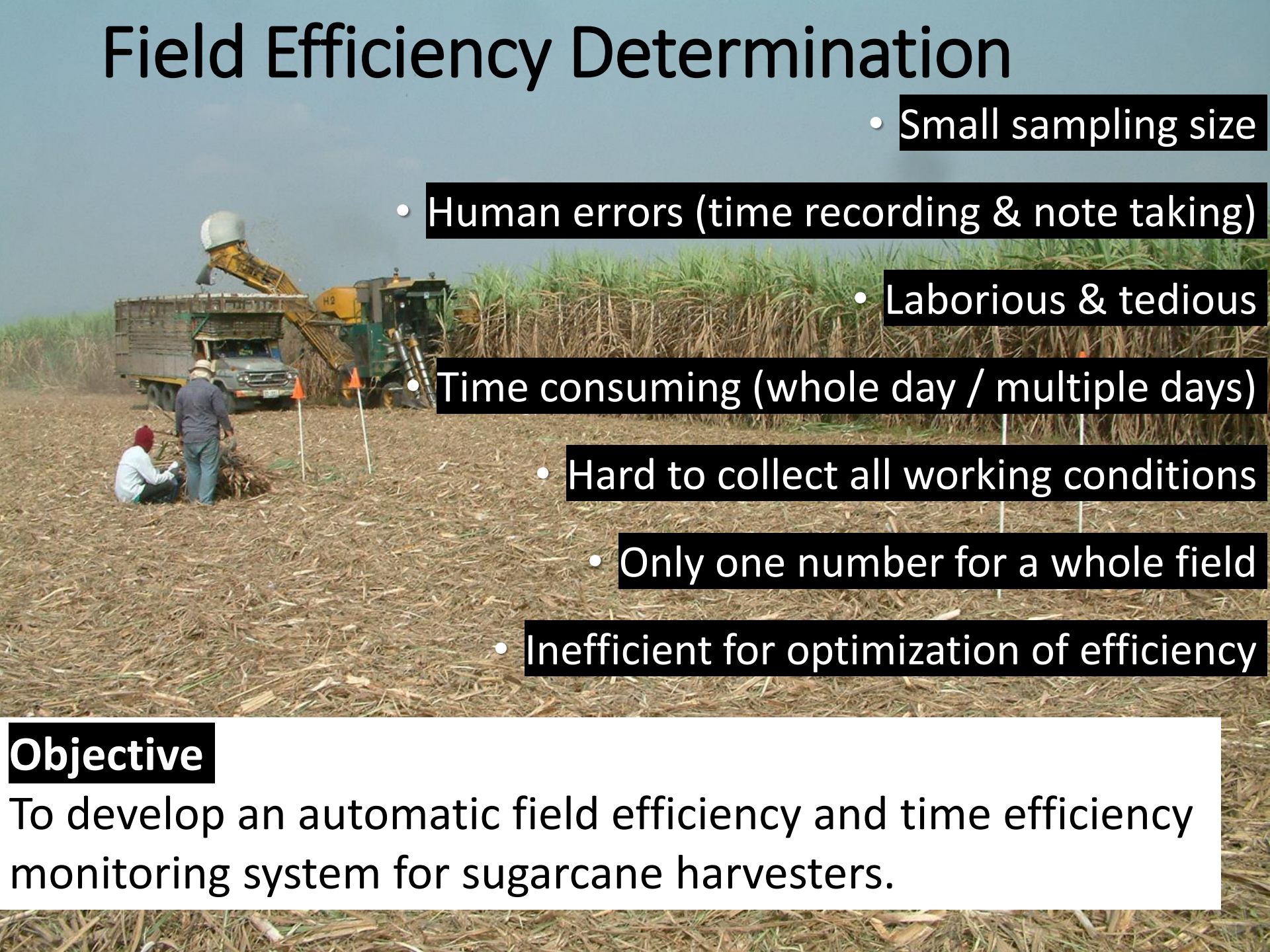
Soil & crop conditions

Field traffic patterns

Operator skills

System limitations

Field Efficiency Determination



- Small sampling size
- Human errors (time recording & note taking)
- Laborious & tedious
- Time consuming (whole day / multiple days)
- Hard to collect all working conditions
- Only one number for a whole field
- Inefficient for optimization of efficiency

Objective

To develop an automatic field efficiency and time efficiency monitoring system for sugarcane harvesters.

Operational Efficiency

$$\text{Field Efficiency} = \frac{\text{Total Area / Actual Time}}{\text{Row Spacing} \times \text{Optimum Speed}}$$

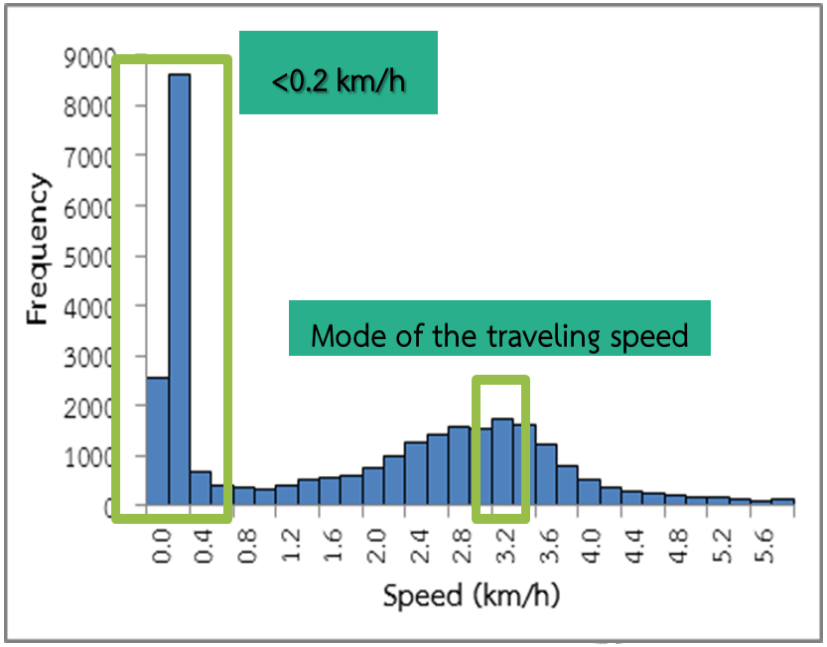
GNSS speed

$$\text{Time Efficiency} = \frac{\text{Time with no loss}}{\text{Total Time}} = \frac{\text{Active Time}}{\text{Total Time}}$$

GNSS time
+ Cutting Status Sensor

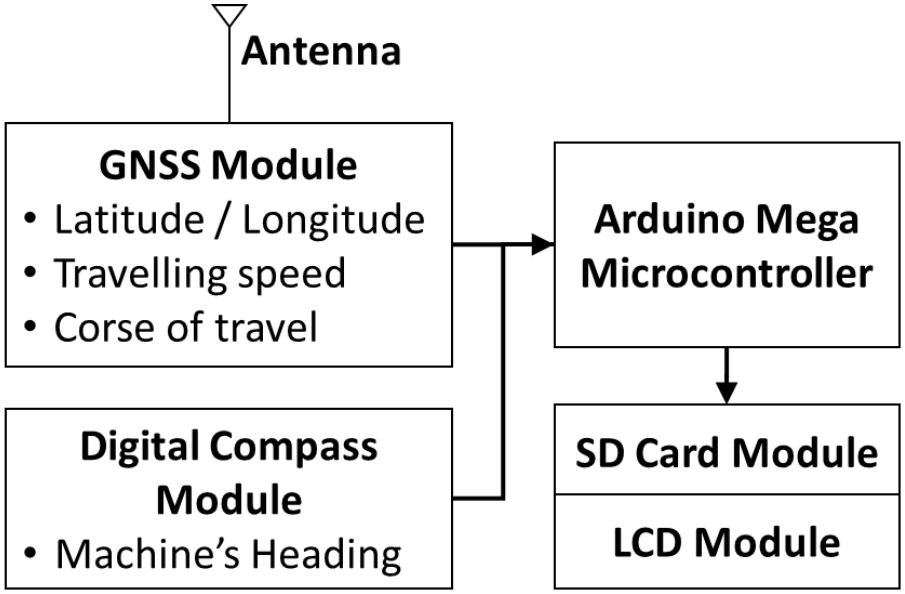
Lost Time (Time without cutting operation)

- Turning
- Loading / unloading materials
- Obstructers & field conditions
- Adjustment, maintenance & breakdown
- Operator's personal time

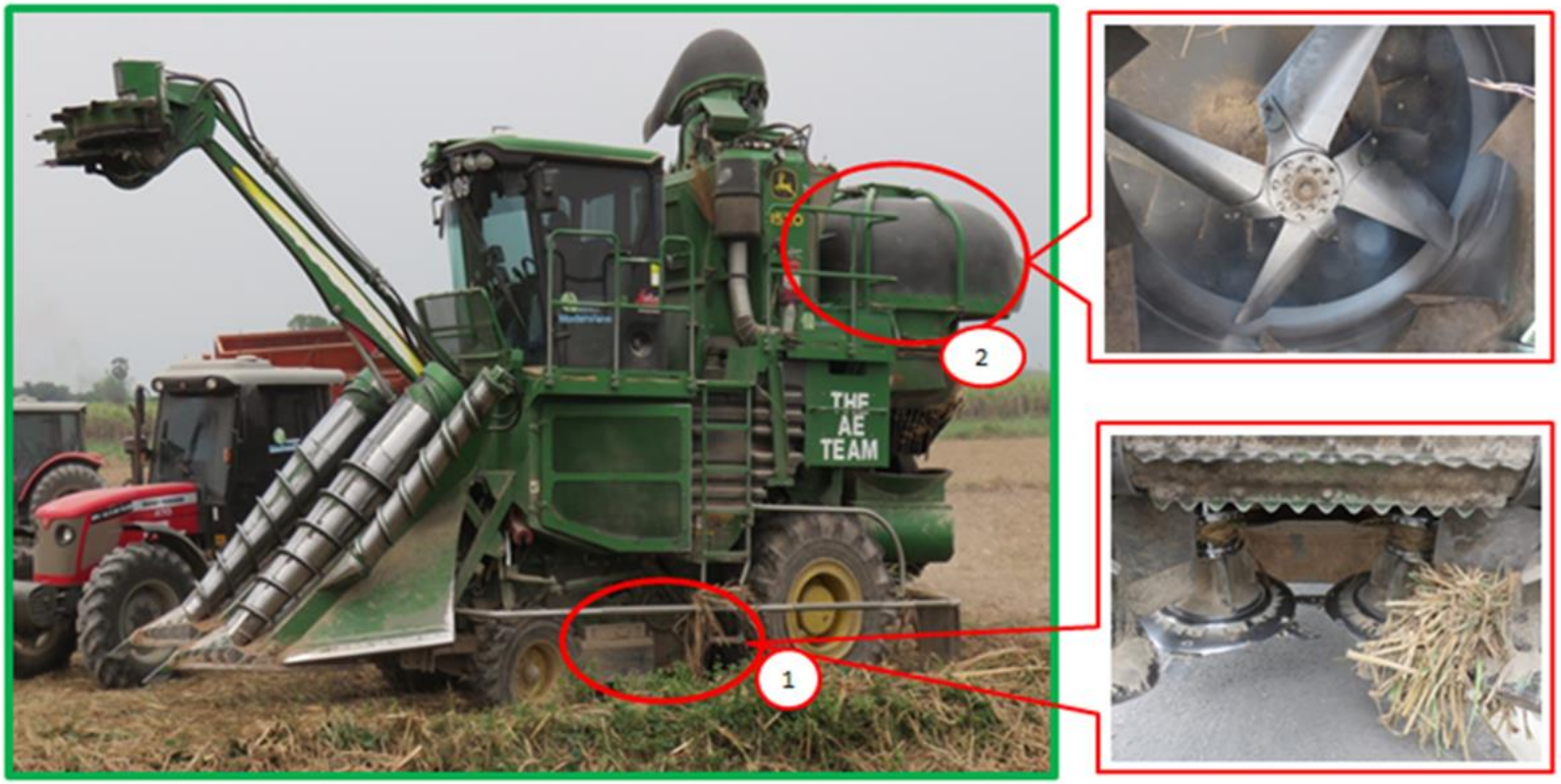


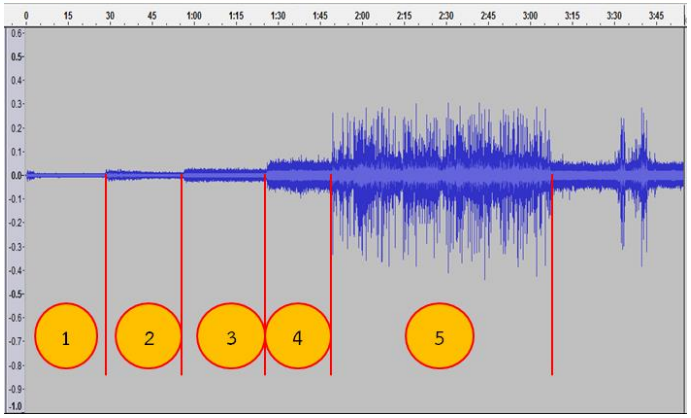
Monitoring System

- Arduino MEGA Microcontroller
- GNSS module (U-blox NEO M8N, GPS+GLONASS L1) + Antenna
- 3-Axis Digital Compass Module (Honeywell HMC5883L)
- SD card Module
- In-cab Camera



Acoustic Cutting Status Detector



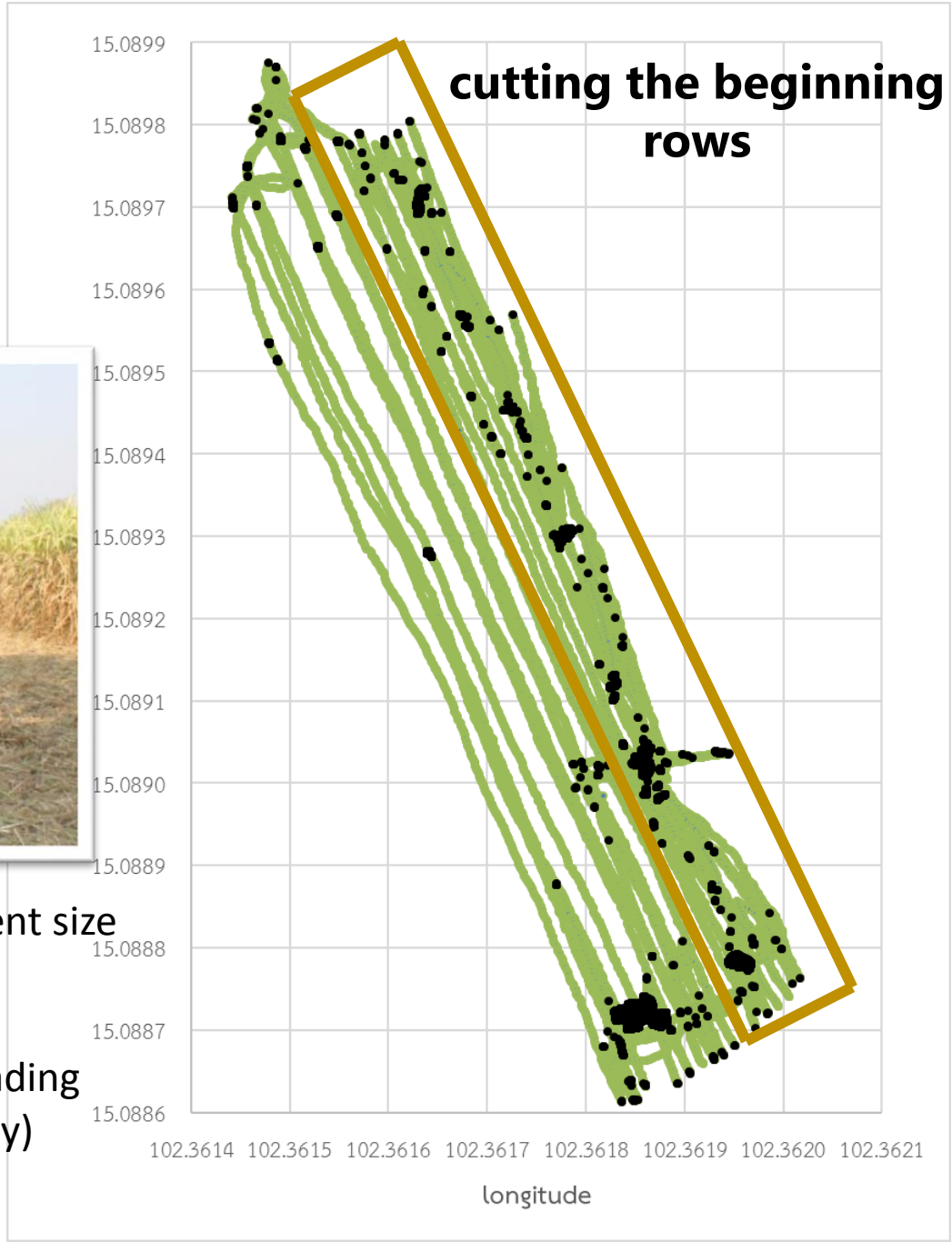


- However, noises from the other parts of the machine were much greater than the cutting sound, leading inconsistence of the detection
- This study used the recorded video for manually classifying of the operational status


• Active Time 2:16:40 hr
• Total Time 5:04:00 hr
➔ Time Efficiency = 45.0%
0.95 ha
1st truck: 19.6 ton
2nd truck: 20.3 ton
3rd truck: 9.8 ton
Total yield: 49.7 ton / 0.95 ha
Image © 2014 CNES / Astrium
Google earth

Case study

- Low efficiency in the beginning rows due to field accessibility



- 6 fields from 3 Harvesters with different size
- Comparing efficiencies
  - The whole field
  - Discarding data from the first loading truck (that facing low accessibility)

Result

Field Efficiency	240 Hp		290 Hp		340 Hp	
	Field 1	Field 2	Field 3	Field 4	Field 5	Field 6
Area (ha)	0.64	0.32	1.36	0.80	1.17	0.48
Actual Capacity (ha/h)						
- Whole Field	0.18	0.23	0.29	0.20	0.29	0.27
- Without beginning rows	0.29	0.27	0.35	0.39	0.34	0.31
Theoretical Capacity (ha/h)	0.49	0.45	0.67	0.53	0.50	0.48
Field Efficiency (%)						
- Whole Field	37.4	50.3	43.4	38.2	58.0	56.6
- Without beginning rows	59.4	60.1	52	72.8	67	80.2
The Improvement (%)	**+22.0**	**+9.8**	**+8.6**	**+34.6**	**+9.0**	**+23.6**

Time Efficiency	240 Hp		290 Hp		340 Hp	
	Field 1	Field 2	Field 3	Field 4	Field 5	Field 6
Area (ha)	0.64	0.32	1.36	0.80	1.17	0.48
Active Time (h)						
- Whole Field	1:37	0:44	2:24	1:45	2:04	1:04
- Without beginning rows	1:02	0:10	1:51	0:58	1:45	0:32
Total Time (h)						
- Whole Field	3:29	1:25	4:40	3:56	3:59	1:46
- Without beginning rows	1:55	0:17	2:31	1:39	3:04	0:50
Time Efficiency (%)						
- Whole Field	46.6	52.0	51.7	44.7	51.7	60.6
- Without beginning rows	53.9	57.9	73.5	59.5	56.9	64.7
The Improvement (%)	**+7.3**	**+5.9**	**+21.8**	**+14.8**	**+5.2**	**+4.1**

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Conclusion

- A system to monitor sugarcane harvester activities was developed using a low-cost GNSS system
- Field Efficiency could be evaluated using GNSS velocity information
- Time Efficiency determination required additional cutting status detector for automatic monitoring
- Example showed the clear improvement of having good accessibility to the field. However, more field data is required for a robust conclusion

Future work

- Sensors
  - Cutting Status Sensors
  - Image processing to evaluate operator & field conditions
  - Yield sensing
  - Wireless data transfer
- Positioning Accuracy
  - Higher accuracy GNSS systems, Multi-GNSS
  - IMU for dynamics of the harvesters
- Synchronization with loading trucks
  - More GNSS unit
- Whole season data from many harvesters
  - Efficiency prediction models from field data
- Spatial-variability maps of field efficiency
  - Field-level optimization and advices for efficiency
- Practical computerized harvester scheduling system
  - Optimum time-fuel consumption
- Applying for other ag. machines

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THANK YOU

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