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

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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

Efficiency = \( \frac{\text{Actual Capacity}}{\text{Theoretical Maximum Capacity}} \)

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

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

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

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

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 inconsistency 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%

1st truck: 19.6 ton
2nd truck: 20.3 ton
3rd truck: 9.8 ton
Total yield: 49.7 ton / 0.95 ha
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

<table>
<thead>
<tr>
<th></th>
<th>240 Hp</th>
<th>290 Hp</th>
<th>340 Hp</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Field 1</td>
<td>Field 2</td>
<td>Field 3</td>
</tr>
<tr>
<td>Area (ha)</td>
<td>0.64</td>
<td>0.32</td>
<td>1.36</td>
</tr>
<tr>
<td>Actual Capacity (ha/h)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Whole Field</td>
<td>0.18</td>
<td>0.23</td>
<td>0.29</td>
</tr>
<tr>
<td>- Without beginning rows</td>
<td>0.29</td>
<td>0.27</td>
<td>0.35</td>
</tr>
<tr>
<td>Theoretical Capacity (ha/h)</td>
<td>0.49</td>
<td>0.45</td>
<td>0.67</td>
</tr>
<tr>
<td>Field Efficiency (%)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Whole Field</td>
<td>37.4</td>
<td>50.3</td>
<td>43.4</td>
</tr>
<tr>
<td>- Without beginning rows</td>
<td>59.4</td>
<td>60.1</td>
<td>52</td>
</tr>
<tr>
<td>The Improvement (%)</td>
<td>+22.0</td>
<td>+9.8</td>
<td>+8.6</td>
</tr>
</tbody>
</table>

### Time Efficiency

<table>
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<tr>
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<td>1.36</td>
</tr>
<tr>
<td>Active Time (h)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Whole Field</td>
<td>1:37</td>
<td>0:44</td>
<td>2:24</td>
</tr>
<tr>
<td>- Without beginning rows</td>
<td>1:02</td>
<td>0:10</td>
<td>1:51</td>
</tr>
<tr>
<td>Total Time (h)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Whole Field</td>
<td>3:29</td>
<td>1:25</td>
<td>4:40</td>
</tr>
<tr>
<td>- Without beginning rows</td>
<td>1:55</td>
<td>0:17</td>
<td>2:31</td>
</tr>
<tr>
<td>Time Efficiency (%)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Whole Field</td>
<td>46.6</td>
<td>52.0</td>
<td>51.7</td>
</tr>
<tr>
<td>- Without beginning rows</td>
<td>53.9</td>
<td>57.9</td>
<td>73.5</td>
</tr>
<tr>
<td>The Improvement (%)</td>
<td>+7.3</td>
<td>+5.9</td>
<td>+21.8</td>
</tr>
</tbody>
</table>
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
THANK YOU

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