On-Farm Traffic Optimization for Increased Efficiency

Agribusiness Classic

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Motivation

- Silage is the prominent forage component for many livestock feeding operations.
- Substantial production inputs: time, machinery, labor.
- Increasing harvest efficiency improves silage quality.

There is a need for understanding production efficiency limitations.

Harvest Equipment

- Self-Propelled Forage Harvester

- Hay Equipment

- Transport Units

- Packing Equipment

Objectives of Study

- Producers benefit from improvements in efficiency:
  - Lower production cost
  - Better silage quality

1. Observation of the forage harvest process:
   - Stand-off data logging methods
   - Characterize machine work states

2. Determine harvest efficiency in terms of machine utilization and productivity.

Case Study: Operation A

- 2015 – 2016 Harvest Season:
  - Commercial dairy
  - 4,000 head milking heard
- Major silage operations were ryelage, alfalfa haylage, corn silage.
- Equipment:
  - 2 – SPFH
  - 4 – 4 m small hoist-bed straight-frame trucks
  - 6 – 8 m medium conveyor straight-frame trucks
  - 2 – 12 m conveyor semi-tractor trailers.
  - 3 – 4WD packing tractors

Case Study: Operation B

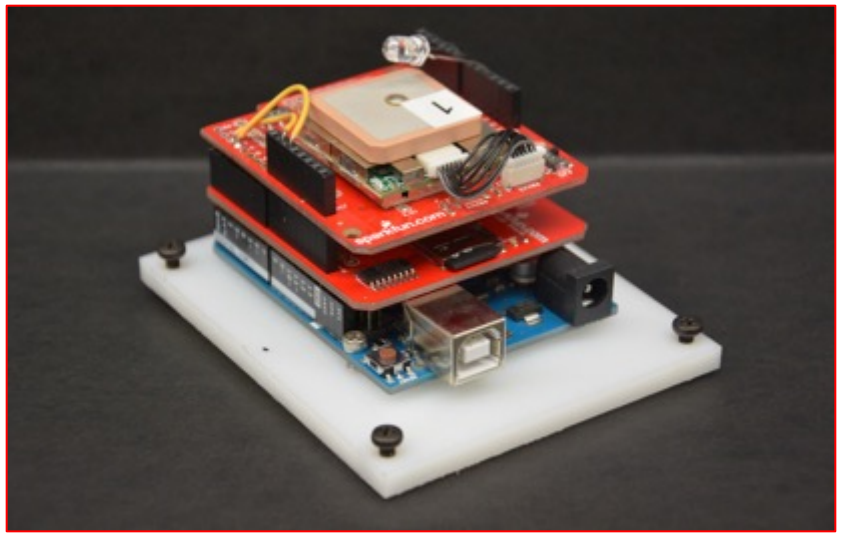
- 2016 Harvest Season:
  - Contracted custom harvesting
  - Harvest, transport, pack for local growers
- Major operations were alfalfa haylage, corn silage.
- Equipment:
  - 2 – SPFH
  - 4 – 7 m hoist-bed straight-frame trucks
  - 3 – 7 m conveyor tractor-drawn wagons
  - 1 4WD packing tractor if needed

CAN Data Collection

- Vector CANcaseXL and GL1000
- Database configuration
- Multichannel
- Small/Large Storage Capacity
- Log file format allowed for signal extraction
- Files stored by date

Geospatial Data Collection

- Arduino Uno/Leonardo microcontroller bases
- Received power from 12V in vehicle cab
- 1Hz
- Large storage capacity
- Files stored by date



- 30 loggers made

SPFH Data Loggers

Support Equipment Data Loggers

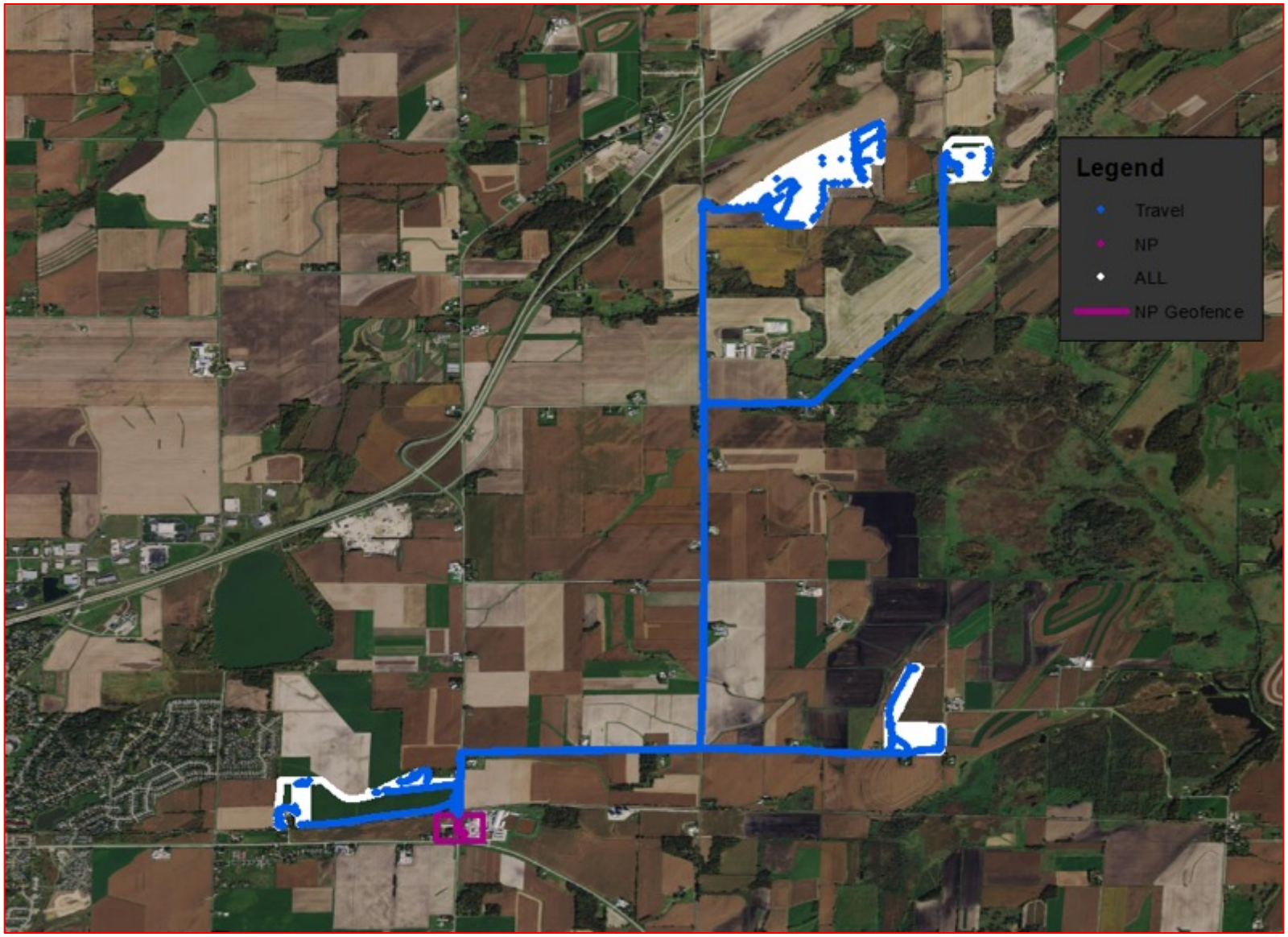
Machine Work States

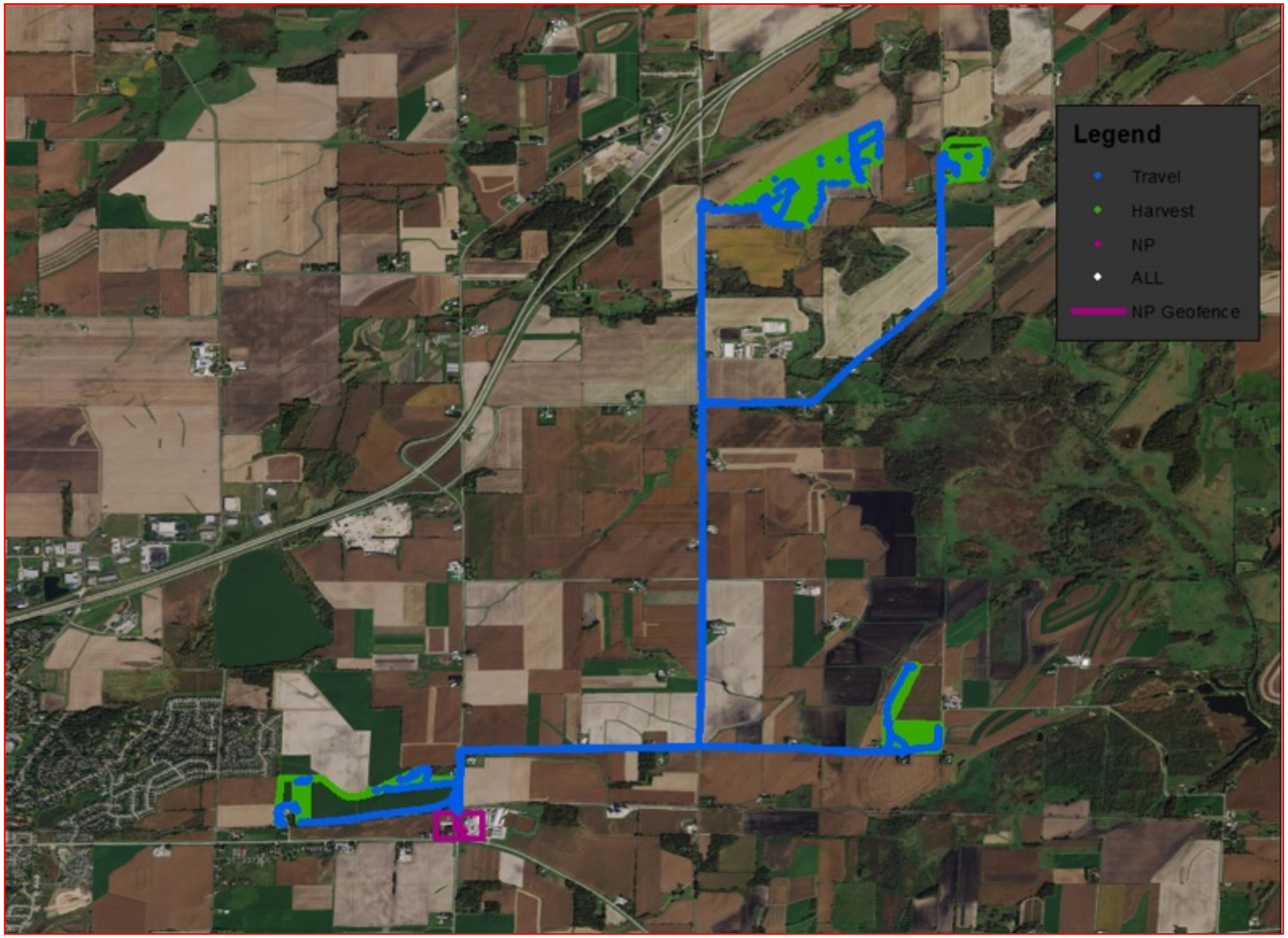
- SPFH:
  - **Harvest**: actively harvesting.
  - **Travel**: travelling on-road or in-field between work areas.
  - **Idle**: time when availability for work exists but SPFH is not harvesting.
  - **Delay**: equipment downtime due to metal detection.
  - **No-Production** (NP): time spent in NP areas such as storage shed, maintenance areas, etc.
  - **Downtime** (DT): time when machine is not running.
- Transport:
  - **Harvest/load**: transport is being loaded by SPFH.
  - **Travel**: Moving between SPFH and storage site.
  - **Unload**: Unloading at storage site.
  - **Idle**: Vehicles not harvesting, travelling or loading are idle.

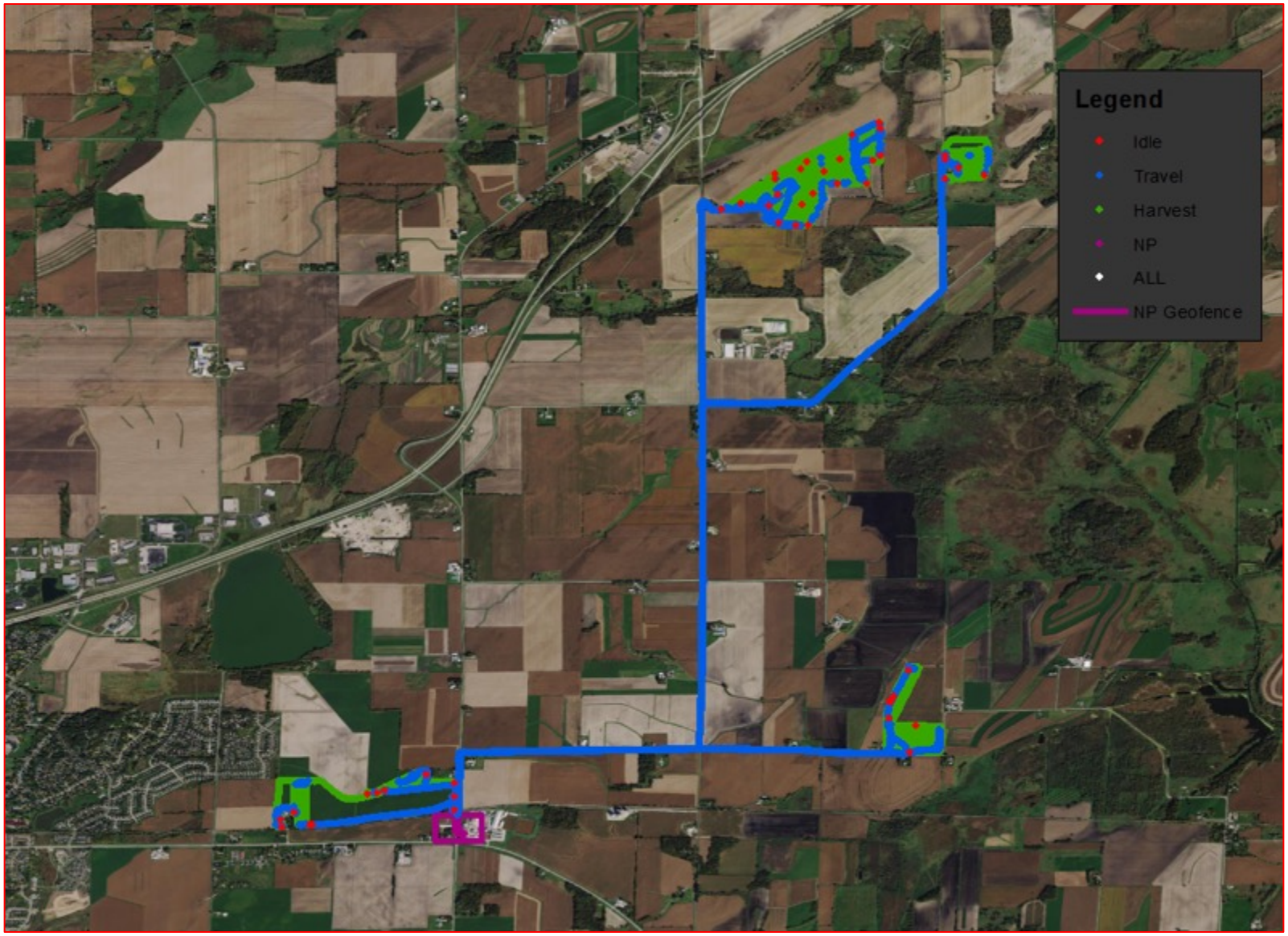
Data Processing

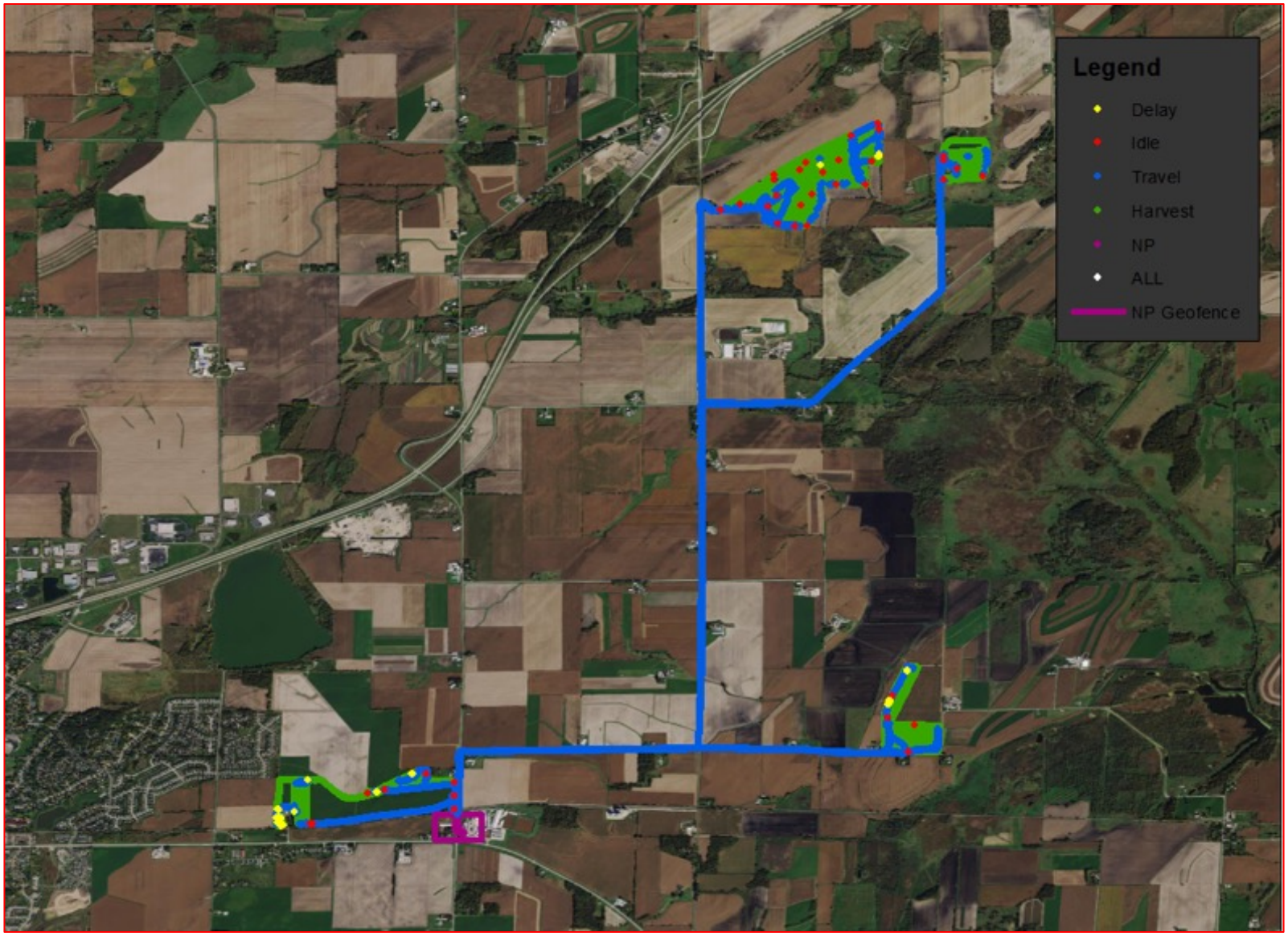

Legend
ALL

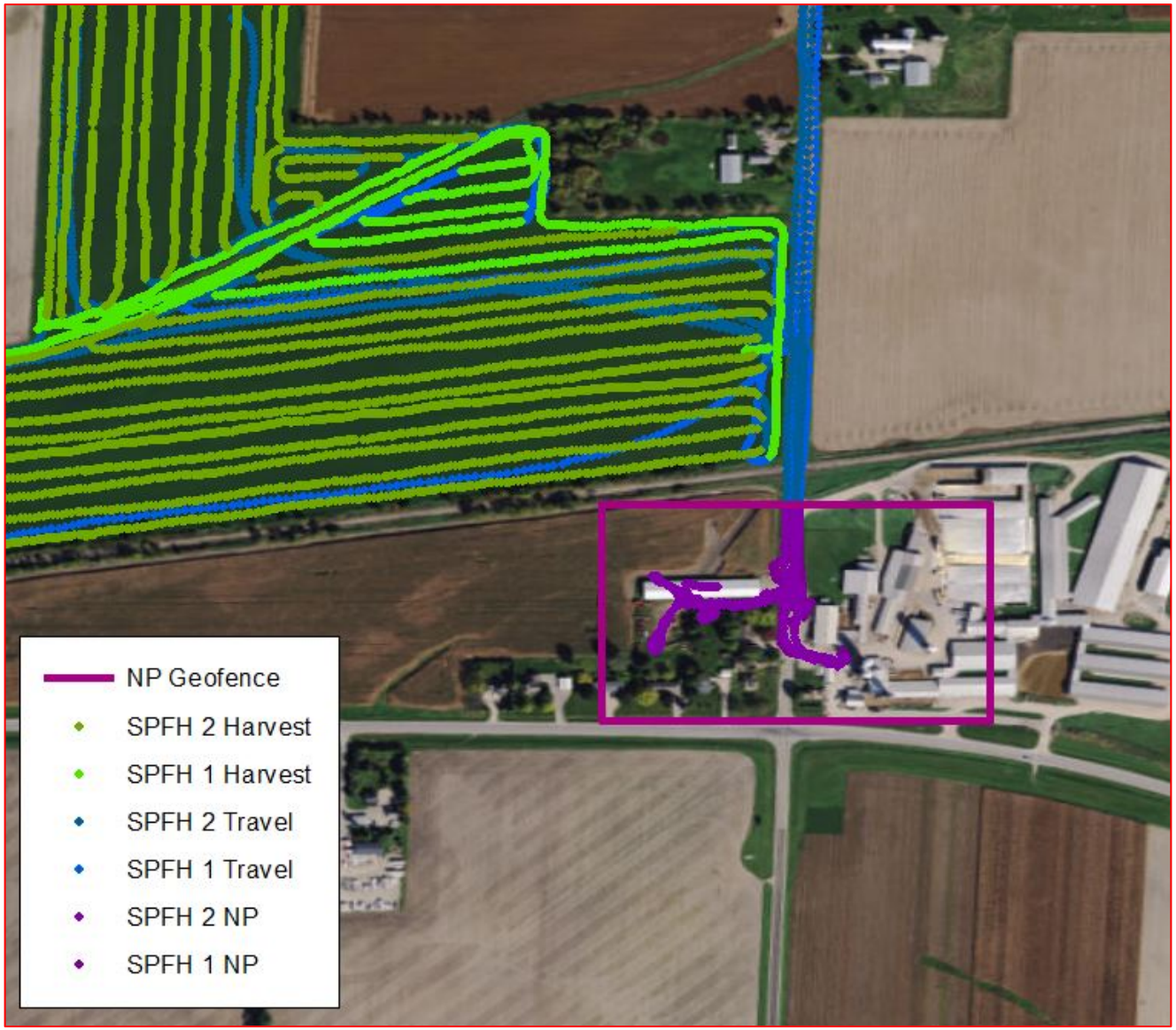

Legend
NP
ALL
NP Geofence

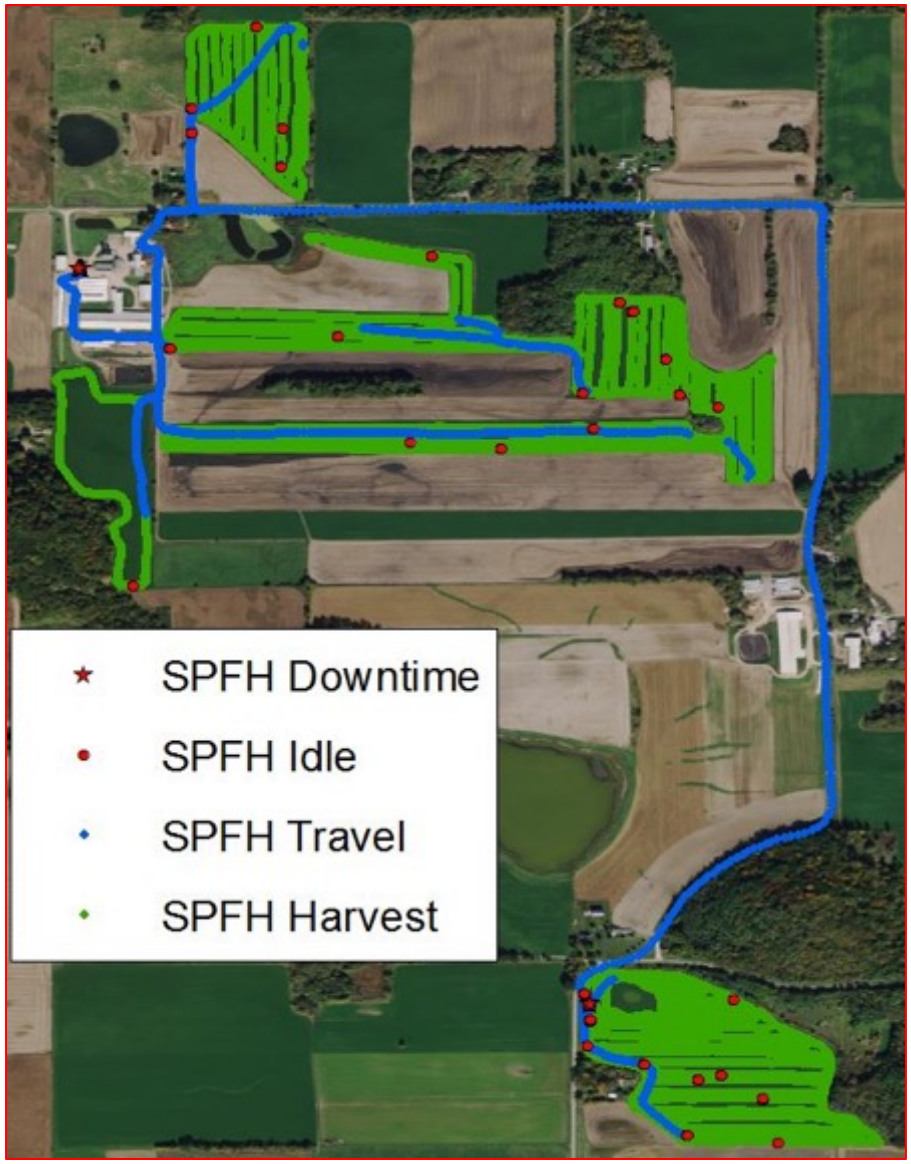

Legend
Travel
NP
ALL
NP Geofence

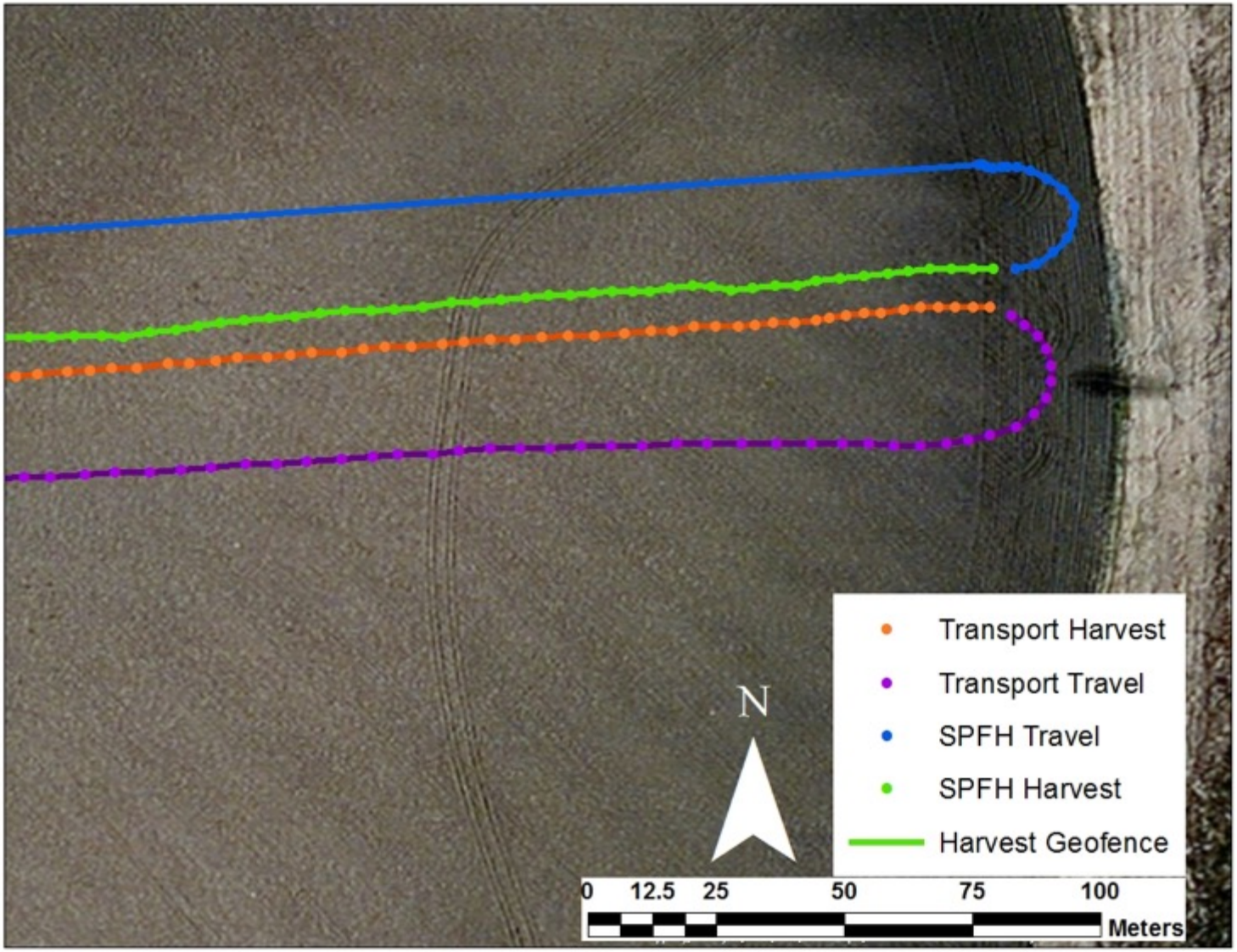

Legend
Travel
Harvest
NP
ALL
NP Geofence

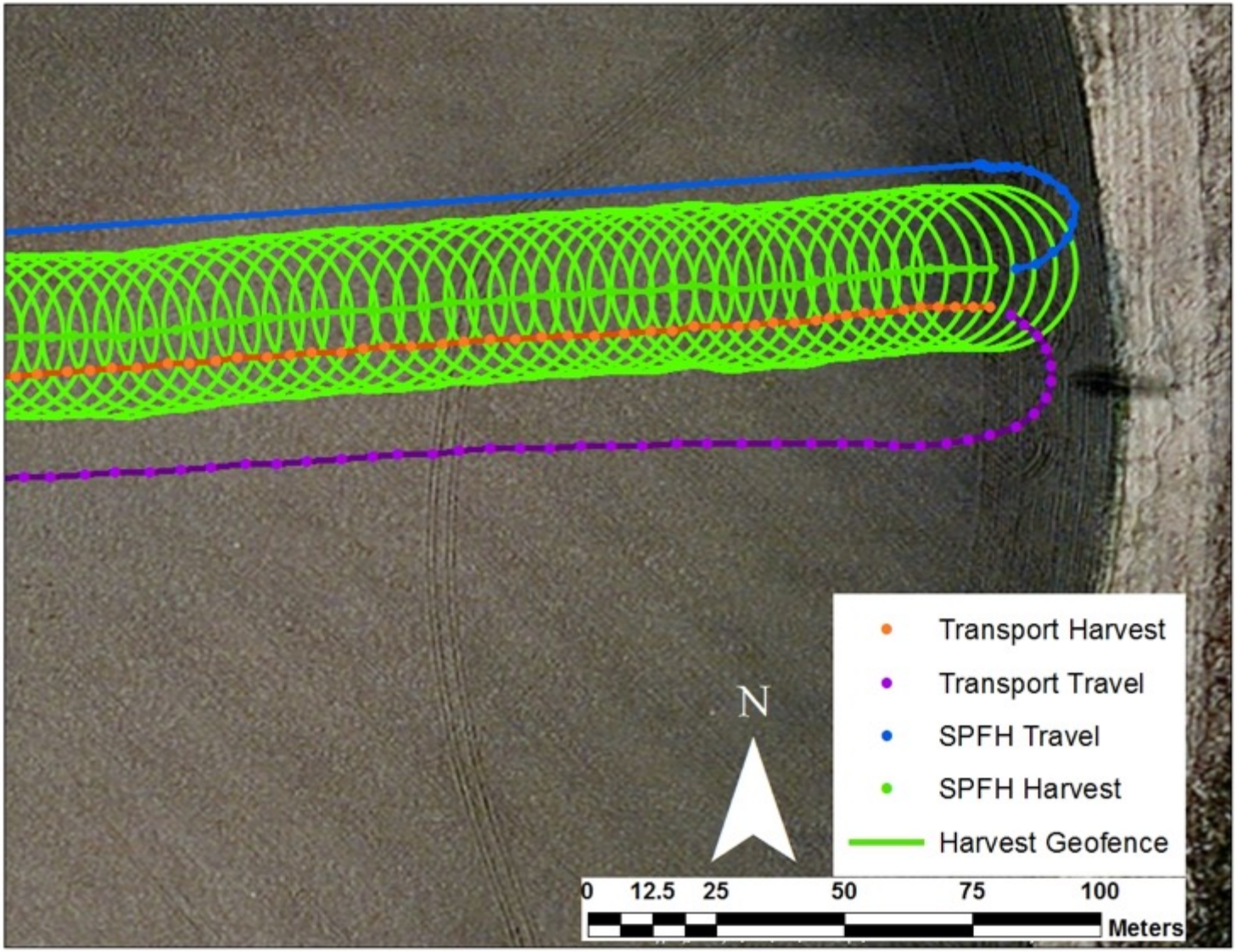

Legend
Idle
Travel
Harvest
NP
ALL
NP Geofence

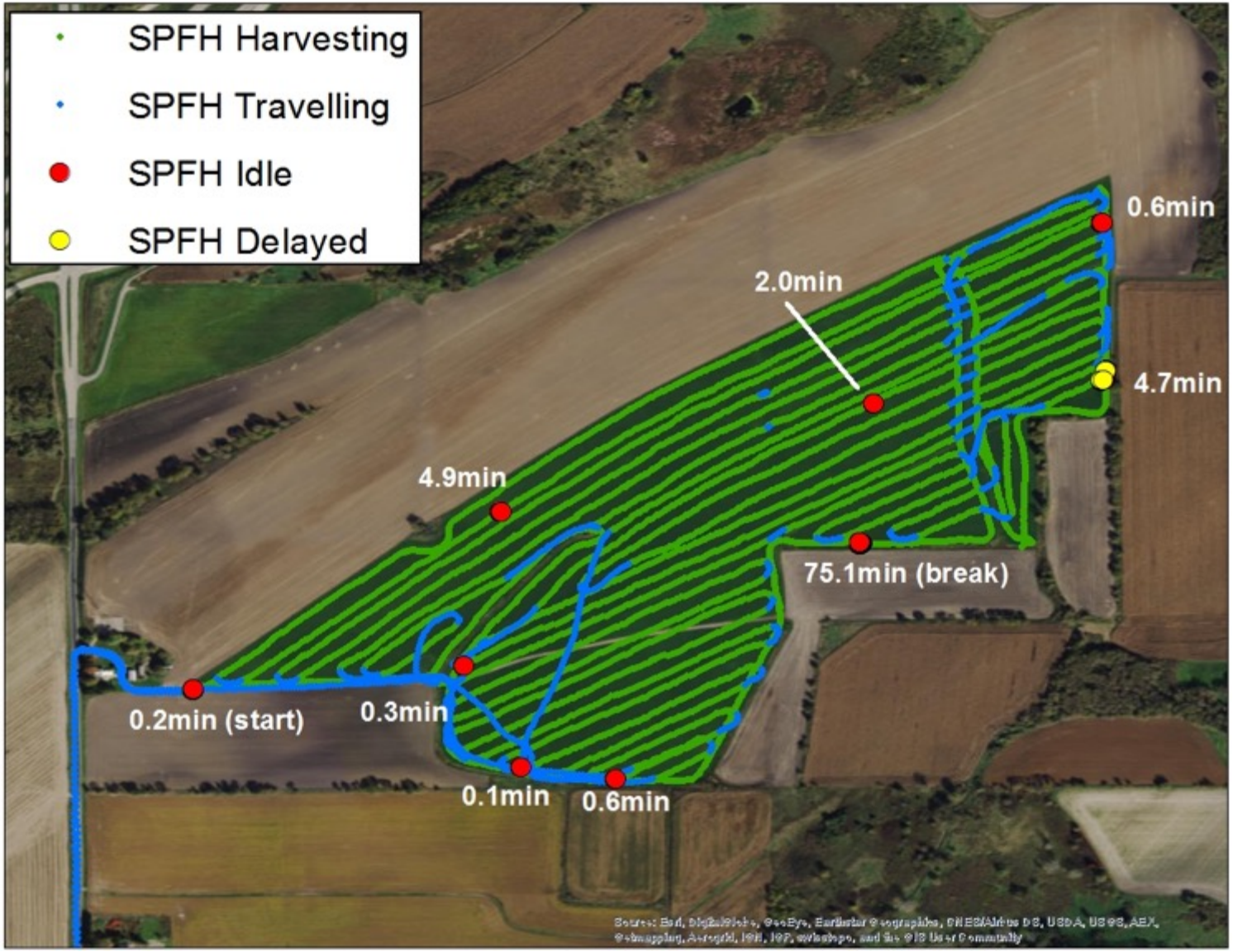

Legend
Delay
Idle
Travel
Harvest
NP
ALL
NP Geofence

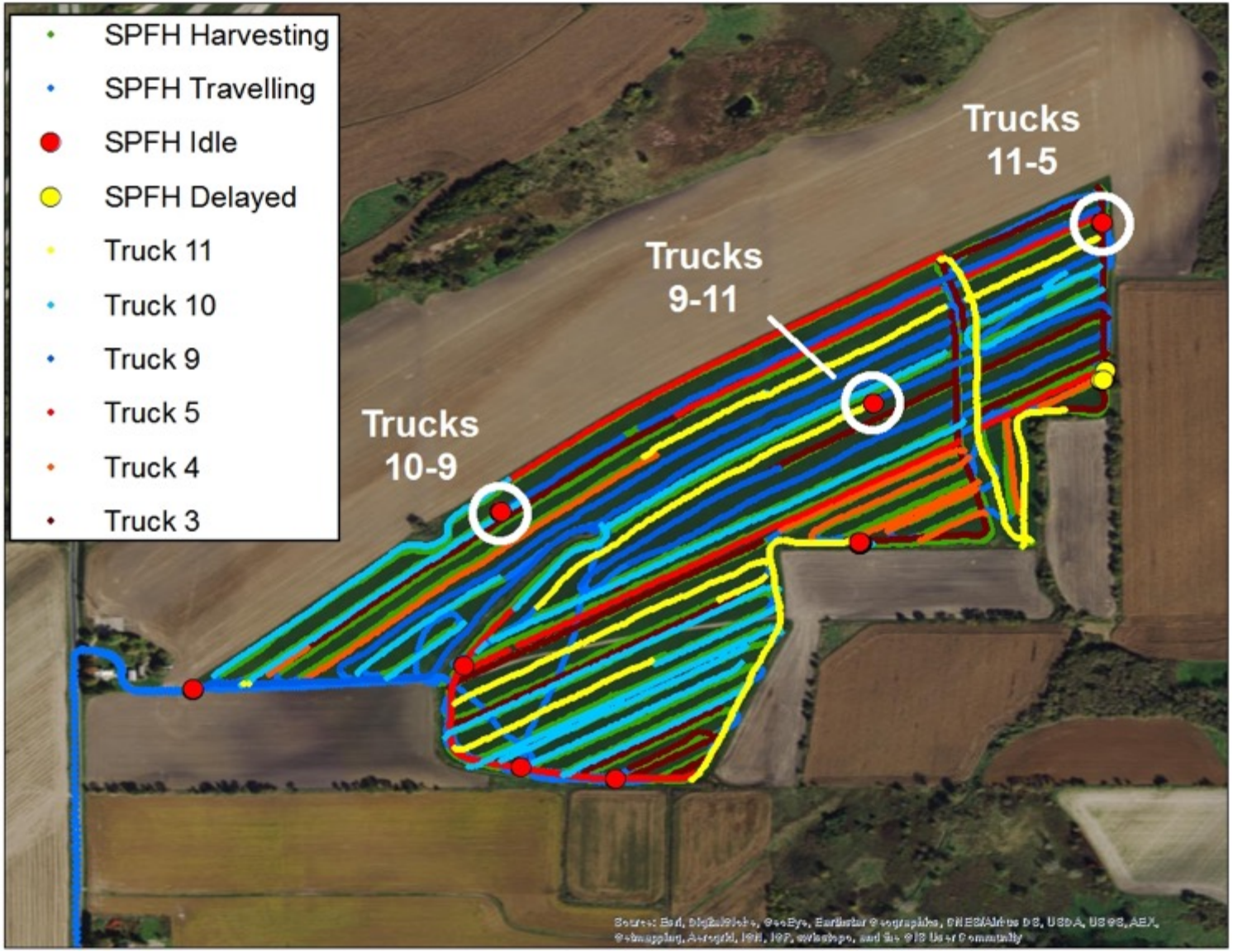

NP Geofence
SPFH 2 Harvest
SPFH 1 Harvest
SPFH 2 Travel
SPFH 1 Travel
SPFH 2 NP
SPFH 1 NP

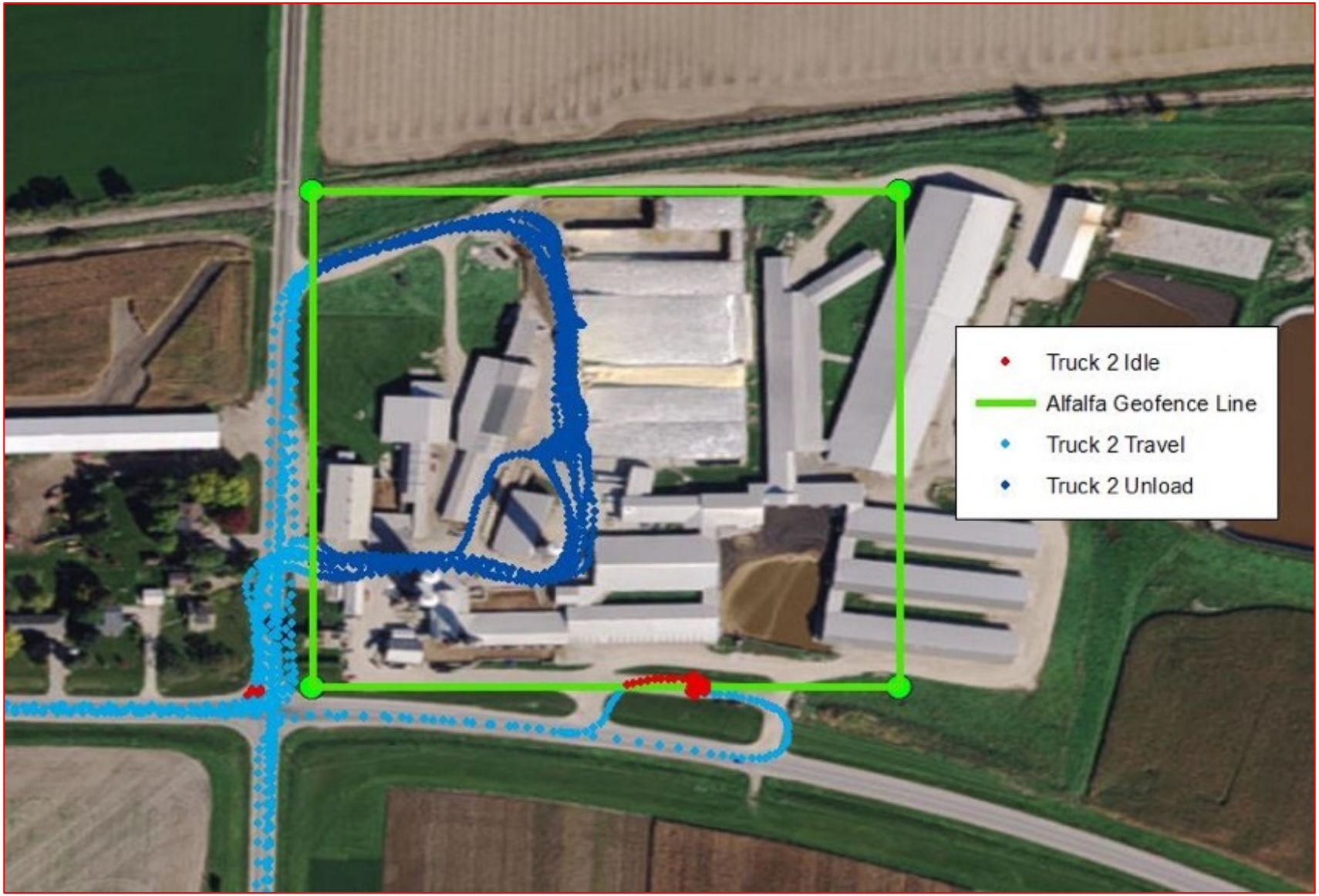

SPFH Downtime
SPFH Idle
SPFH Travel
SPFH Harvest

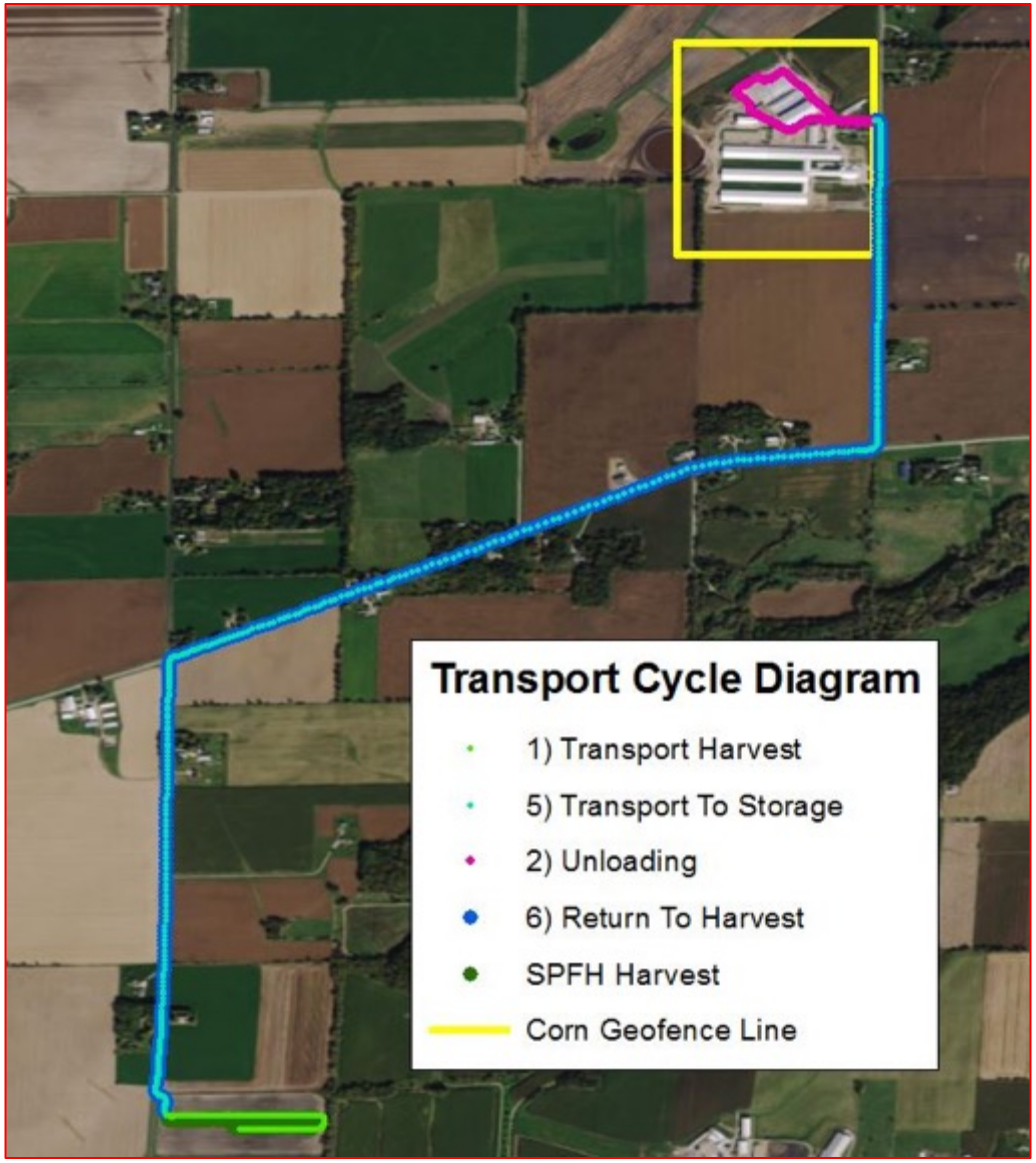

Transport Harvest
Transport Travel
SPFH Travel
SPFH Harvest
Harvest Geofence
N
0
12.5
25
50
75
100
Meters


Transport Harvest
Transport Travel
SPFH Travel
SPFH Harvest
Harvest Geofence
N
0
12.5
25
50
75
100
Meters


SPFH Harvesting
SPFH Travelling
SPFH Idle
SPFH Delayed
0.6min
2.0min
4.7min
4.9min
75.1min (break)
0.2min (start)
0.3min
0.1min
0.6min


SPFH Harvesting
SPFH Travelling
SPFH Idle
SPFH Delayed
Truck 11
Truck 10
Truck 9
Truck 5
Truck 4
Truck 3
Trucks 11-5
Trucks 9-11
Trucks 10-9


Truck 2 Idle
Alfalfa Geofence Line
Truck 2 Travel
Truck 2 Unload


Transport Cycle Diagram
1) Transport Harvest
5) Transport To Storage
2) Unloading
6) Return To Harvest
SPFH Harvest
Corn Geofence Line

Harvester Utilization

Operation time was determined as the amount of time during the day available for harvesting:

- $O_h = A_h - NP_h - DT_h$

Utilizations were as follows:

- $U_{Hh} = H_h/O_h$, harvest utilization, (h harvest h^{-1} operating)
- $U_{Th} = T_h/O_h$, travel utilization, (h travel h^{-1} operating)
- $U_{Dh} = D_h/O_h$, delay utilization, (h delay h^{-1} operating)
- $U_{Ih} = I_h/O_h$, idle utilization, (h idle h^{-1} operating)

Transport Utilization

Operation time was determined as the amount of time between first fill and last unload.

Utilizations were as follows:

- $U_{Hh} = H_h/O_h$, harvest utilization, (h harvest h^{-1} operating)
- $U_{Th} = T_h/O_h$, travel utilization, (h travel h^{-1} operating)
- $U_{Ih} = I_h/O_h$, idle utilization, (h idle h^{-1} operating)

Transport Productivity

- This study required a means of comparing transport work capacity.
- Transport productivity was defined as the level of production a transport could maintain:

$$P_t = \frac{m_t * d_t}{C_t}$$

Where:

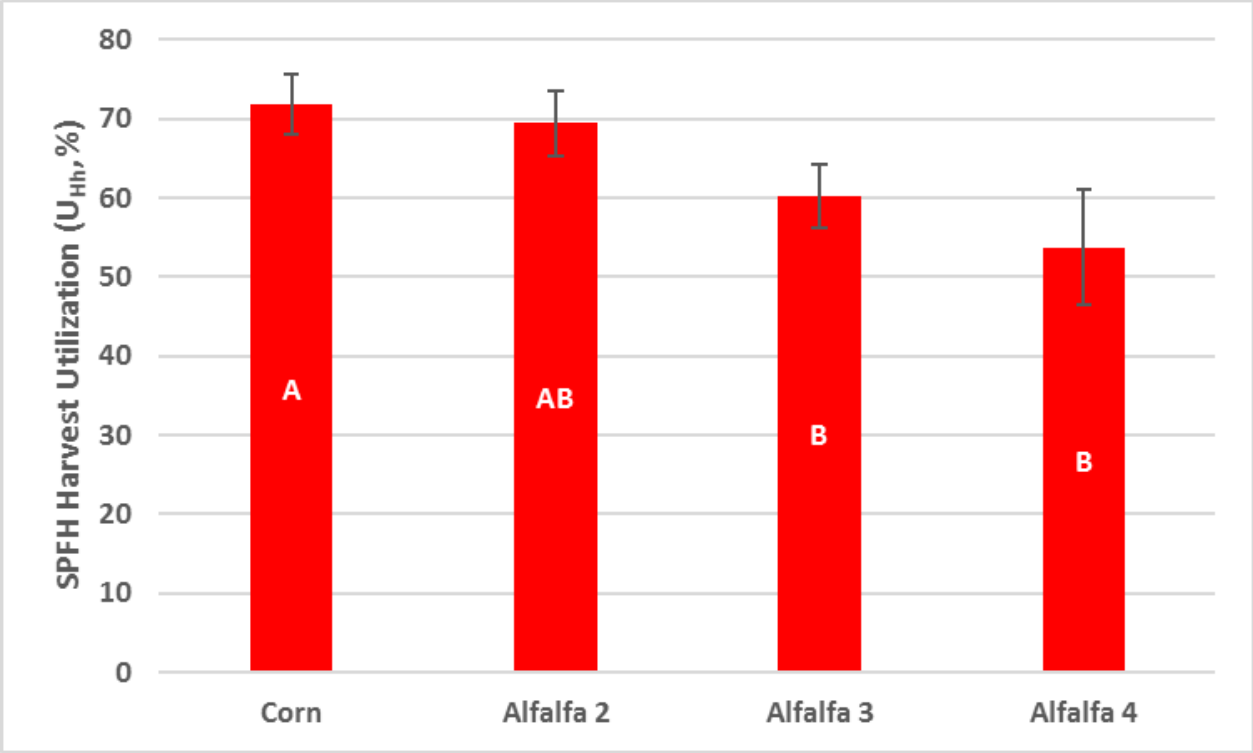
P_t = Productivity of the transport, ton mi h^{-1}

m_t = Mass of transported material, ton

d_t = Distance of cycle, mi

C_t = time to complete one cycle for a transport, h

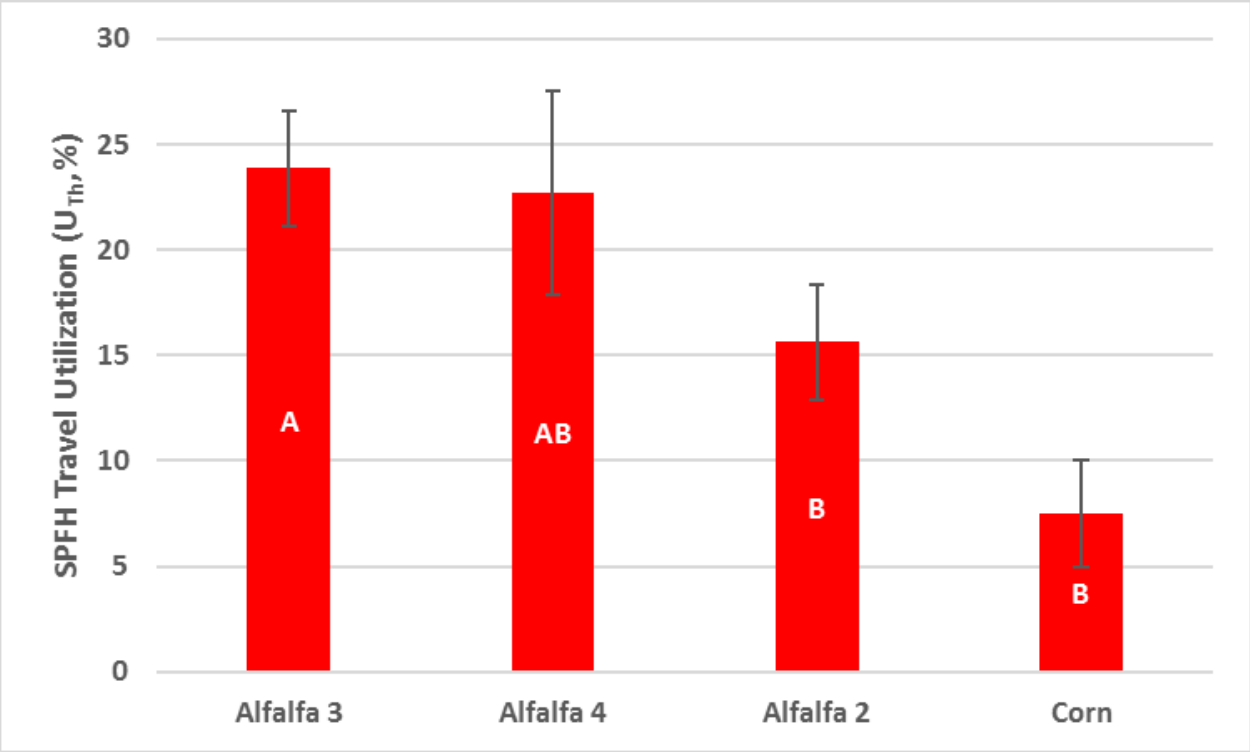
2016 Harvester Results



Mean SPFH harvest utilization (U_{Hh}) for Operations A and B.

Crop	Average (%)	Standard Error (%)	Letter Group
Corn	71.84	3.8	A
Alfalfa 2	69.47	4.1	AB
Alfalfa 3	60.21	4.1	B
Alfalfa 4	53.68	7.3	B

2016 Harvest Results



Mean SPFH travel utilization (U_{Th}) for Operations A and B.

Crop	Average (%)	Standard Error (%)	Letter Group
Alfalfa 3	23.86	2.70	A
Alfalfa 4	22.73	4.82	AB
Alfalfa 2	15.63	2.71	B
Corn	7.49	2.52	C

2016 Transport Results

Mean transport harvest utilization (U_{Ht}) for Operation A.

Type	Average (%)	Standard Error (%)	Letter Group
Semi-truck	18.63	1.26	A
Med. Straight Truck	11.43	0.67	B
Sm. Straight Truck	2.09	3.22	C

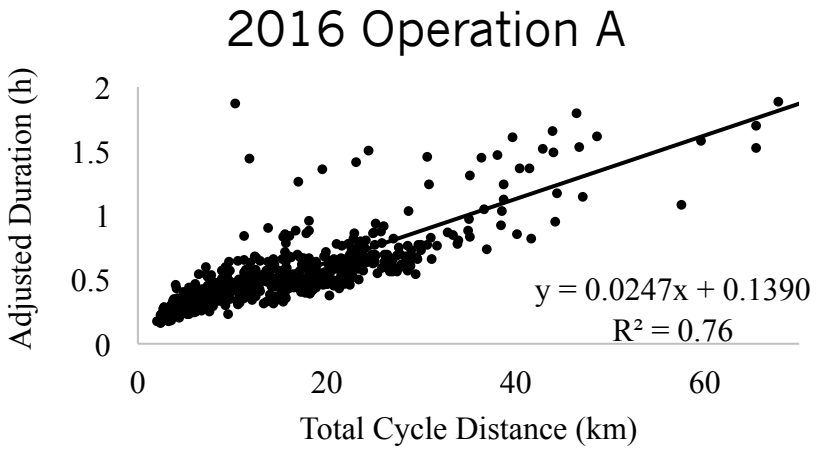
Mean transport speeds for Operation B hauling from SPFH to storage.

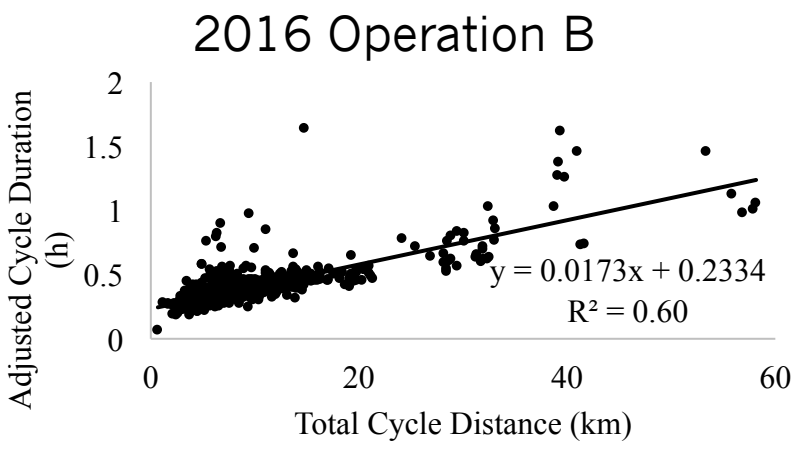
Type	Average (mi h^{-1})	Standard Error (mi h^{-1})	Letter Group
Truck	14.24	0.57	A
Tractor	12.09	0.51	B

Mean unloading durations (L_t) for Operation B by transport type.

Type	Estimate (min)	Standard Error (min)	Letter Group
Tractor	6.6	< 0.06	A
Truck	5.4	< 0.06	B

Transport Cycle Analysis





Transport Productivity

2016 Operation A: Mean transport productivity (P_t) of transports by type.

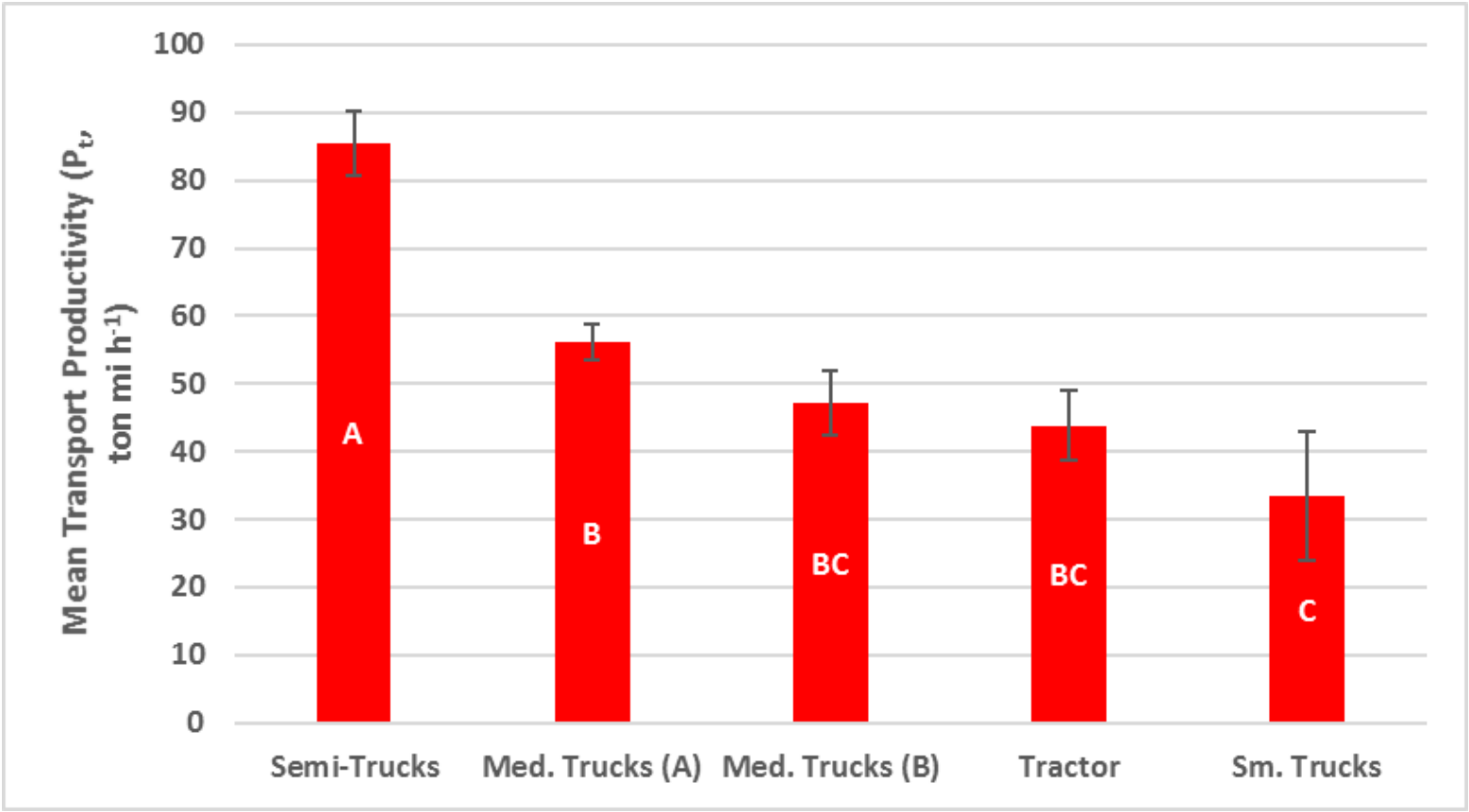
Type	Estimate (ton mi h^{-1})	Standard Error (ton mi h^{-1})	Letter Group
Semi-truck	84.2	4.4	A
Med. Straight Truck	50.0	2.5	B
Sm. Straight Truck	40.4	9.1	B

2016 Operations A and B: Mean transport productivity (P_t) of transports by type.

Type	Estimate (ton mi h^{-1})	Standard Error (ton mi h^{-1})	Letter Group
Semi-trucks	85.5	4.8	A
Med. Trucks[A]	56.1	2.7	B
Med. Trucks[B]	47.2	4.8	BC
Tractor	43.8	5.2	BC
Sm. Trucks	33.5	9.5	C

[A] Medium-sized transport trucks of Operation A.
[b] Medium-sized transport trucks of Operation B.

Transport Productivity



Evaluation Conclusions

- No significant differences found for SPFH utilizations between operations for 2016.
- For both operations, SPFH occupied more in corn, 2nd crop than 3rd or 4th crop.
- Semi-trucks were more productive than any other transport units.
- Medium-sized trucks were more effective than tractors, even though tractor capacity was higher.
- Small trucks had poor utilization. Possibly could have done as well as tractors or better, but unloading time was significantly long due to hoist beds.

Producer Recommendations

- For Operation A, producers should invest in semi-trucks based on utilization and productivity.
  - Cost analysis might conclude otherwise.

- For Operation B, trucks were more productive.
  - Field conditions do not always permit truck travel.

Questions

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