ASSESSMENT OF CATTLE GRAZING IMPACTS ON INTEGRATED CROP-LIVESTOCK SYSTEMS

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Agriculture systems have combined crop and livestock production for millennia.

Agriculture in the U.S. has become increasingly specialized in the past century, resulting in decoupling of crop and livestock systems.

The increasing specialization of agricultural systems has contributed to a number of environmental issues:

- Impairments of water quality
- Depletion of soil fertility
- Soil erosion
  
Most evidence suggests that integrated crop-livestock systems are more environmentally protective than modern monoculture systems.

- Greater biological diversity
- Efficient nutrient cycling
- Enhancement of soil fertility
- Carbon sequestration
  
...
Two scales of integration of crop and livestock farming in the U.S.:
- Within an individual farm
- Among farms or regional integration

Crop residue grazing:
- Corn residue – a vast feed source to livestock producers.
- Reduce cost for purchasing winter feeds

Impacts of grazing on agroecosystem performance remain unclear:
- Livestock performance
- Soil physical and chemical properties
- Subsequent crop production
- ...

Corn residue grazing at Dudley Smith Farm in Central Illinois (Fall 2012)
We see the potential of an integrated corn-cattle system:
- Positively impact economic performance and yield
- Improve delivery of ecosystem services

Fundamental hypothesis
The spatial heterogeneity of impacts of cattle grazing on integrated corn-cattle system represent missed opportunities that may be captured by developing innovative management practices to improve overall agroecosystem performance.

Long-term goal
To provide decision support capabilities for agricultural producers and policy makers to develop innovative approaches that increase productivity, while simultaneously improving the sustainability of agroecosystems.
Our long-term study plan includes several aspects of an integrated corn-cattle system:

- Grazing behavior
- Cattle performance
- Soil characteristics
- Crop yield

Field experiment at the DSI farm in fall 2012 and 2013.
An updated tracking system of the GPS HAWK (Davis et al. at, 2011) was implemented for our study.

- Lower unit cost
- Batteries last for 5 consecutive days
- Reduced handling challenges
- Horizontal 95% accuracy of 4.0 meters (ION STD 101)

Approach

- Monitoring cattle movement
GPS data were stored and visualized using ESRI® ArcGIS.

- **Approach**
- GPS data management
A set of analysis methods and tools has been applied for modeling and analysis of cattle movement data.

- Data analysis
  - Spatial analysis
  - Movement characterization
  - Pattern identification

- Movement knowledge
  - Spatial utilization of lands
  - Movement characteristics
  - Behavioral patterns
  - ...

- Pattern-oriented modeling
  - Agent-based modeling
  - Stochastic modeling
  - Empirical methods

- Cattle movement models

- GPS raw data

- Density map of field visitation by cattle
Soil sampling was conducted before and after the grazing study (2012 and 2013).

Approach:

- Soil sampling
Soils were sampled to depth of 50 cm (20 in.).

- Analyzed for:
  - Penetration Resistance (compaction)
  - Bulk Density
  - Nitrogen (NO$_3$ & NH$_4$)
  - Available Phosphorous
  - Moisture Content
PRELIMINARY RESULTS

Cattle spatial occupancy was uneven throughout strip and continuously grazed paddocks (2012 fall).
Strip grazing management has significant impacts on the spatial distribution pattern of animal locations.

2012 Fall
First Period:
09/27-10/02 and 10/11-10/12

Preliminary results

Observation of cattle movement
Strip grazing management has significant impacts on the spatial distribution pattern of animal locations.

2012 Fall
First Period: 09/27-10/02 and 10/11-10/12
Second Period: 10/12-10/16 and 10/25-10/26
Strip grazing management has significant impacts on the spatial distribution pattern of animal locations.

2012 Fall

First Period:
09/27-10/02 and 10/11-10/12

Second Period:
10/12-10/16 and 10/25-10/26

Third Period:
10/26-11/08

Preliminary results

Observation of cattle movement
Preliminary results for 2012 suggest:

- Strip & continuous had greater bulk densities than control
- CG & SG had increased PR in top 10 cm
  Only CG had greater PR than CT at greater depths
- No significant differences in P, NO$_3$, & NH$_4$
  - Highly variable in soils

- Soil characteristics
Increase in bulk density and penetration resistance are not yet of agronomic importance.

- All values of bulk density and penetration resistance are within optimal values on silt loam soils
- Strip grazing requires increase in labor, but resulted in significant increase in body weight.
- No significant spatial correlation between grazing and crop yield has been observed so far.
- More years of research is needed to discern the long-term trajectories from the uncertainty of year-to-year data.

Preliminary results

- System performance
We have investigated the effects of number of animals monitored on representations of cattle group movement characteristics and spatial occupancy.

- Data collection
- Data preprocessing
- Movement characterization
  - Data synchronization
  - Generating subset groups
  - Calculating movement metrics
- Spatial occupancy analysis
  - Generating subset groups
  - Kernel density estimation
- Comparative statistics

- Preliminary results
- GPS data analysis
Decisions regarding selection of an appropriate subset group size for monitoring a group of cattle depend on the specific use of data for subsequent analysis.

Monitoring a relatively small group of animals may be enough for identifying areas visited by cattle.

Preliminary results

GPS data analysis
Periodic movement patterns (e.g. associated with water) can be identified using data mining.

Periods (associated with water) detected: $P = 24.8$ hours

Source: Periodica, Li et al. 2012
An agent-based model has been developed to simulate cattle movement on crop residue lands under various grazing management practices.
Interactive modeling environment (NetLogo, Wilensky, U.(1999))

Dynamic display of simulation results

Preliminary results

Modeling cattle movement
CONCLUSIONS

- The corn fields were not evenly utilized by cattle. Cattle changed their preferred locations according to the changes of fences.
- Strip grazing has significantly changed hot spots of cattle visitation compared to continuous grazing.
- Preliminary results show that cattle may have periodic movement associated with the water.
- Both strip and continuous grazing systems resulted in greater soil bulk densities and penetration resistance than the ungrazed control; however, their ranges are within optimal values for crop production.
FUTURE WORK

- These results are preliminary – livestock, crop and soil data will be collected and studied continuously to assess grazing impacts on agroecosystems.
- The cattle grazing model will be calibrated and validated using GPS data.
- The integrated systems will be modeled using integration of livestock, crop and soil models.
- Methane emissions associated with grazing management practices will be studied using the Ruminant Emission Measurement system.
- A decision support platform will be developed for identifying best management for integrated crop-livestock systems for small-to-medium farms.
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