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Nitrate concentration-drainage flow (C-Q) relationship for a drained agricultural field in Eastern North Carolina Plain

Bio&Ag ENGINEERING

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Abstract

- High frequency measurements of water quality samples from drainage tiles provided another view of hydrological and biochemical processes from an artificial drained agricultural field.
- We measured drainage flow and nitrate concentration from drainage tiles at an interval of 45 minutes for year of 2017.
- We investigated the relationship between nitrate concentration and drainage flow (C-Q) at an event basis and collected 15 events during the measuring period.
- We employed hysteresis metrics to classify the hysteresis patterns of selected events and identified the major category pattern of the events.

Hypotheses

- The measuring interval of 45 minutes is able to capture the rapid changes of hydrograph and chemograph from drainage tiles.
- Hysteresis effects evidently exist in nitrate concentration and flow relationship from a drained agricultural field.

Site Description

- Research site:
  - ❖ Tidewater research station in Plymouth, NC.
- Drainage flow:
  - ❖ V-notch weir + Campbell Scientific pressure transducers + HOBO CR200 dataloggers;
- In-situ Nitrate(NO_3^-) concentration:
  - ❖ S::can multispectral water quality sensor;
- Rainfall:
  - ❖ Rain gauges and an adjacent weather station (35.84887° , -76.65058°);
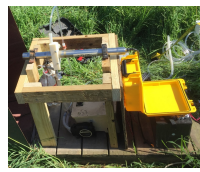- Animal waste application:
  - ❖ A set of rain gauges in the field.

Fig. 1 Equipment for in-situ nitrate measurement

Fig. 2 Animal waste application

Metrics to characterize hysteresis patterns

a) Time series data
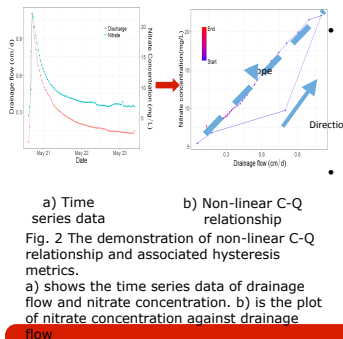b) Non-linear C-Q relationship

Fig. 2 The demonstration of non-linear C-Q relationship and associated hysteresis metrics.
a) shows the time series data of drainage flow and nitrate concentration. b) is the plot of nitrate concentration against drainage flow

- Hysteresis Index (HI):
  - ❖ Improved by Lloyd et al.[1]
  - ❖ Quantifies the direction and strength of hysteresis loop.
- Flushing Index (HI):
  - ❖ Developed by Vaughan et al.[2]
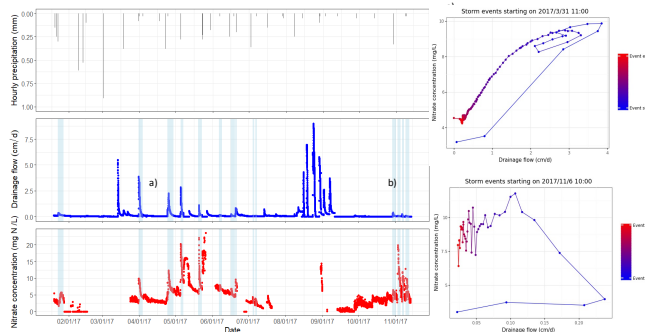 - ❖ Quantifies the flushness or dilution of nitrate at the rising limb.

Results

Fig. 4 Results of precipitation (black bars), drainage flow (blue dots) and nitrate concentration (red dots) in the year of 2017. Light blue rectangles represent the selected events (number = 15) during the measuring period. The authors also showed two events on the right, which happened on 2017-3-31 (a) and 2017-11-6 (b).

- Able to capture rapid changes after rainfall or irrigation at a sampling interval of 45 minutes;
- 15 events were collected at different seasons in 2017;
- Obvious hysteresis effects were observed for nitrate concentration and discharge (C-Q) relationship;
- Hysteresis Index (HI) and Flushing Index (FI) were calculated for al the events for further analysis;

Hysteresis patterns of C-Q relationship

- Most of the events (9 out of 14) were anti-clockwise loops with nitrate flushing from the field;
  - ❖ HI < 0: drainage flow with higher nitrate travels slower than flow with lower nitrate;
  - ❖ FI > 0: drainage flow flushes more nitrate from field compared with base flow.
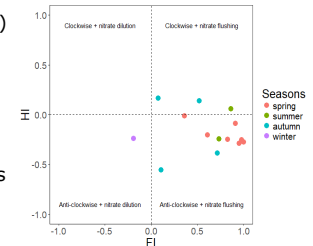- Possible seasonal variations, but more data are needed.

Fig. 5 Classification of events at different seasons using hysteresis metrics. Labels in plots indicate the category of hysteresis patterns.

Potential reasons of hysteresis
- ❖ Preferential flow
- ❖ Heterogeneous distribution of nitrate (vertically and horizontally)
- ❖ Antecedent conditions

Future work:
- ❖ Seasonal variations analysis.
- ❖ Evaluate the controls and influences of hydrological, biogeochemical and antecedent factors

Conclusions

- Hysteresis effects were observed for nitrate concentration-drainage flow relationship in tile drainage.
- Most of the measured events were classified as anti-clockwise loops with nitrate flushing from the field.
- Further analysis is needed for seasonal variations and parameters that influence the hysteresis patterns.

Authors

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References

[1] Lloyd et al., 2016   [2] Vaughan et al., 2016