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

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Abstract

- High frequency measurements of water quality samples from drainage tiles provided a more in-depth 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 during 2017.
- We investigated the relationship between nitrate concentration and drainage flow (C-Q) at an event basis and collected 14 events during the measurement period.
- We employed hysteresis metrics to classify the hysteresis patterns of selected events and identified the major category pattern of the events.

Hypotheses

- The measurement interval of 45 minutes is adequate for capturing rapid changes of the hydrograph and the chemograph characterizing flow and nitrate concentration for tile drainage.
- Hysteresis effects evidently exist in nitrate concentration and flow relationship from a drained agricultural field.

Site Description

- Research site:
  - ❖ Subsurface tile drained field in eastern North Carolina irrigated with swine lagoon effluent.
- Drainage flow:
  - ❖ V-notch weir + Campbell Scientific pressure transducers + 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 waster application measurement:
  - ❖ A set of rain gauges in the field.

Fig. 1 Location of research site

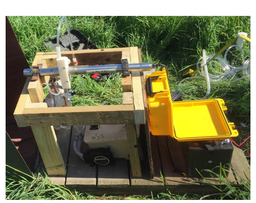
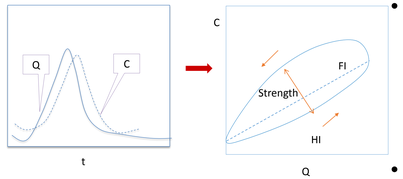


Fig. 2 Set up of S::can probe for in-situ nitrate measurement

Fig. 3 Animal waste application

Metrics to characterize hysteresis patterns



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

Fig. 4 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.
  - ❖ Quantifies the direction and strength of hysteresis loop.
- Flushing Index (FI):
  - ❖ Developed by Vaughan et al.
  - ❖ Quantifies the concentration or dilution of nitrate at the rising limb.

Results

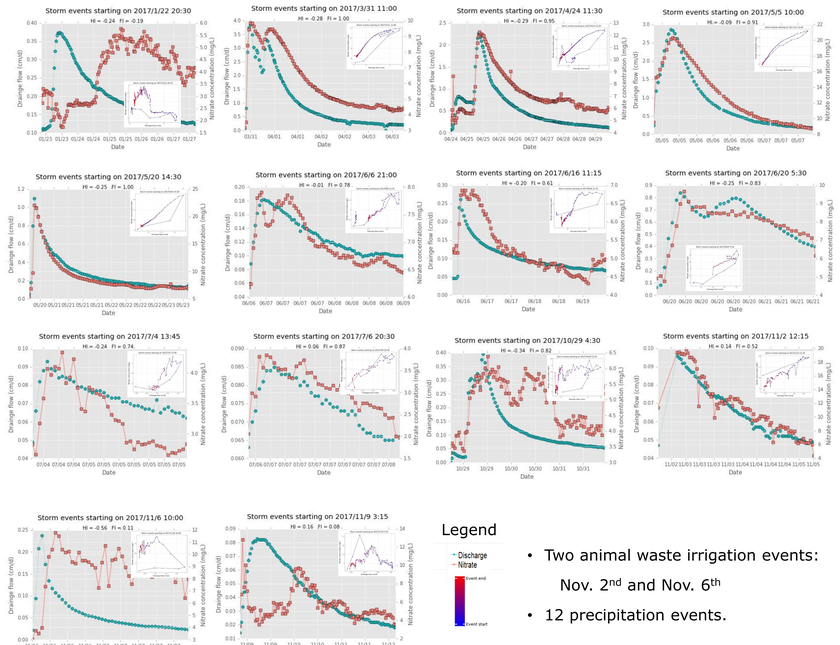


Fig. 5 Nitrate concentration-drainage flow (C-Q) relationship for all 14 events. Large plots present the time-series data of C-Q relationship. Small plots show the hysteresis loops for C-Q relationship; events started at blue dots and ended at dark-red dots.

- Two animal waste irrigation events: Nov. 2nd and Nov. 6th
- 12 precipitation events.

Hysteresis patterns of C-Q relationship

- C-Q relationship of 9 events were classified as anti-clockwise loops with nitrate flushing from the field;
  - ❖ HI < 0: drainage event with higher nitrate concentrations lagging than flow with initial lower nitrate concentrations;
  - ❖ FI > 0: drainage event with higher nitrate concentrations than from base flow.
- Possible seasonal variations, but more data are needed.

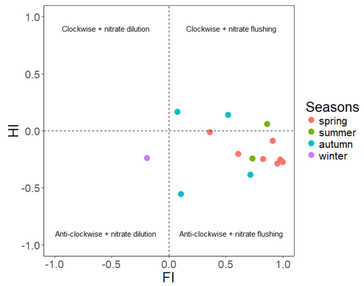


Fig. 6 Classification of events at different seasons using hysteresis metrics. Labels in plots indicate the category of hysteresis patterns.

Potential reasons of hysteresis effects:

The lag between transportability and availability of drainage flow and nitrate, including:

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

Conclusions

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

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