Contrasting Spatial Distribution of the Emission and Export of Diffuse Nutrient at Watershed Level

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Non-point source (NPS) pollution is regarded as a major concern for water quality deterioration. (Ongley et al., 2010)

Relative to point source pollution, NPS pollution is difficult to measure and regulate because of its dispersed origins and intermittent distribution. (Carpenter et al., 1998; Arabi et al., 2006)

However, many studies have indicated that proportional much of nutrient loss originates from relatively small areas which are called critical source areas (CSAs) or priority management areas (PMAs) (Huang et al., 2015; Pionke et al., 2000; Shang et al., 2012; Sharpley et al., 2011; Chen et al., 2014b; Shen et al., 2015)

Targeting the CSAs for implementing best management practices (BMPs) has been recognized as an effective and efficient way to control NPS pollution. (Chen et al., 2014a; Heathwaite et al., 2009; McDowell and Srinivasan, 2009)

Understanding the spatial characteristics of NPS pollution is the key first step to identify the CSAs
The pollutant flux of a certain geographical unit out of from a watershed depends on not only nutrient emission from the landscape but also the biochemical transformations within the delivery process. (Aguilera et al., 2012; Alexander et al., 2002; Bettez et al., 2015)

Delivery process may result in the difference between the emission (to water or reach nearby) and export (to receiving water bodies) of diffuse nutrient in spatial distribution. (Shen et al., 2015)

Understanding the spatial characteristics of NPS pollution require evaluating the influence of delivery process.
Objectives to...

✓ 1) evaluate the export (to receiving water body) of diffuse nutrient from the watershed;

✓ 2) contrastively analyze the spatial features of diffuse nutrient emission (to water or reach nearby) and export;

✓ 3) assess the impact of delivery process on the difference between the emission and export of diffuse nutrient in spatial distribution.
Methodology

The SUB_emission of nutrient was the nutrient (N and P) that was transported by the runoff and with the sediment into the reach described in the SUB files.

The SUB_export was the proportion of subwatershed-emitted nutrient that exported to the outlet of the watershed, which is the result of SUB_emission and the delivery process (Function 1).

\[ SUB_{i\_export} = SUB_{i\_emission} \times \prod_{j=i}^{n} \frac{RCH_{j\_out}}{RCH_{j\_in}} \]  

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The path relationship of the routing reaches was used to calculate the migration distance of emitted nutrient move to outlet of the watershed from the source sub-watershed (1)

\[ \text{SUB}_{i\_export} = \text{SUB}_{i\_emission} \times \prod_{j=i}^{n} \frac{\text{RCH}_{j\_out}}{\text{RCH}_{j\_in}} \] (1)

The delivery process was described by the migration distance and the percentage of output to input nutrient of the reach, such as \( \text{RCH}_{j\_out} \) and \( \text{RCH}_{j\_in} \) in the function 1

The path relationship of the routing reaches was used to calculate the migration distance of emitted nutrient move to outlet of the watershed from the source sub-watershed.

Retention coefficient was used to describe the changes of emitted nutrient within the delivery process (Function 2)

\[ \text{Retention} = \frac{\text{SUB}\_emission - \text{SUB}\_export}{\text{SUB}\_emission} \] (2)
The SWAT model is used in this method.

Calculation of the emission of nutrient described in the SUB output files.

Calculation of the input and output nutrient of the reaches described in the RCH output files.

Receiving water body (Arnold et al. 1998)
Erhai Lake
Research area-

A headwater watershed of Erhai Lake area in Southwestern China

Fengyu River watershed

Agricultural NPS pollution is the major concern of water quality deterioration of Erhai Lake

2016/7/27
Research area-Fengyu River watershed

- **Area**: 218 km²
- **Subtropical plateau monsoon climate**:
  - Annual mean temperature: 13.9 °C
  - Rainfall depth: 740 mm, with more than 85% occurs from May to October
- **Residential area**:
  - Population: 39,000 people
  - Cow: 10,000 heads
Databases for SWAT model

- **DEM (1:50000)**
  - Climate data, soil properties, land cover, etc.

- **Land use (1:100000)**
  - Crop planting, fertilizer application, irrigation, tillage, etc.

- **Soil (1:500000)**
  - Measured data: stream flow, water quality

**OUTPUT**: discharge, N and P load in HRU and Sub files
### Databases - Soil and fertilization

**Red earths, brown earths and dark-brown earths** are the dominant soils which account for **27.8%**, **25.8%** and **22.4%**.

<table>
<thead>
<tr>
<th>Crop type</th>
<th>Data of fertilizer application</th>
<th>Livestock manure</th>
<th>Chemical fertilizer</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>N(kg hm(^{-2}) a(^{-1}))</td>
<td>P(kg hm(^{-2}) a(^{-1}))</td>
</tr>
<tr>
<td>Paddy rice</td>
<td>May 1</td>
<td>70</td>
<td>30</td>
</tr>
<tr>
<td></td>
<td>June 1</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>July 1</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>70</td>
<td>30</td>
</tr>
<tr>
<td>Corn</td>
<td>May 1</td>
<td>81</td>
<td>36</td>
</tr>
<tr>
<td></td>
<td>June 1</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>July 1</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>81</td>
<td>36</td>
</tr>
<tr>
<td>Fava bean</td>
<td>October 1</td>
<td>120</td>
<td>55</td>
</tr>
<tr>
<td></td>
<td>November 15</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>January 1</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>120</td>
<td>55</td>
</tr>
<tr>
<td>Rape</td>
<td>October 1</td>
<td>131</td>
<td>61</td>
</tr>
<tr>
<td></td>
<td>November 15</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>January 1</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>131</td>
<td>61</td>
</tr>
</tbody>
</table>

**Dominant land use includes meadow (35.6%), forest (33.0%), and crop land (29.0%) which is classified into paddy field (12.9%), dry land (11.1%) and orchard (5.0%). Rice-broad bean/rape in paddy field Corn-broad bean/rape in dry land prune tree in orchard**

2016/7/27
Measured data and model setup

- **Discharge**: 2011-2013, daily
- **Water quality**: Oct. 2010-2013, daily
- **Water quality parameters**: TN, TP

<table>
<thead>
<tr>
<th>Constituent</th>
<th>Calibration</th>
<th>Validation</th>
</tr>
</thead>
</table>

- **SWAT version 2009**
- **37 sub-watersheds**
The agreement between the simulated and monthly observed data for the TN and TP load was satisfactory.

<table>
<thead>
<tr>
<th>Constituent</th>
<th>$r^2$</th>
<th>ENS</th>
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</thead>
<tbody>
<tr>
<td>Discharge</td>
<td>0.88</td>
<td>0.68</td>
</tr>
<tr>
<td>TN</td>
<td>0.67</td>
<td>0.54</td>
</tr>
<tr>
<td>TP</td>
<td>0.89</td>
<td>0.89</td>
</tr>
</tbody>
</table>
Spatial distribution of nutrient emission

- Sub-watersheds 5, 10, 15 and 31 emitted higher level of TN
- Sub-watersheds 4, 15 and 31 emitted higher level of TP
- Sub-watersheds 15 and 31 were the hot areas both for TN and TP emission

The emission intensity showed enormous spatial variations that varied from 0.01 to 17.69 kg hm\(^{-2}\) for TN, with the TP range from 0.01-1.82 kg hm\(^{-2}\)
Relationship between nutrient emission and flow and sediment

The sub-watersheds with higher level of TN emission were located in the areas with middle level of flow depth.

Flow generation sediment generation

The sub-watersheds with higher level of TP emission distributed in the higher sediment generation areas.

Good hydrological condition and soil erosion is one of important factors affecting nutrient emission, but not the only.
Relationship between nutrient emission and land use

Relatively higher percentage of dry land and orchard but lower ratio of paddy field or the existence of residential area were also the necessary factors that affected the emission of nutrient.
Spatial distribution of nutrient export

- Heavily polluted sub-watersheds were located close to the outlet of the watershed;
- 5.3% of total area contributed 13.8% of TN loads;
- 5.0% of total area exported 12.5% of TP loads.

- Heavily polluted sub-watersheds coincided with the areas with high level of nutrient emission, but distributed area reduced;
- The export load in these sub-watersheds were lower than nutrient emission intensity.
Considerable variation occurred among sub-watersheds in the proportion of diffuse nutrient emission that exported out from watershed but the ratio of export to emission decreased with increasing sub-watershed number generally.
Nutrient retention in delivery process

Retention coefficient was defined as the proportion of the emission of diffuse nutrient that was removed in the transporting process.

Retention coefficient was positively related to migration distance because the travel time was calculated from migration distance divided by flow velocity.
Multiple-year (2010-2013) mean annual 56% of emitted TN and 19% of TP emission was removed in the delivery process.
Conclusion

- The emission of diffuse nutrient was positively related to the ratio of dry land and orchard but negatively related to the percentage of paddy field.

- Spatial distribution of the export of diffuse nutrient was determined by both nutrient emission and the delivery process, which showed significant variations relative to nutrient emission due to the delivery process.

- Nutrient retention showed great variations among sub-watersheds because of the different migration distances.
Agricultural Non-point Source (NPS) Pollution Research Group

Monitoring the nutrient loss at field/farm and watershed level.

Evaluating the influence of agricultural NPS pollution on the regional water quality.

Optimizing nutrient management strategies at Field/Farm and watershed Scales

Agricultural NPS pollution control and prediction

Key laboratory of NPS pollution control, ministry of agriculture

Experimental method

1. Nitrogen research
2. Phosphorus research

Model method

3. Model research
4. Pre-warning model research

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We have established a national wide agricultural NPS pollution monitoring network since 2007, supported by the Special Fund for Agro-scientific Research in the Public Interest from the Ministry of Agriculture, China (Grant No.: 201303089 and No.: 201003014).
We also have established three typical watershed monitoring sites including Taihu Lake, Three Gorges Reservoir and Erhai Lake for nutrient loss since 2010.
International cooperation and exchanges-China-UK

N-CIRCLE: Virtual Joint Centre for Closed-Loop Cycling of Nitrogen in Chinese Agriculture
Family team
Thanks