Modelling seasonal river export of nutrients to Lake Tana, Upper Blue Nile

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Introduction

- **Water resources all over the world are under pressure**
- **Eutrophication is one of the environmental problems**
- **It is caused by excess loads of N and P**
- **N and P come from diffuse and point sources**

Introduction…

Consequences of eutrophication

- Algal blooming
- Reduced water transparency
- Depletion of dissolved oxygen
- Toxins

Impacts of eutrophication

- Public and ecosystem health
- Socioeconomic activities

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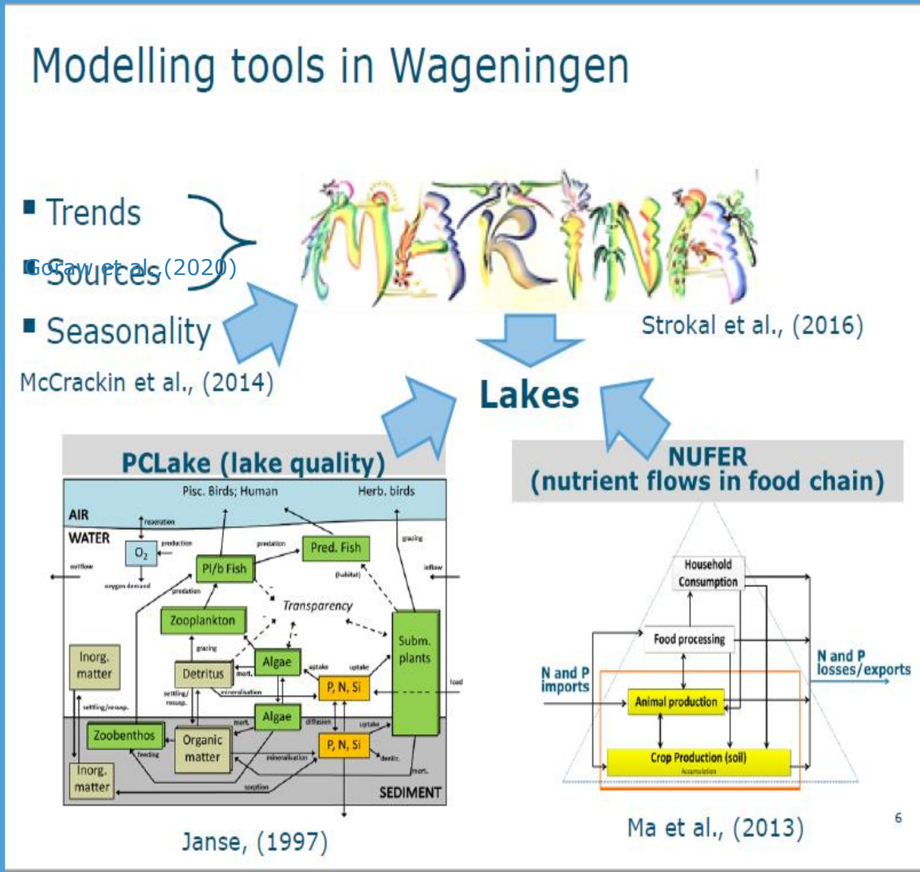
Introduction…

Seasonality of eutrophication

- Cycles of N and P
- N and P loading
- Hydrology, climate and human activities
- …better reflects the seasonality in the effects and the feed-backs (Janssen et al., 2019)

Introduction…

Some of N and P modelling tools in WUR



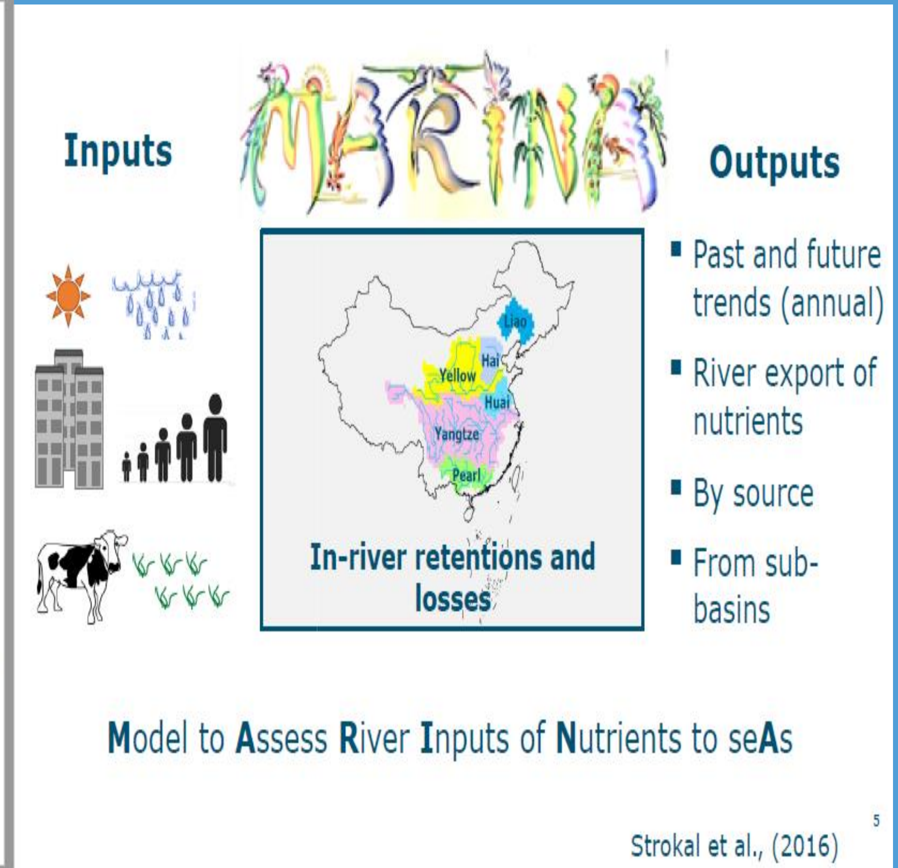


Fig. 1 Modelling tools in WUR. Source: Adapted from Strokal and Goraw, 2018. Modelling nutrient export to lakes. Water Science for Impact, October 2018, Wageningen, The Netherlands

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Objective

- **To assess the seasonality and sources of dissolved inorganic N (DIN) from sub-basins to Lake Tana**

  - **sub-basin scale approach of Strokal et al. (2016)**
  - **seasonal approach of McCrackin et al. (2014)**
  - **we validated the results in the same area.**

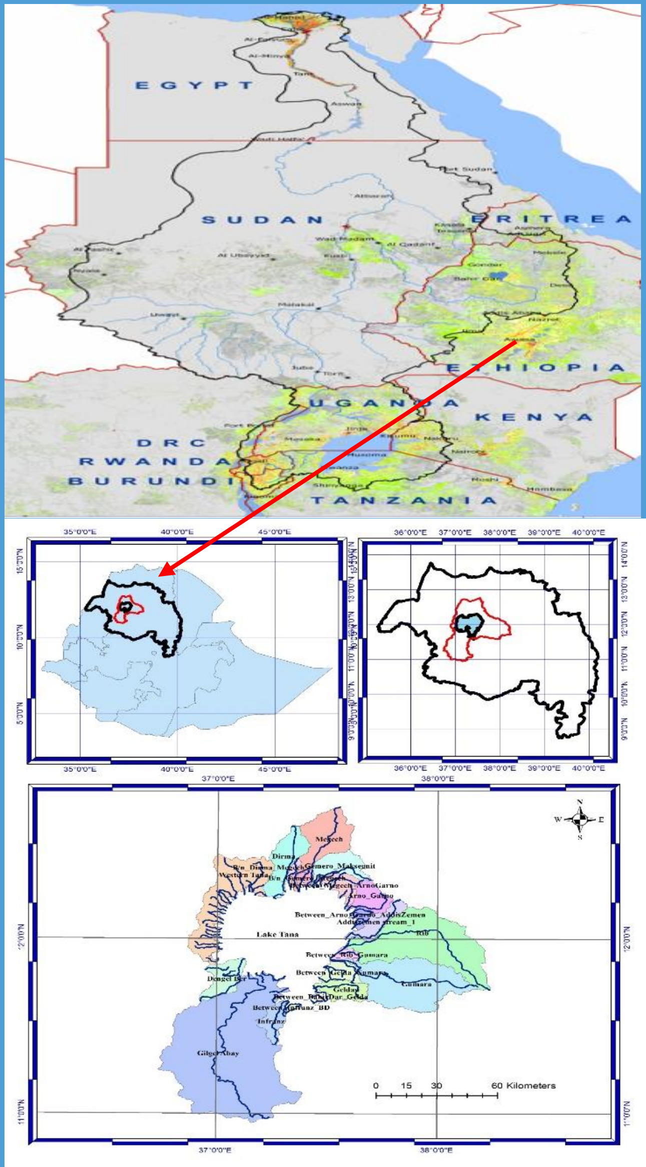
Methodology

Lake Tana Basin

- Area - 15,046 km^2
- Economic corridor
- About 4,5 m people
- **20 sub-basins**

Lake Tana

- Area - 3111 km^2
- Unique biodiversity
- **Source of Blue Nile**
- The largest fresh water resource
- > 6 perineal rivers, >40 seasonal



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Methodology...

Lake Tana basin

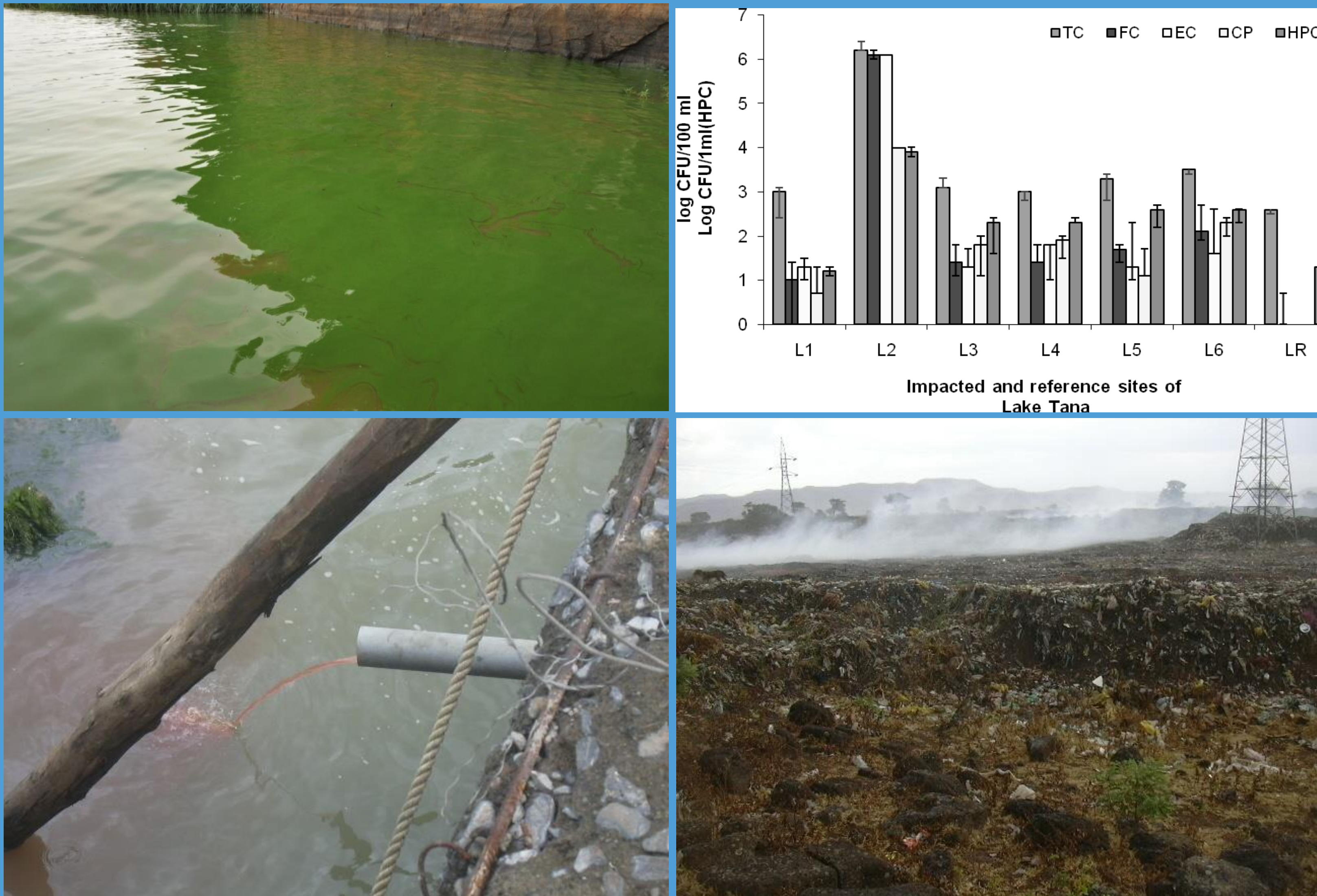

Fig. 3 Some of the human activities in Lake Tana.

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Modelling approach

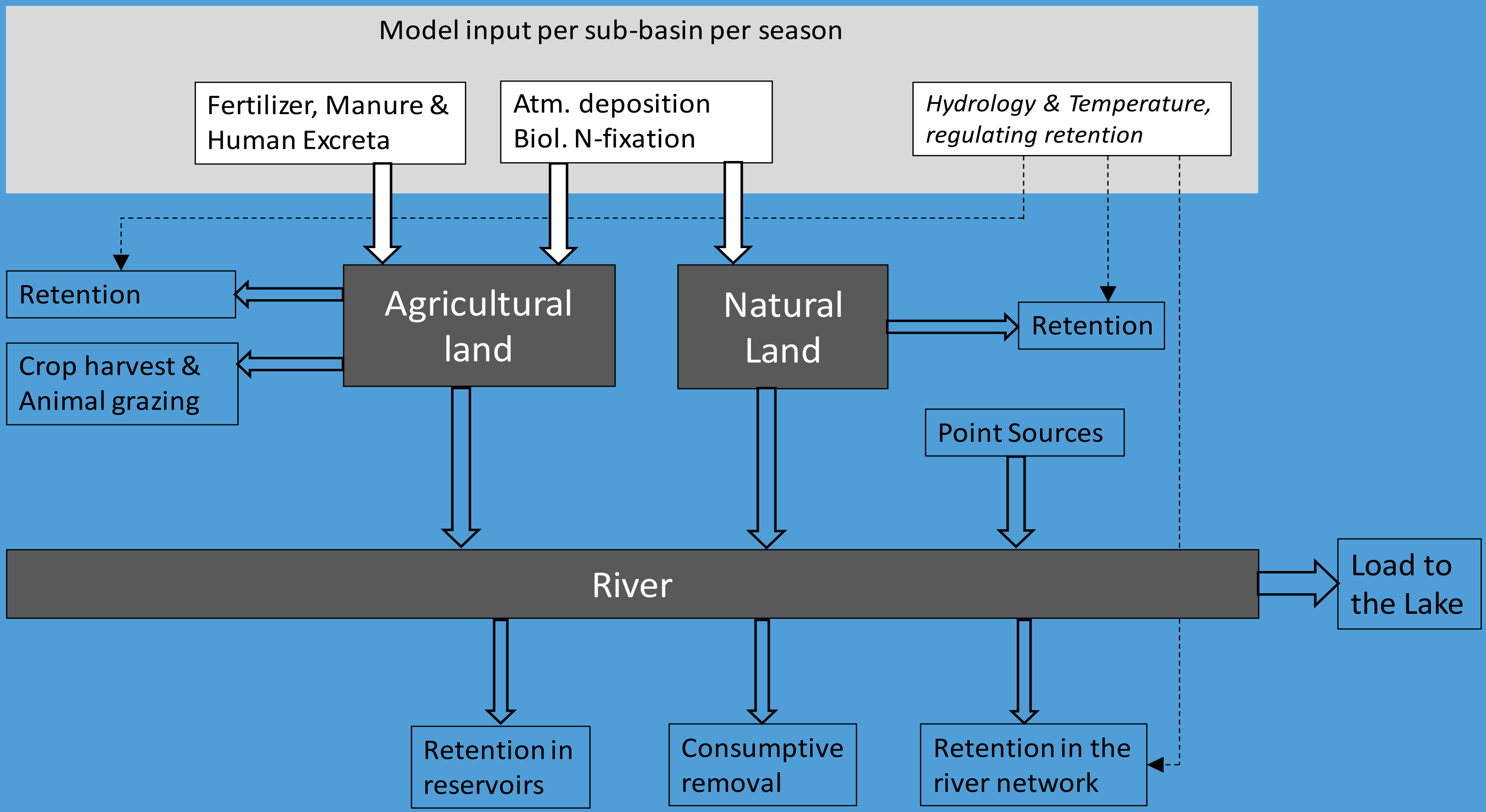

Fig.4 Modelling approach of seasonal DIN export model for Lake Tana. Source: Goraw et al.,(2020)

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Methodology…

Definition of seasons

- **Rainy: July, August and September (JAS),**
- **Post-rainy: October, November and December (OND)**
- **Dry: January, February and March (JFM).**
- **Pre-rainy: April, May and June (AMJ),**

Step 1: Quantifying inputs of N from diffuse and point sources to land and rivers

Sources of N

- Animal manure
- Synthetic fertilizer
- Human waste
- Biological fixation
- Atmospheric deposition

Animal manure - *WSdifN.man.y.j.S*

- **N excretion rate**
- **No. of animals**
- **Loss through denitrification, N_2O, NH_3**

Human waste - $WSdif_{N.hum.uncon.y.j.s}$

- **Housing units without toilet facilities**
- **Faeces and urine generation rates**
- **N content in produced faeces and urine**
- **N loss through ammonia is corrected**

Synthetic fertilizer - *WSdifN.fe.y.j.S*

- **Sum of N inputs from (DAP) and Urea**
- **Rates of DAP and Urea application**
- **Area of land where DAP and Urea applied**
- **N content in DAP and Urea.**

Biological N_2 fixation- WSdifN.fix.ant y.j.s

- **Biological N_2 fixation agri + Biological N_2 fixation natural**
- **Biological N_2 fixation agri**
  - **Legumes- Biomass harvested**
  - **Non-legumes-5 kg N ha^{-1}**
  - **Rice-25 kg N ha^{-1}**

Atmospheric N deposition - $WSdif_{N.dep.ant.j.s}$ and $WSdif_{N.dep.\mathit{nat}.j.s}$

- Depostion rates over agr. Area and

  natural area

- Depostion rates from global News model

- Average seasonal rainfall

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Step 2: Quantifying DIN inputs to rivers from diffuse and point sources

Equations (goraw et al.,2020)

$$M_{DIN.y.j} = \sum M_{DIN.y.j.S} \quad \text{(eq.1)}$$

$$M_{DIN.y.j.S} = RS_{DIN.y.j.S} \cdot FE_{riv.DIN.outlet.j.S} \cdot FE_{riv.DIN.mouth.j.S} \quad \text{(eq.2)}$$

$$RSdif_{DIN.y.j.S} = WSdif_{N.y.j.S} \cdot G_{N.j.S} \cdot FE_{WS.DIN.j.S} \quad \text{(eq.3)}$$

$$FE_{ws.DIN.j.S} = FE_{ro.j.S} \cdot \left(1 - F_{temp.j.S}\right) \quad \text{(eq.4)}$$

$$FE_{ro.j.S} = b \cdot (Rnat_{j.S} * 4)^{a} \quad \text{(eq.5)}$$

$$F_{temp} = d(T_{j,S}/100)^{c} \quad \text{(eq.6)}$$

Step 3:Quantifying river export of DIN from sub-basin outlets to river mouths

(eq.8)

$$FE_{riv.DIN.outlet.j.S} = \left(1 - D_{DIN.j.S}\right) \cdot \left(1 - L_{DIN.j.S}\right) \cdot \left(1 - FQrem_{j.S}\right)$$

(eq.9)

$$D_{DIN.j.i} = 0.8845 \times \left(\frac{h_{j.i}}{\Delta\tau_{R.j.i}}\right)^{-0.3677}$$

(eq.10)

$$L_{DIN.j.S} = \left(0.0605 \times \ln\left(Area_j\right) - 0.0443\right) \cdot Q_{10}^{\frac{\left(T_{j.S} - T_{average.j}\right)}{10}}$$

(eq.11)

$$FQrem_j = 1 - Q_{act.j.S}/Q_{nat.j.S}$$

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Calibration and validation

- Model setup for the year 2017
- DIN load and yield
- Monthly DIN data
- Model performance metrics
  - R^2P, R^2NSE, RSR

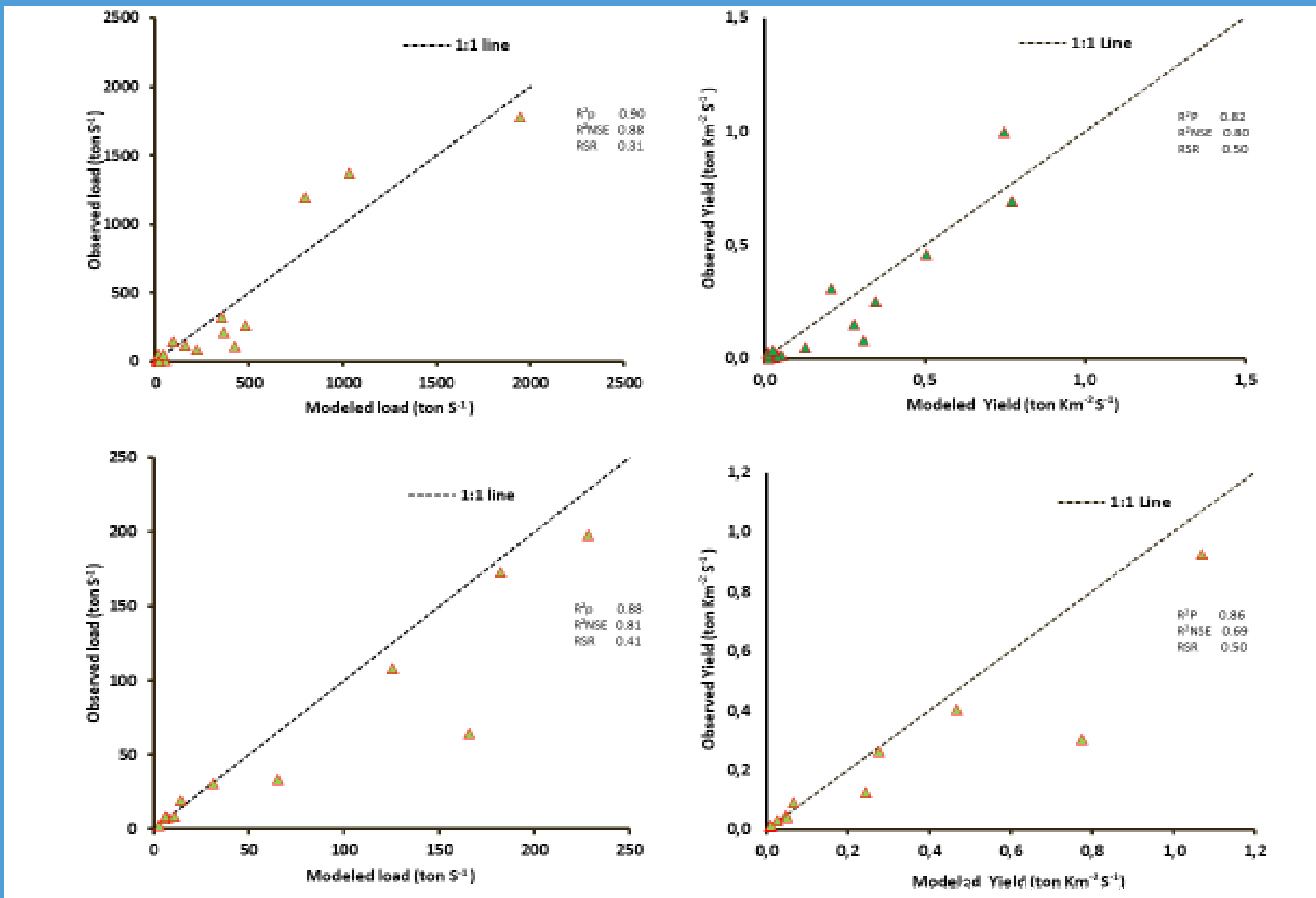
(eq.12)

$$L = \frac{\sum_{i=1}^{m} Q_i .}{m} . \frac{\sum_{j=1}^{n} Cj .}{n}$$

(De Vries and Klavers, 1994)

Results and Discussion

Calibration and Validation



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Results and Discussion…

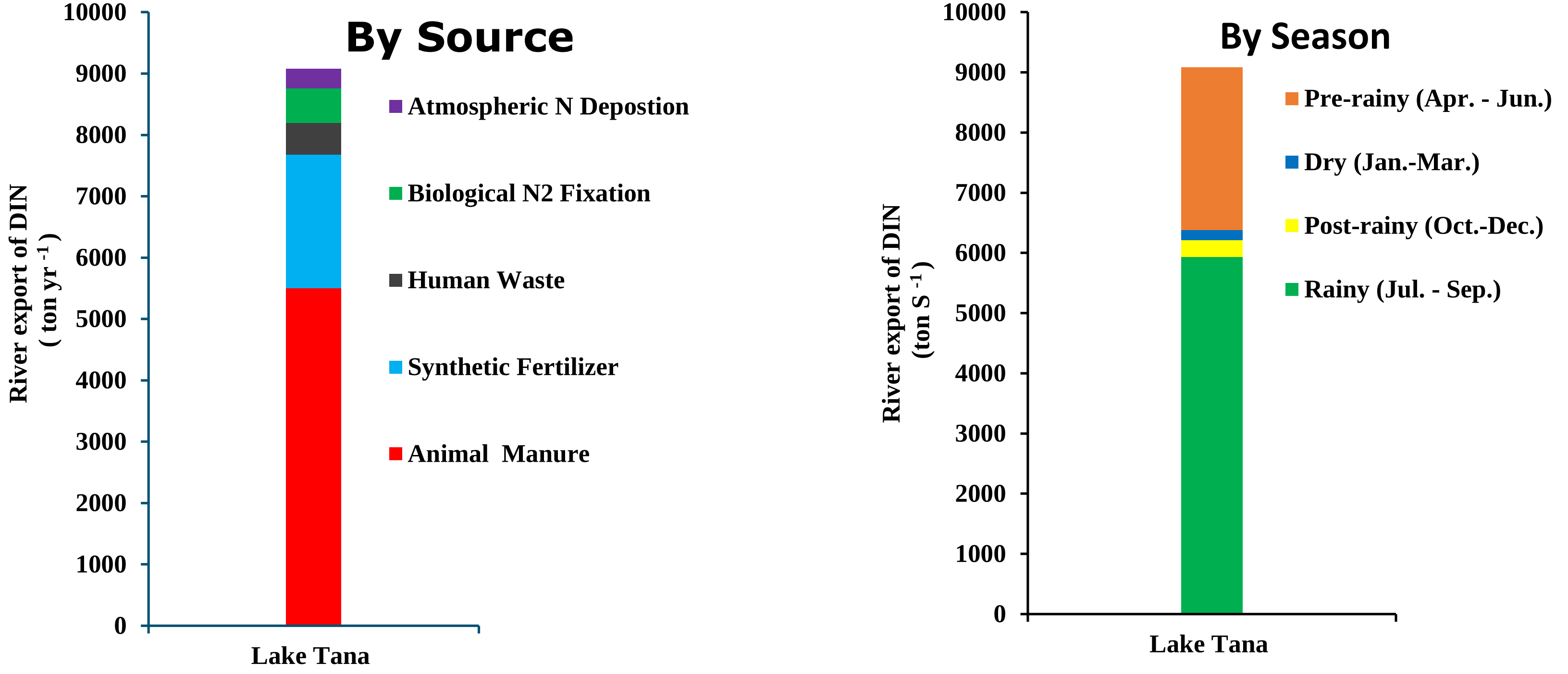

Fig. 6 DIN export to Lake Tana by source and season for the year 2017.

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Results and Discussion...

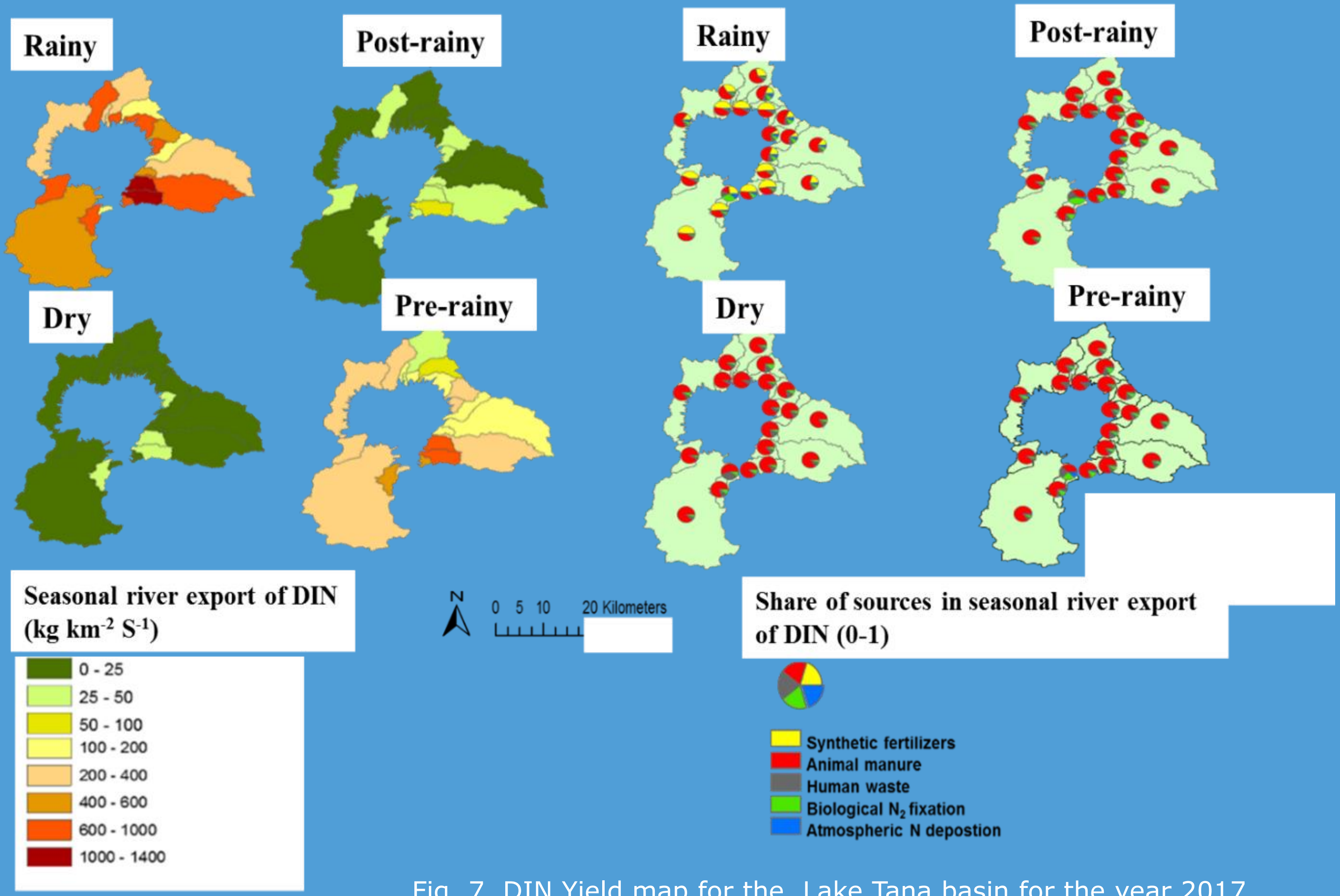

Fig. 7 DIN Yield map for the Lake Tana basin for the year 2017

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Results and Discussion...

Table 1. Modelled N inputs to Land by source and season for Lake Tana in 2017 (kg Km-2S-1)

Sources	Rainy	Post-rainy	Dry	Pre-rainy
Animal manure	201–2,904	201–2,904	201–2,904	201–2,904
Synthetic fertilisers	260–2,873	0	0	0
Human waste	37–249	37–249	37–249	37–249
Biological N_2 fixation*	100–334	135–237	11–162	31–181
Atmospheric N deposition*	131–196	10–24	2–6	43-77

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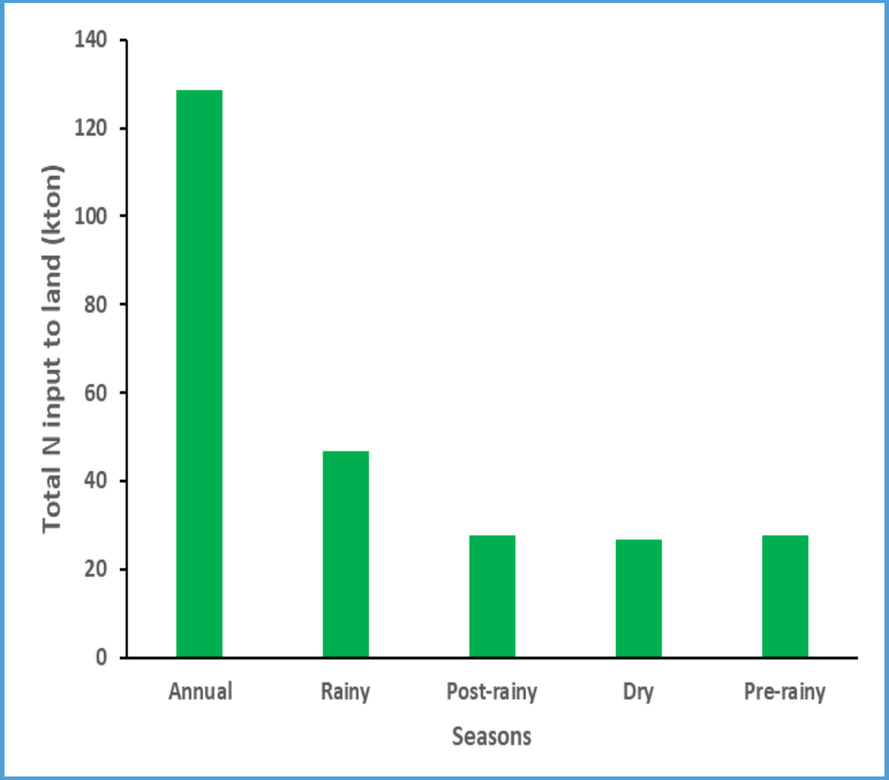
Results and Discussion....



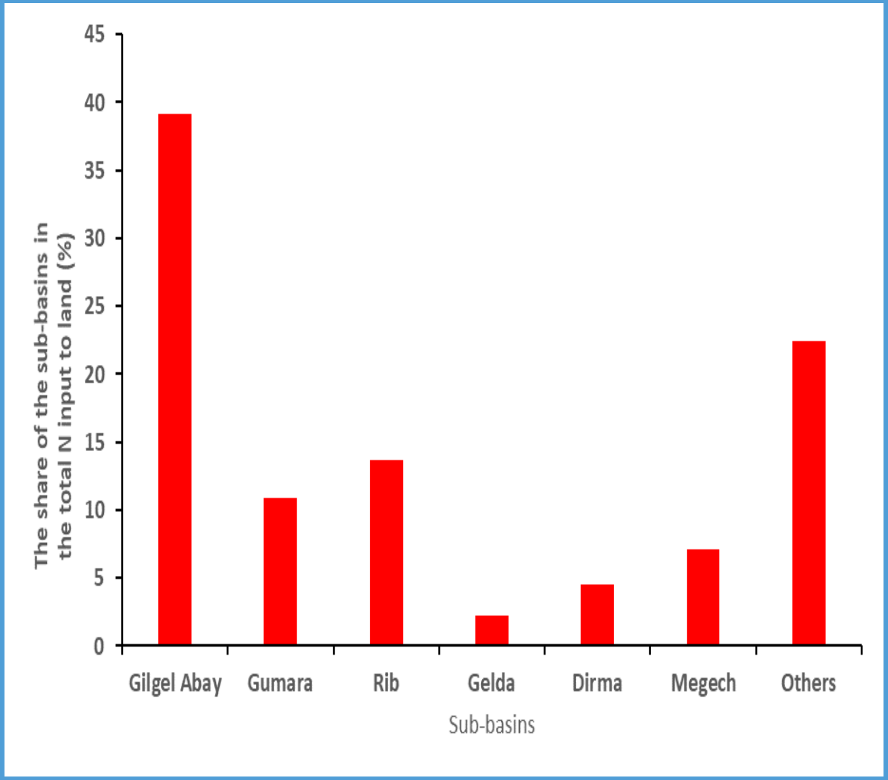


Fig. 7 Total N input to land (kton)(left panel) and the share of the sub-basins in the total N input to land (%) (right panel) for Lake Tana basin in 2017.

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Take home messages

- We adapted and applied a model to Lake Tana to capture seasonality in the river export of nitrogen.
- We modelled nutrient exports to Lake Tana, showing good agreement with measured loads.
- We found that river export of nitrogen to Lake Tana is highest in rainy and lowest in dry seasons.
- We found that animal manure is the dominant source of nitrogen in rivers in all seasons

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Future research outlook

- **Lake Tana and GERD**
  - Monitor N and P concentrations in rivers and GERD
  - Conduct sensitivity and uncertainty analysis
  - Apply the model to other sub-basins
  - Setting critical thresholds
  - Mapping hotspots of N and P losses
  - Study impact of SDG instruments
  - Water quality and ecosystem modelling under different dam filling scenarios

Acknowledgment

- **WUR**
- **BDU**
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Thank YOU!!!

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