

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



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

Modelling tools in Wageningen

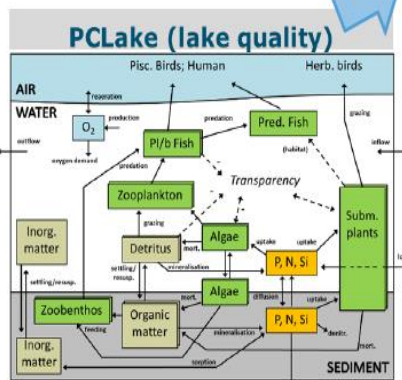
- Trends
- Sources
- Seasonality

McCrackin et al., (2014)



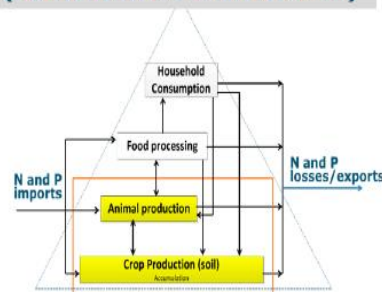
Strokal et al., (2016)

Lakes



Janse, (1997)

NUFER
(nutrient flows in food chain)



Ma et al., (2013)

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Inputs



Outputs



In-river retentions and losses

- Past and future trends (annual)
- River export of nutrients
- By source
- From sub-basins

Model to Assess River Inputs of Nutrients to seAs

Strokal et al., (2016)

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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

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.

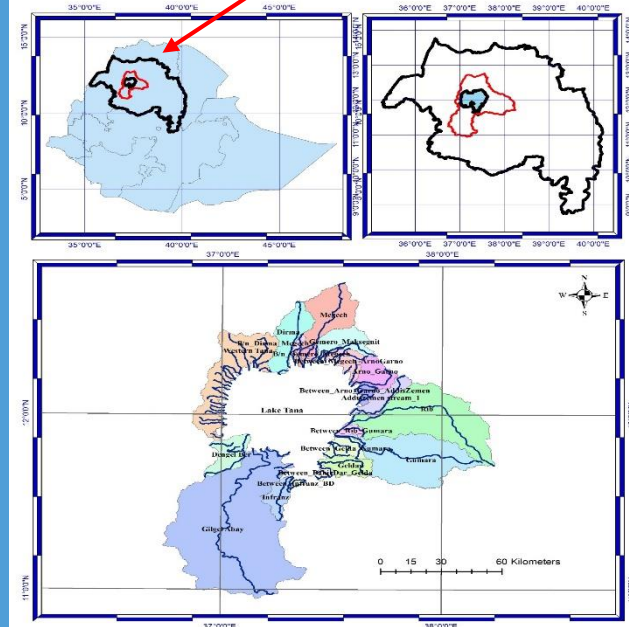
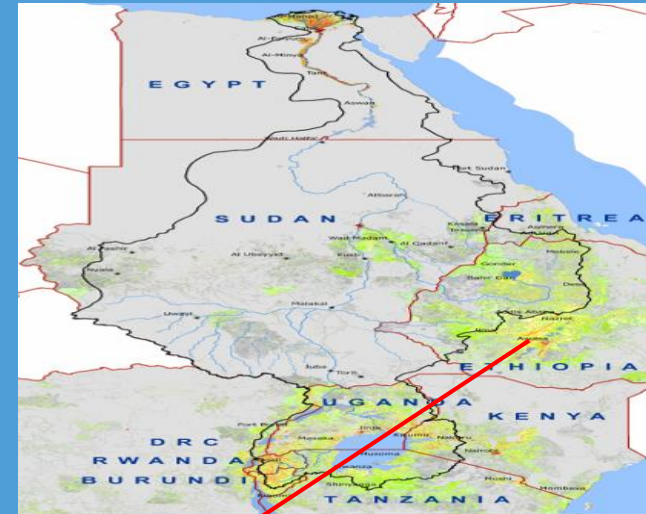
Methodology

Lake Tana Basin

- Area - 15,046 km²
- Economic corridor
- About 4,5 m people
- **20 sub-basins**

Lake Tana

- Area - 3111 km²
- Unique biodiversity
- **Source of Blue Nile**
- The largest fresh water resource
- > 6 perineal rivers, >40 seasonal



Methodology...

Lake Tana basin

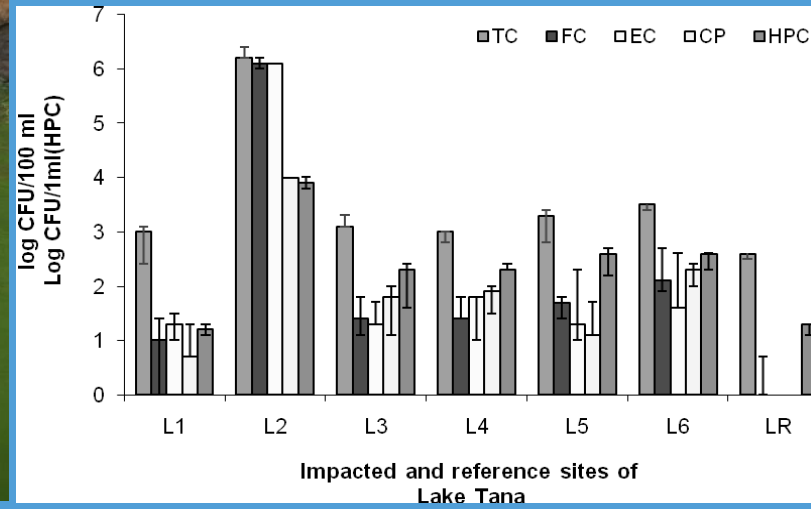


Fig. 3 Some of the human activities in Lake Tana.



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Modelling approach

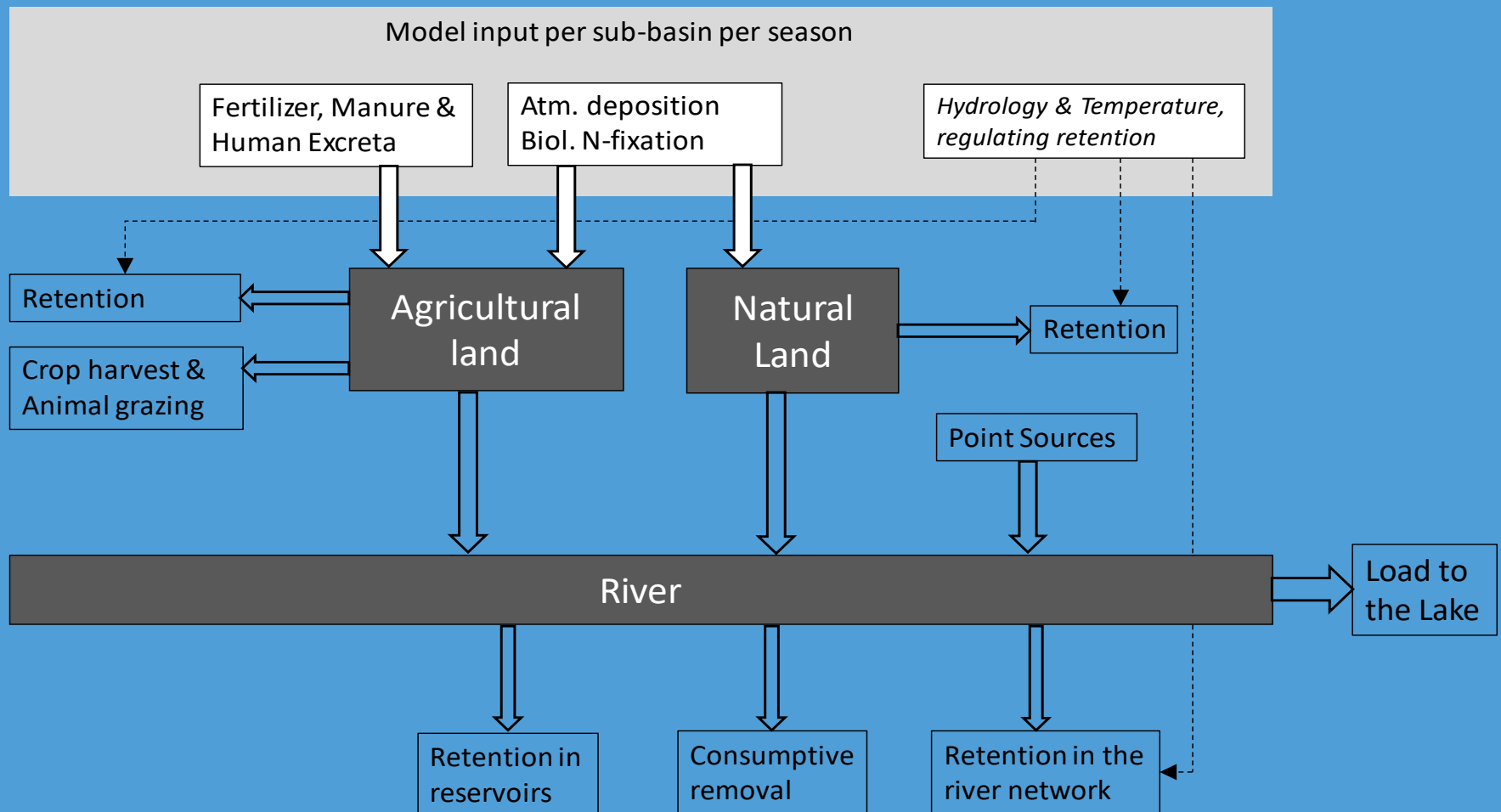


Fig.4 Modelling approach of seasonal DIN export model for Lake Tana. Source: Goraw et al.,(2020)

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 - $WS_{dif}^{N.hum.uncon.y.j.s}$

- 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 N₂ fixation- WSdifN.fix.ant y.j.s

- **Biological N₂ fixation agri + Biological N₂ fixation natural**
- **Biological N₂ 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 $WSdif_{N.dep.nat.j.s}$

- Deposition rates over agr. Area and natural area
- Deposition rates from global News model
- Average seasonal rainfall



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

Equations (goraw et al.,2020)

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

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

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

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

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

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

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

$$FE_{\text{riv.DIN.outlet.j.S}} = (1 - D_{\text{DIN.j.S}}) \cdot (1 - L_{\text{DIN.j.S}}) \cdot (1 - FQ_{\text{rem.j.S}}) \quad (\text{eq.8})$$

$$D_{\text{DIN.j.i}} = 0.8845 \times \left(\frac{h_{\text{j.i}}}{\Delta\tau_{\text{R.j.i}}} \right)^{-0.3677} \quad (\text{eq.9})$$

$$L_{\text{DIN.j.S}} = (0.0605 \times \ln(\text{Area}_j) - 0.0443) \cdot Q_{10}^{\frac{(T_{\text{j.S}} - T_{\text{average.j}})}{10}} \quad (\text{eq.10})$$

$$FQ_{\text{rem.j}} = 1 - Q_{\text{act.j.S}}/Q_{\text{nat.j.S}} \quad (\text{eq.11})$$

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)

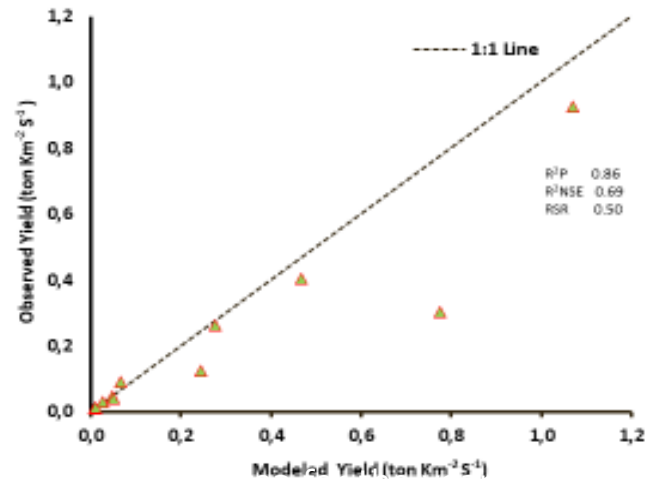
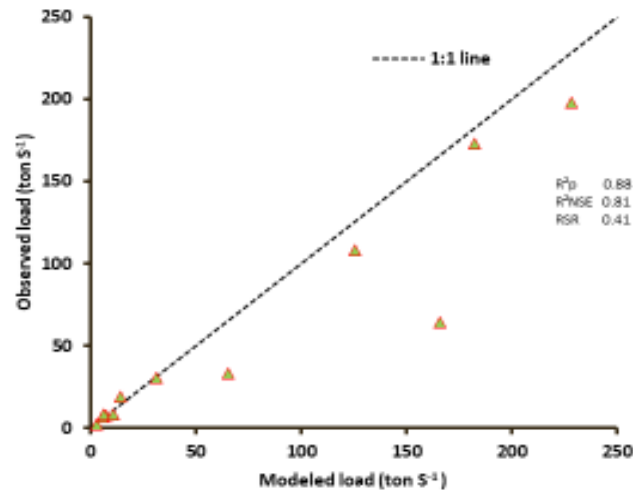
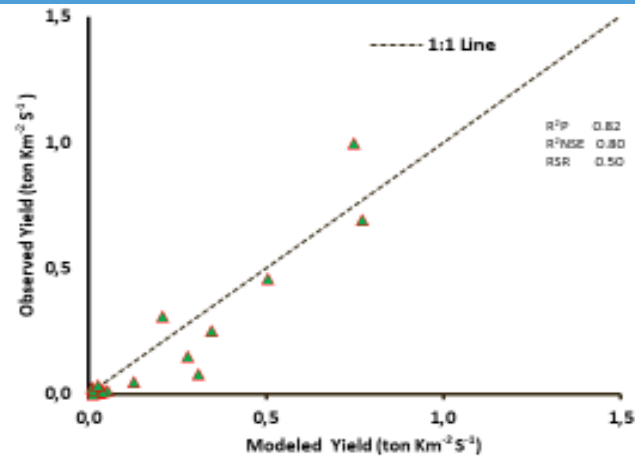
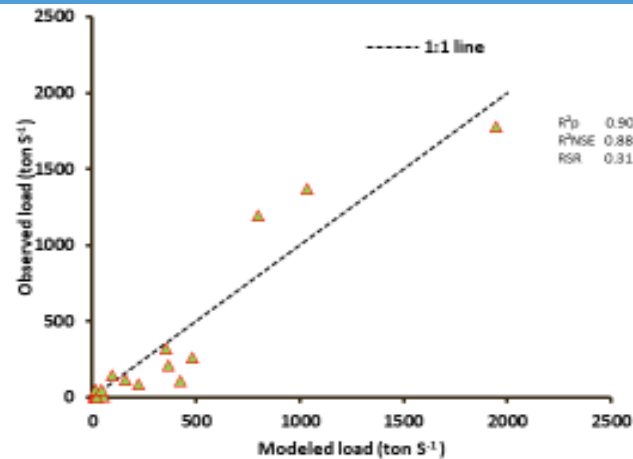
$$L = \frac{\sum_{i=1}^m Q_i}{m} \cdot \frac{\sum_{j=1}^n C_j}{n}$$

(De Vries and Klavers, 1994)



Results and Discussion

Calibration and Validation



Results and Discussion...

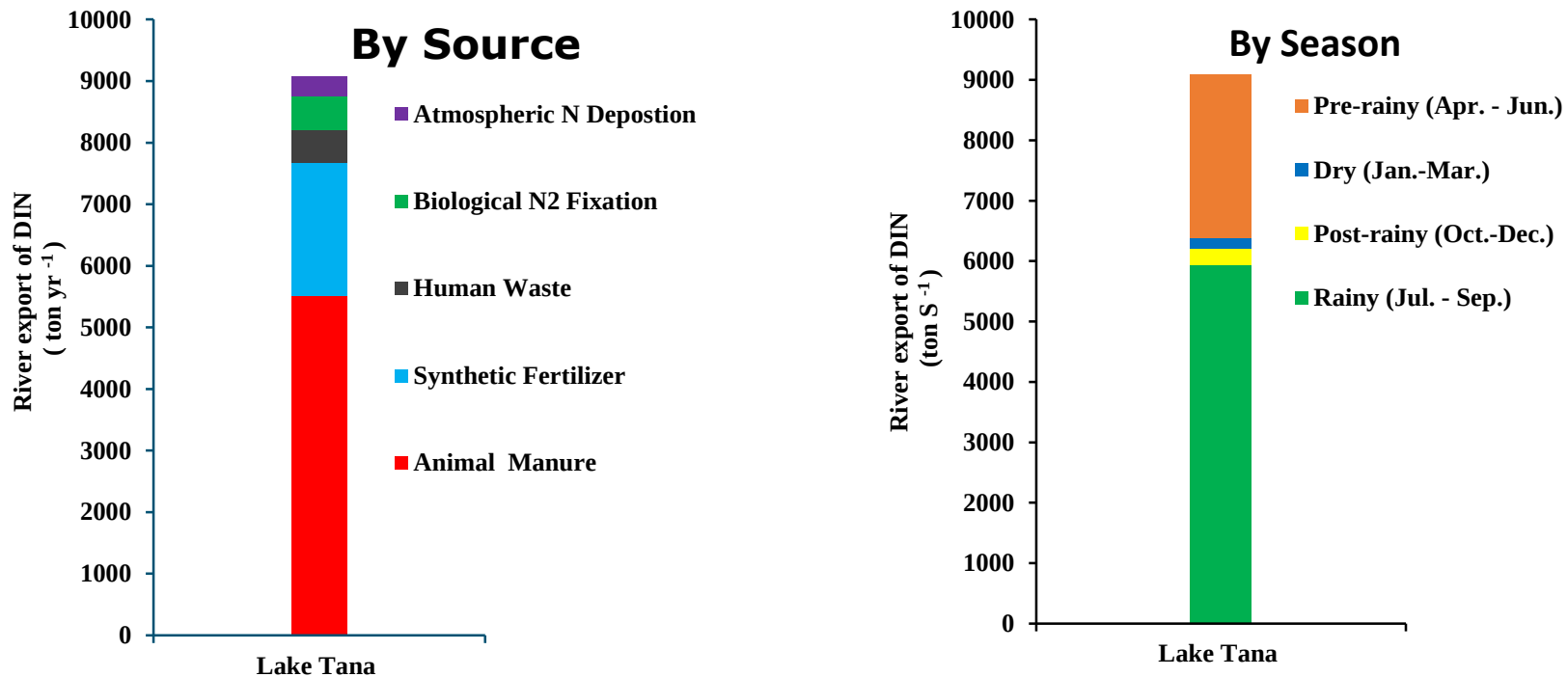


Fig. 6 DIN export to Lake Tana by source and season for the year 2017.

Results and Discussion...

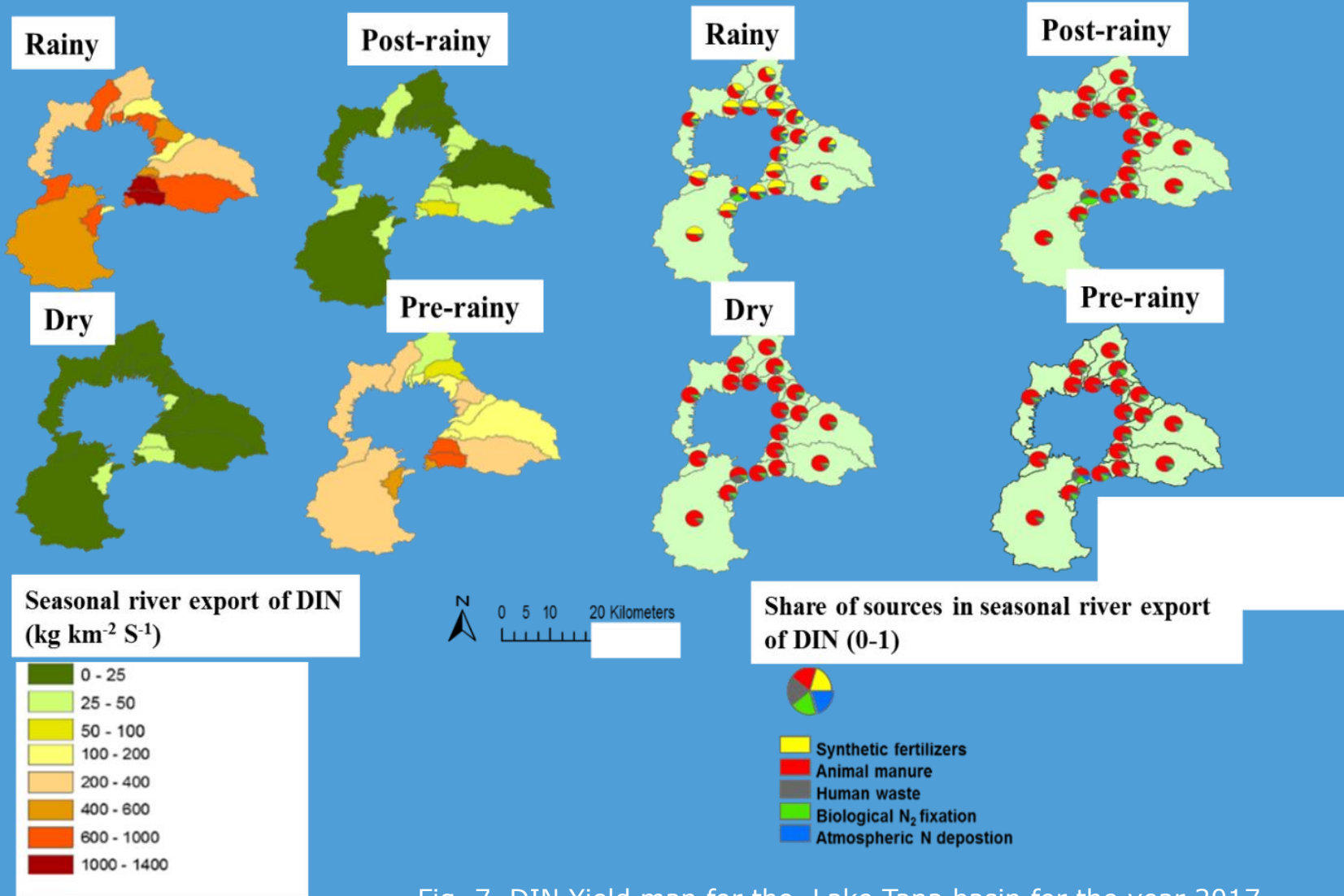


Fig. 7 DIN Yield map for the Lake Tana basin for the year 2017

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



Results and Discussion....

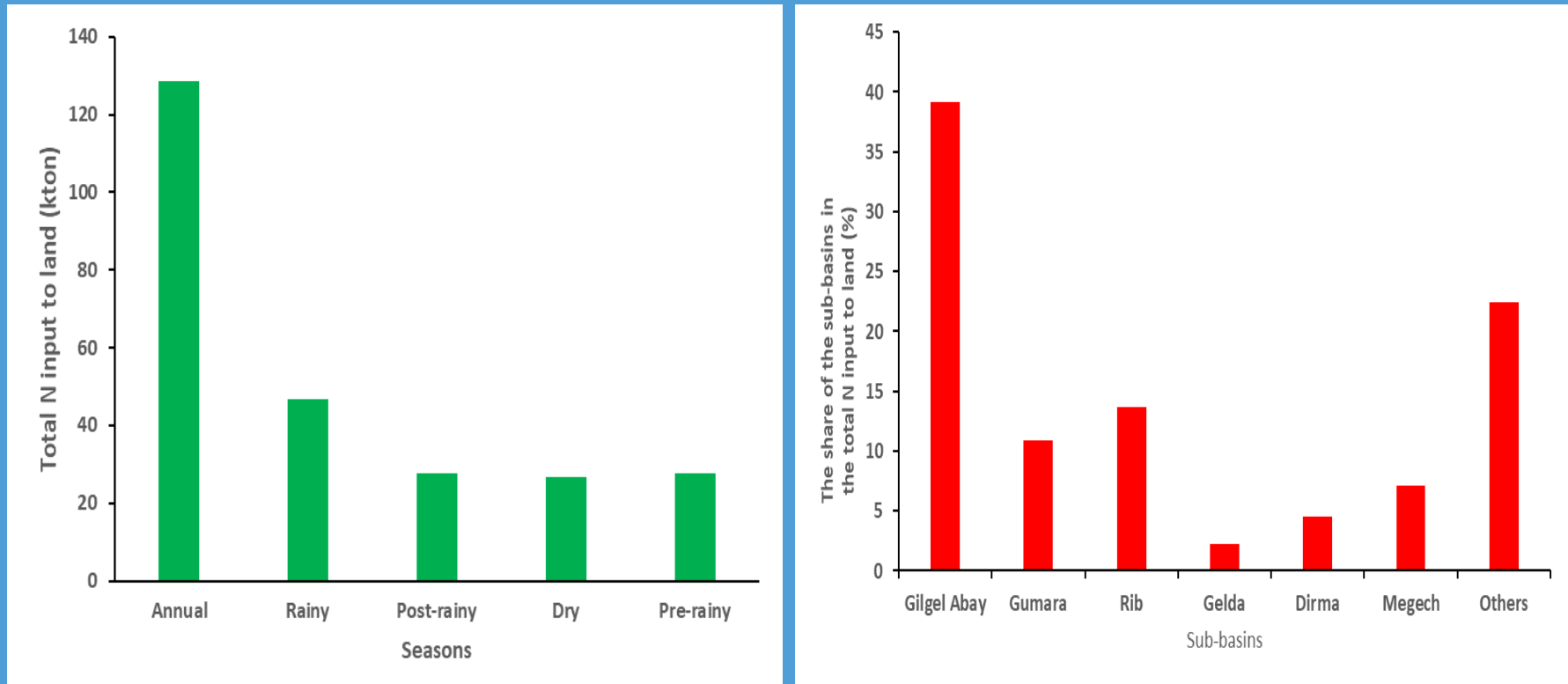


Fig. 7 Total N input to land (kton)(left panel) and the share of the sub-basins in the total N input to land (%) (right panel) for Lake Tana basin in 2017.



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**



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
- NUFFIC

Thank YOU!!!