MONITORING **TURBIDITY DYNAMICS** IN **SMALL RESERVOIRS** USING **REMOTE SENSING** TO SUPPORT **AGRICULTURE** AND **AQUACULTURE** IN **SUB-SAHARAN AFRICA**

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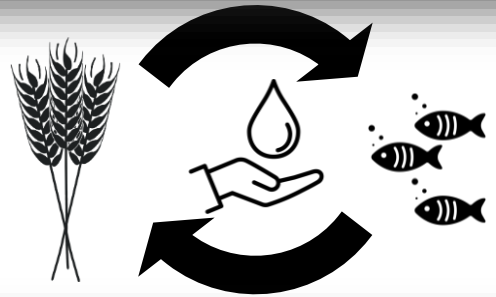
Small Reservoirs

- **Tens of thousands** of **small reservoirs** <100 ha in Africa (IWMI 2019, Kibret et al. 2021)
- **Inexpensive** and **easy** to construct
- **Farmer-led irrigation** and **aquaculture development**

→ **Resilience**, **food** and **water security**


Small-scale irrigation, Nyeri county, Kenya.




Aquaculture pilot site in Ghana. Photo: Barbara van Rijn / IWMI Source: https://www.iwmi.org/news/aquaculture-in-small-reservoirs-in-ghanas-north-east-region/

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Water Quality

Reservoir in Nyeri county, Kenya.

→ Applicable **water quality assessment**

→ **Transferable** and **scalable approaches**

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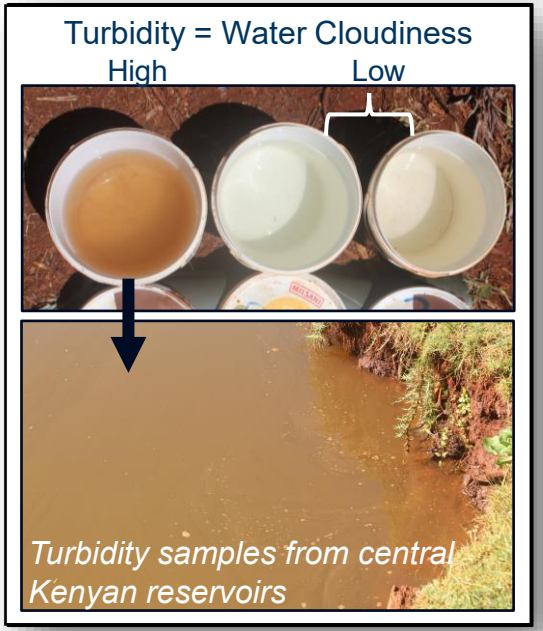
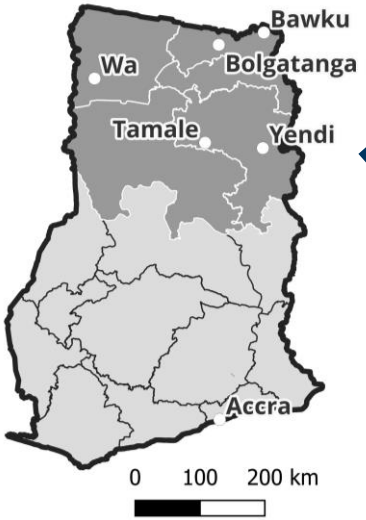
Approach

- **Turbidity** → light availability; suspended detritus and non-algal sediments (Nechad et al. 2010)
- **Measurement** in Nephelometric Turbidity Units (NTU)
- Indicates **overall water quality**
- **Sentinel-2** & **C2RCC processor** in SNAP (Brockman et al. 2016)



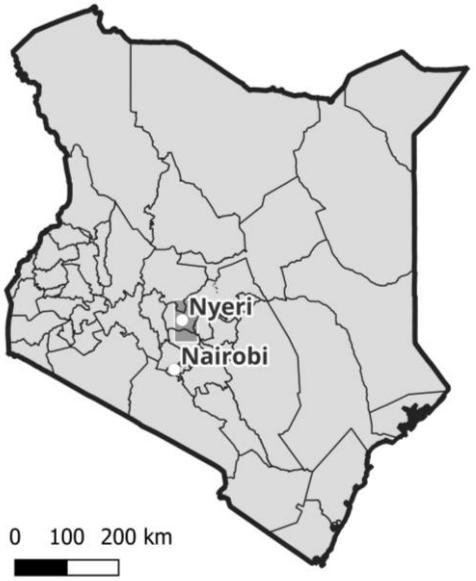
Study Sites

- Study site: **Northern Ghana**
- **~165,000 km², 3,079 reservoirs**
- **Aquaculture** development



→ **Scale** turbidity assessment

- Study site: **Central Kenya**
- **~3,700 km², 34 reservoirs**
- **Agriculture** development



→ **Develop** EO-based turbidity **assessment** and **prediction** workflow

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Kenya: Workflow

- **Turbidity assessment:**
  - Sentinel-2 MSI 1C 2017-2023 to **monthly turbidity dynamics** with parameterized C2RCC
- **Turbidity prediction:**
  - EO-based **predictors:** meteorology, topography, volume, land cover, land use (Wetland Use Intensity, WUI*)
  - ML-based **predictions** and **variable importance** for **annual** and **long-term** analyses

*Franke et al., 2012, Steinbach et al., 2023.

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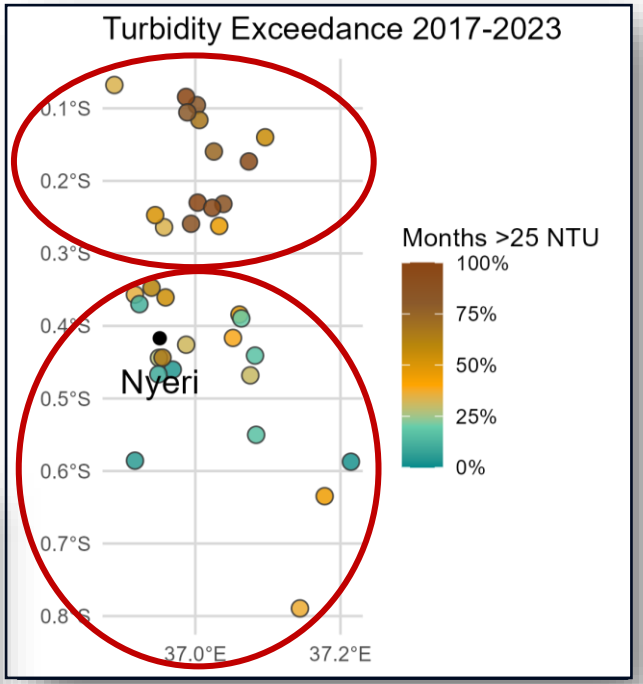
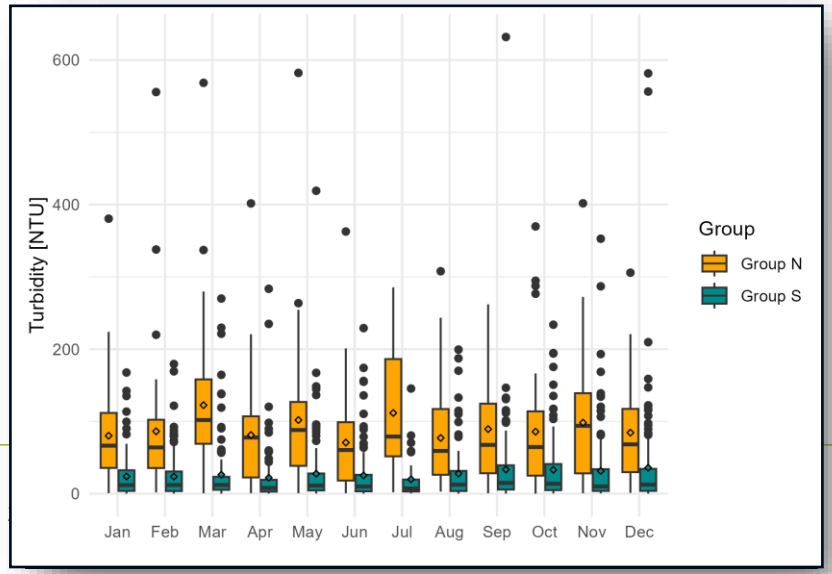
Kenya: Results

- **Exceedance** of **safe turbidity threshold**
- **Cluster** identification



Turbidity limit exceedance.



Clusters with differing turbidity dynamics.

C2RCC model: R^2 = 0.76, nRMSE = 13.9% (n = 45)

Steinbach et al., 2024.
Steinbach et al., 2025.

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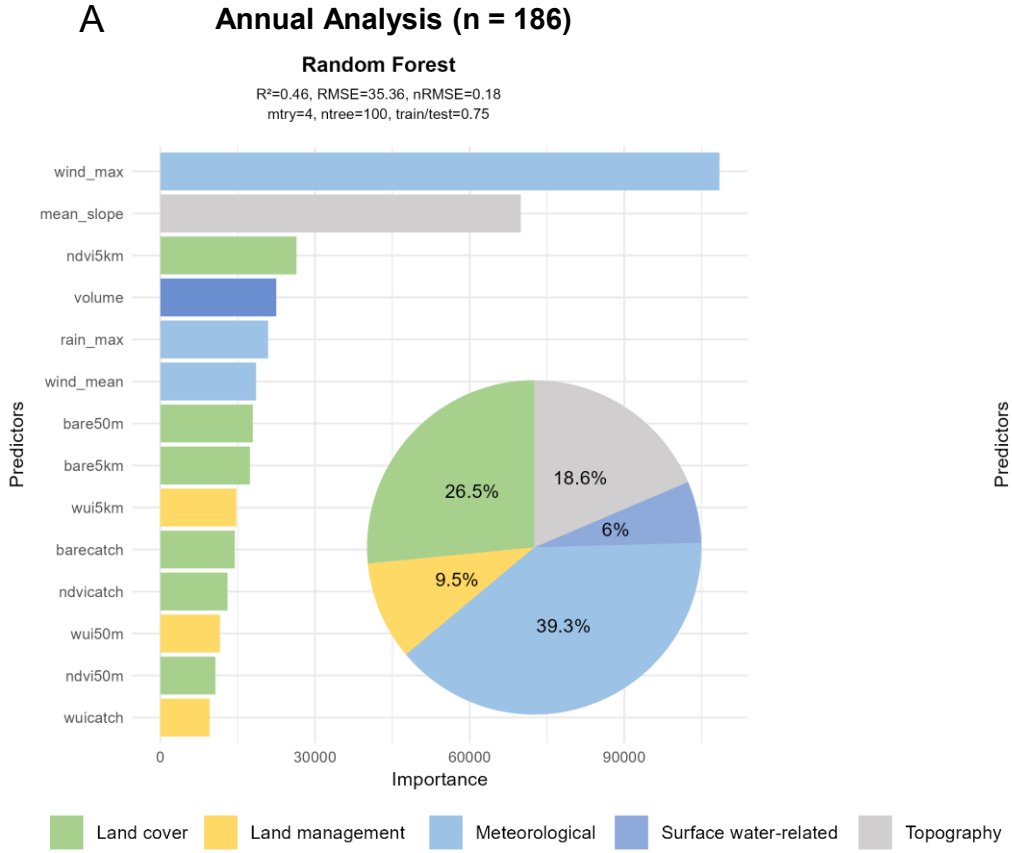

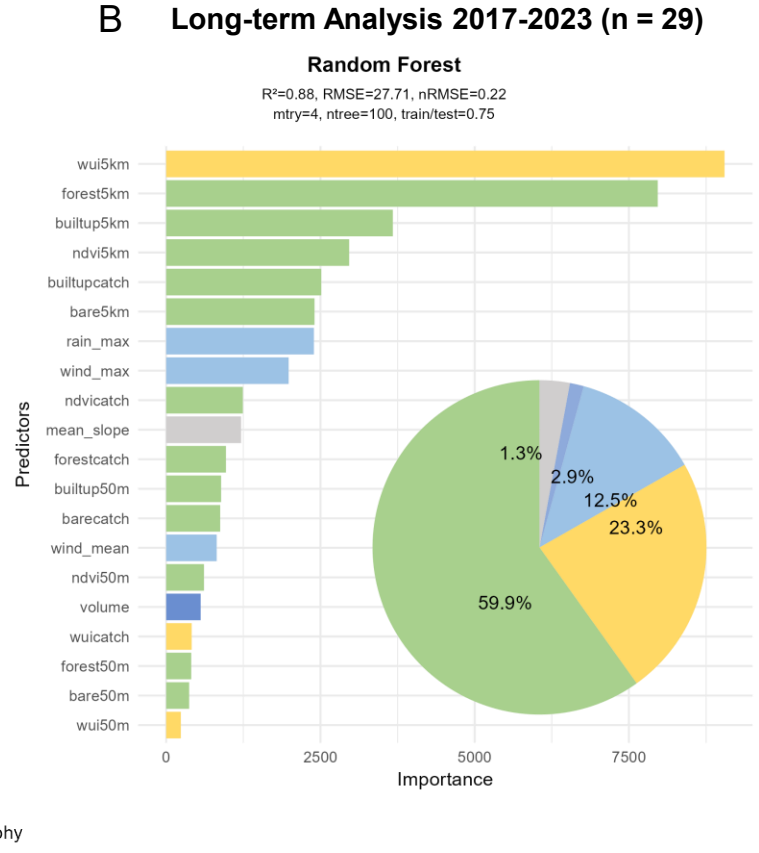

***A** Annual and **B** long-term RF averaged predictor importances and accuracy metrics*

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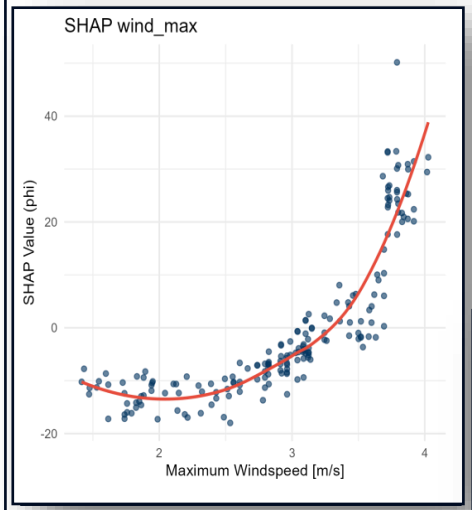
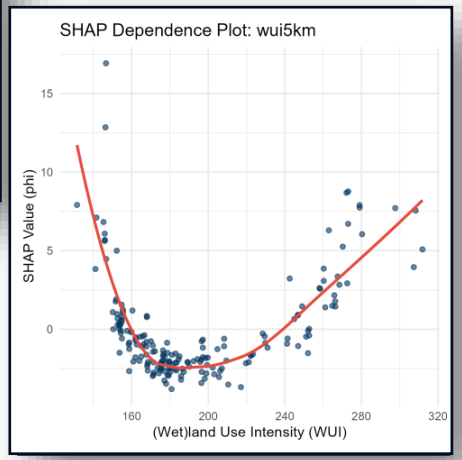
A **Annual Analysis (n = 186)**



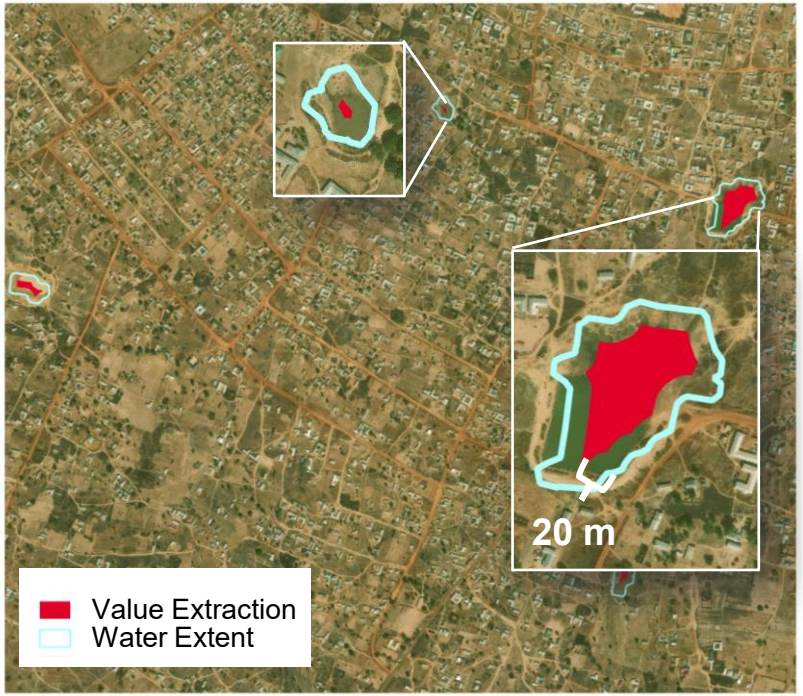


***A** Annual analysis-based SHAP dependance plots.*

- Identify **problematic patterns**
- **Targeted** interventions
- Inform **(agricultural) land management**

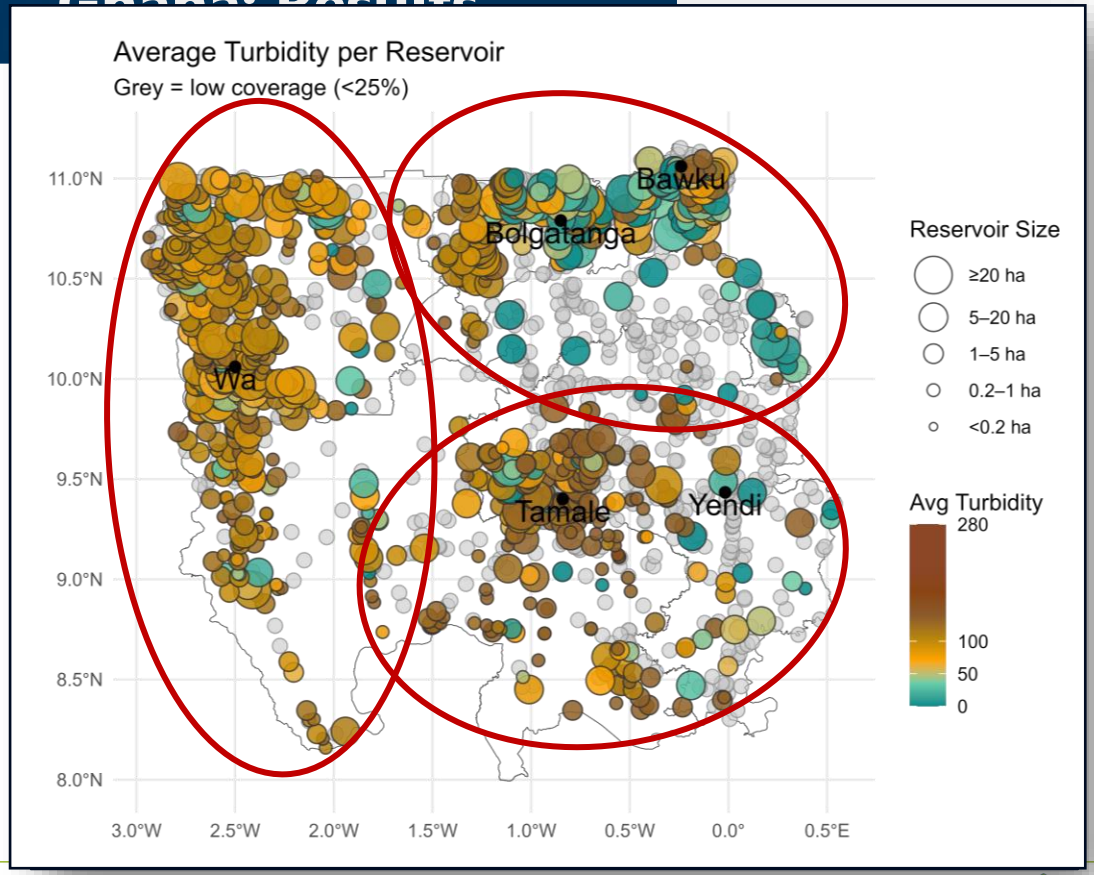
Ghana: Workflow

- Small reservoir **water extent** survey 2017-2023 (IWMI 2023)
- **Default C2RCC parameters**
- Matching data with **closest date** from survey, extraction with **20 m inside buffer**



Small reservoir extent and value extraction area.

Ghana: Results



- **3,079 → 1,052 reservoirs** with sufficient values

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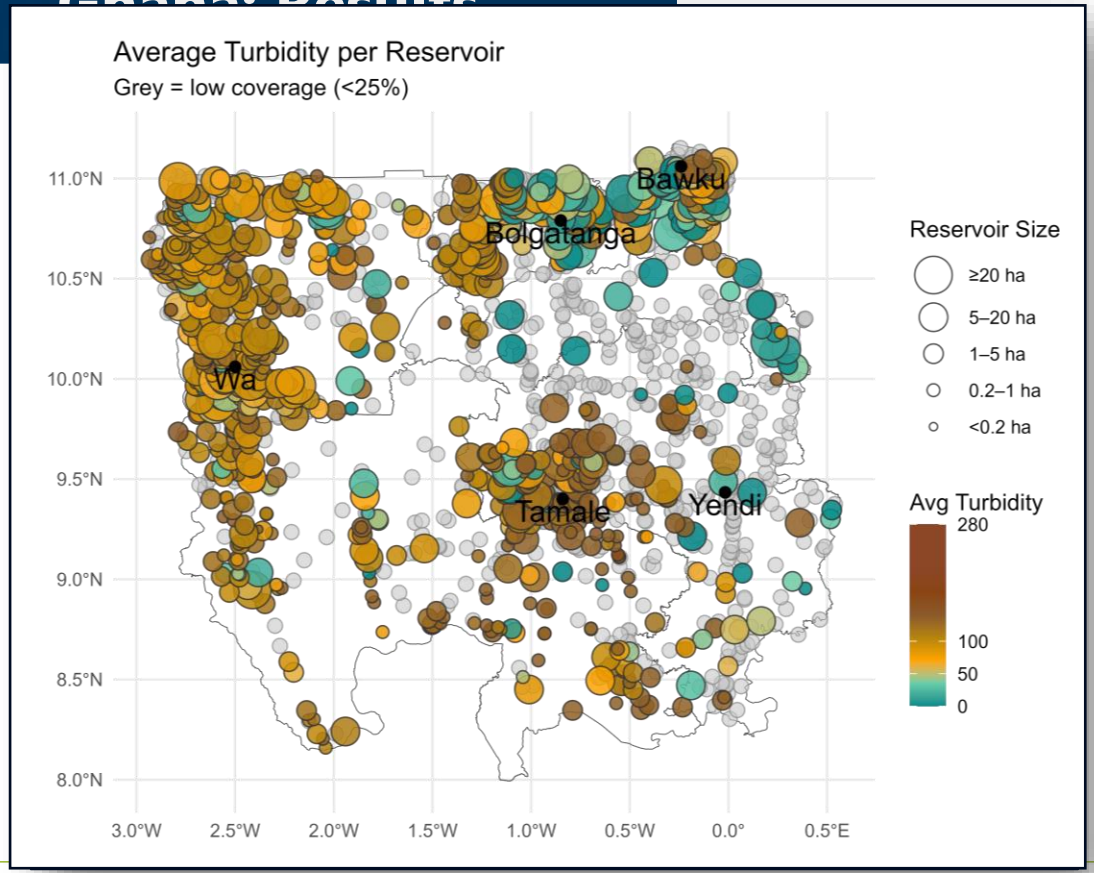
Ghana: Results



- **Scaling** for >1,000 small reservoirs

Next steps:

- **Understanding** the clusters
- **In-situ validation** campaign
- Defining **suitable turbidity indicators** to **match aquaculture** requirements

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Conclusions & Recommendations

- EO workflows to efficiently complement water **quantity** and water **quality** assessments
- Assessments and thresholds **adapted to water use**
- Identify **patterns** and **inform management**
- **Advance knowledge** around the **complexity** of small reservoir systems

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Thank you for your kind attention!

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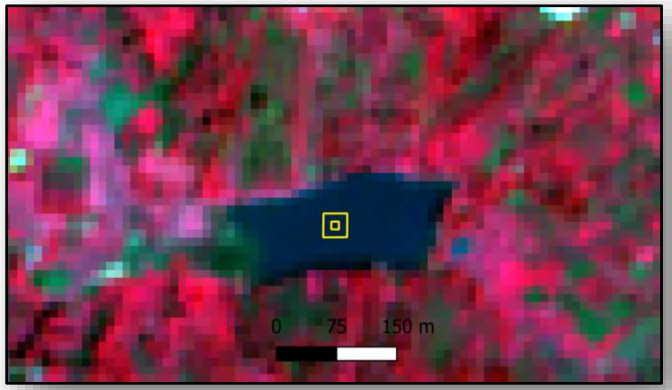
Approach



False-colour Sentinel-2 image of a Kenyan dam with 3x3 pixel window.

- **C2RCC processor** in SNAP (Brockman et al. 2016)
- **Inverts radiative transfer simulations** using neural networks to derive Inherent Optical Properties (IOPs)
- **Improved transferability** compared to purely statistical models
- 45 match-ups from an averaged **3x3 pixel window**

Steinbach, S., Rienow, A., Chege, M.W., Dedring, N., Kipkemboi, W., Thiong'o, B.K., Zwart, S.J., Nelson, A., 2024. Low-Cost Sensors and Multitemporal Remote Sensing for Operational Turbidity Monitoring in an East African Wetland Environment. IEEE JSTARS 17, 8490–8508.

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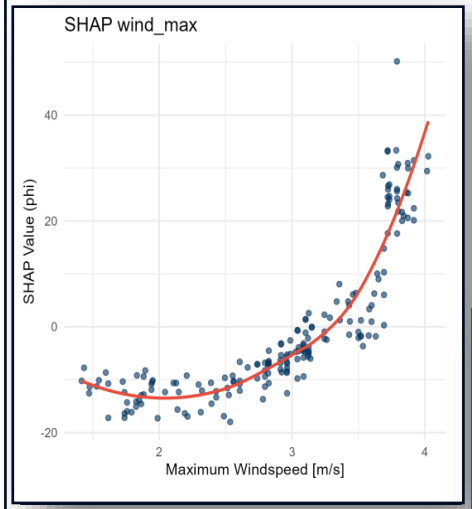
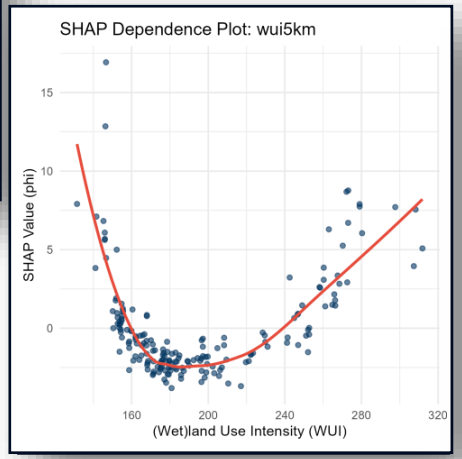
A **Annual Analysis (n = 186)**

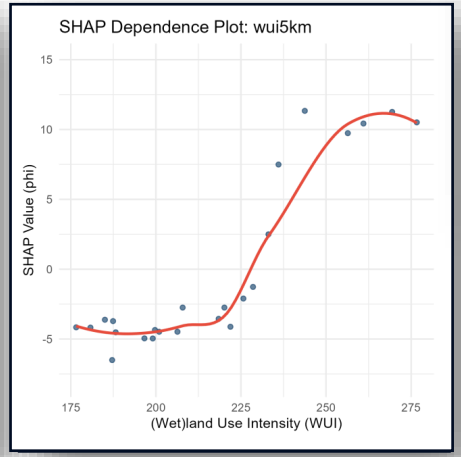
B **Long-term Analysis 2017-2023 (n = 29)**

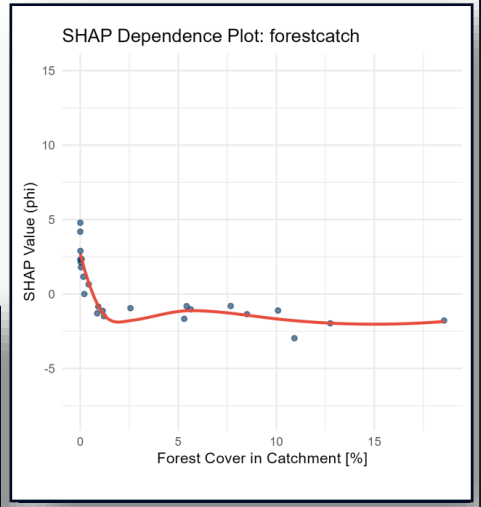


SHapley **A**dditive ex**P**lanations (**SHAP**)

(Lundberg & Lee 2017)







***A** Annual and **B** long-term analysis-based SHAP dependance plots.*

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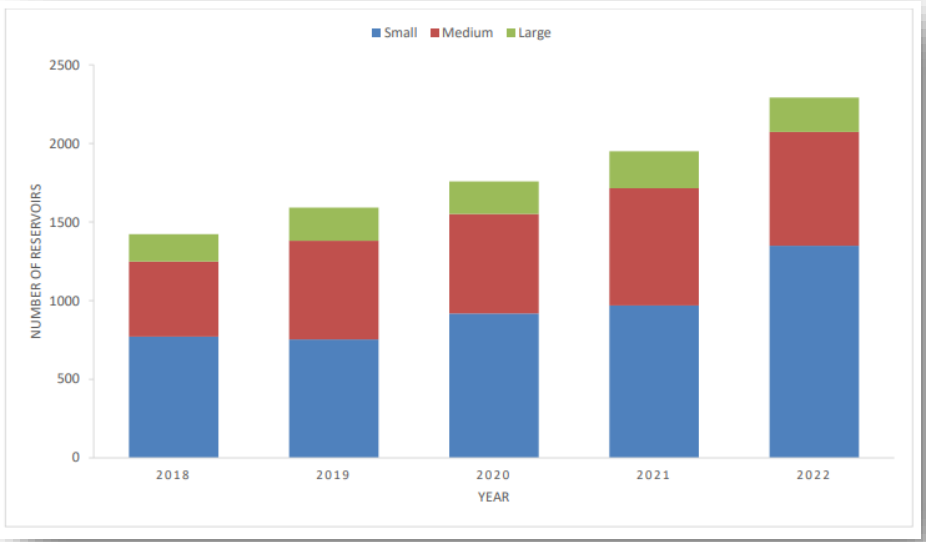
Ghana: Workflow



Number of reservoirs by size at the beginning of dry year.
Source: IWMI 2023.

IWMI small reservoir survey 2017-2023:

- Sentinel-2 based **detection**, **maximum extent (median = 0.5 ha)**
- ~50% at **very high risk** of **drying up**
- **3,079 reservoirs**

(IWMI 2023)

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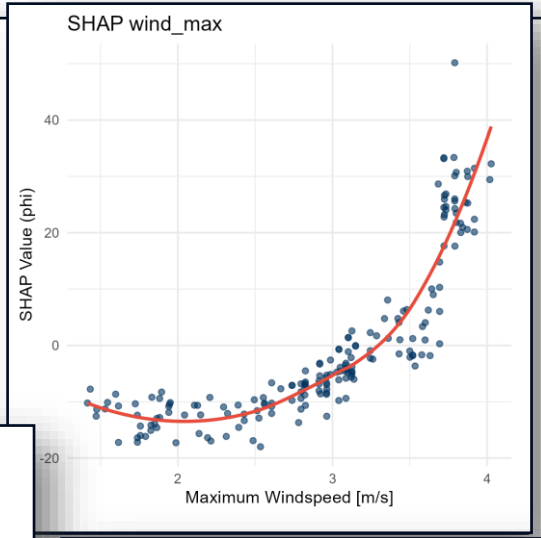

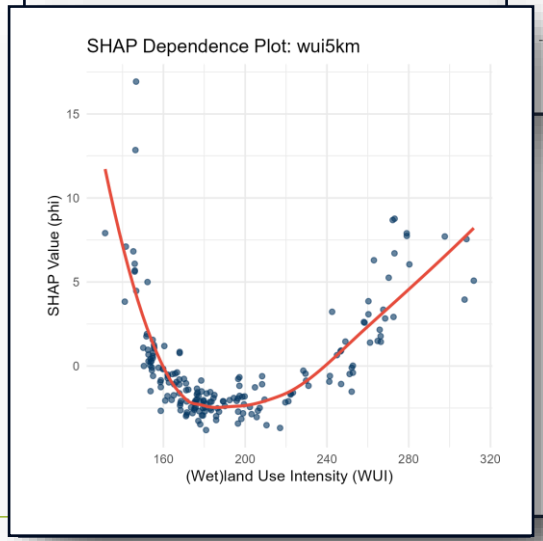

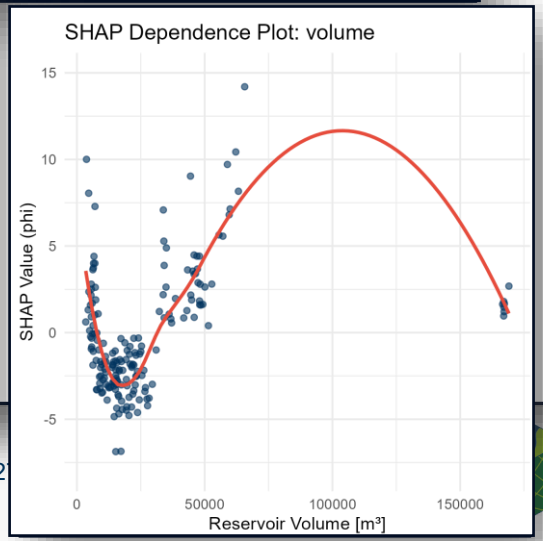

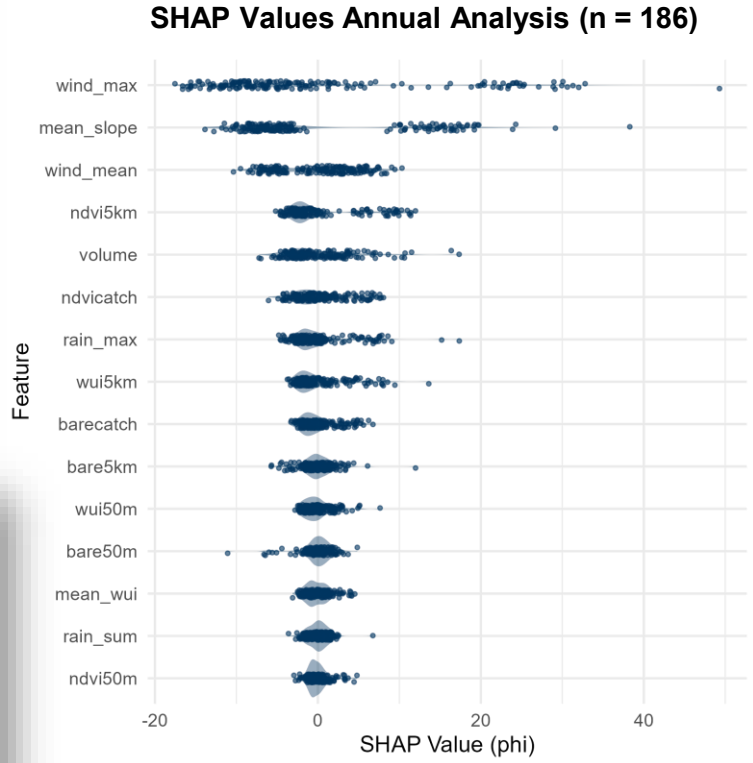

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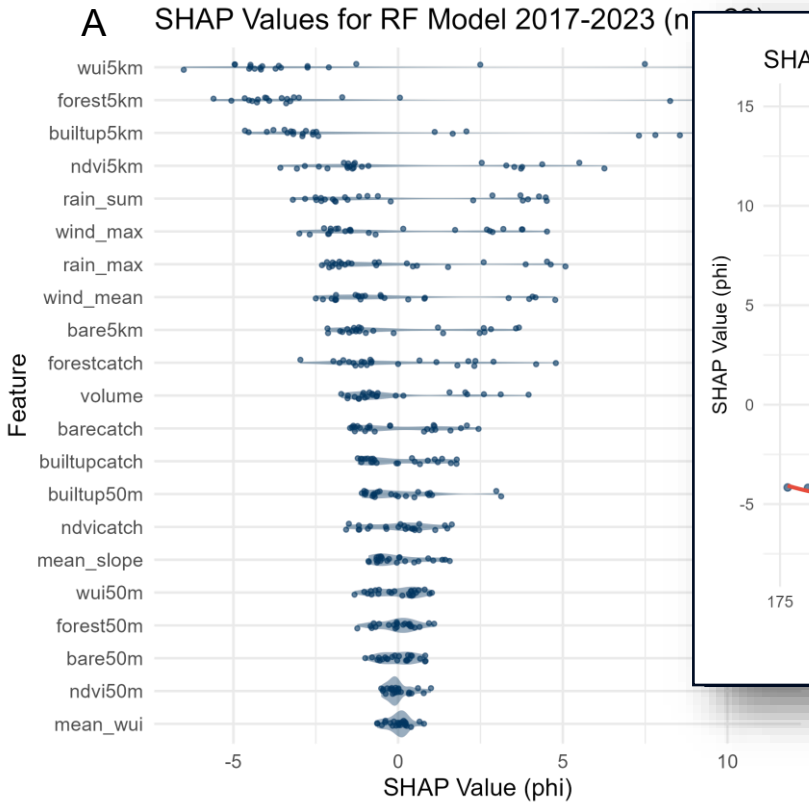

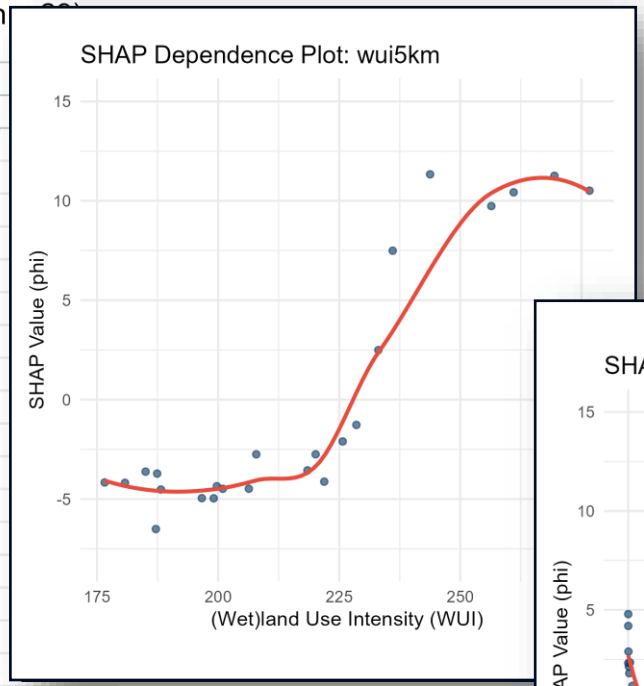

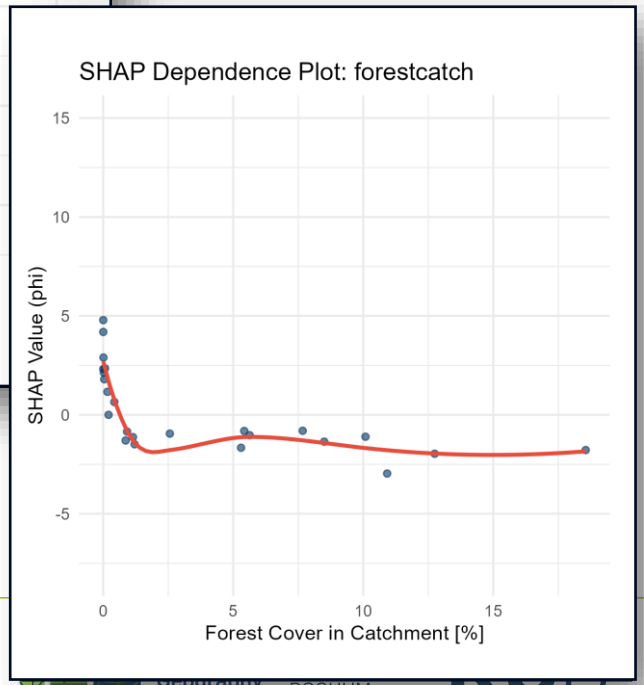

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