Including water quality in the water-energy-food nexus: An Upper White Nile case study

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1. INTRODUCTION

- The ecological and climatic crisis are threatening water, energy, and food security
- The water-energy-food (WEF) nexus provides an integrated solution to sustainable development by considering the interlinkages and interdependencies between resources
- Current WEF research often remains theoretical and there is a lack of comprehensive environmental and water quality considerations in the available modelling tools

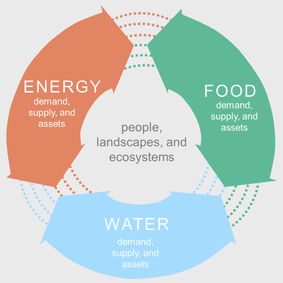


Figure 1: Water-energy-food (WEF) nexus framework, adapted from IWA, 2018

IWA. (2018). Sustainable Development: The Water-Energy-Food Nexus.

2. CASE STUDY

- The Upper White Nile (UWN) basin Includes the Lake Victoria basin and Victoria Nile basin, it extends into Uganda, Kenya, Tanzania, Burundi, and Rwanda and drains an area of 351,500 km^2
- The UWN basin is one of the most densely populated rural regions in the world and economically supports approx. 70 million people
- Fisheries, agriculture, hydropower generation, tourism, and transboundary conservation are all crucial in supporting the population but are faced with numerous environmental challenges

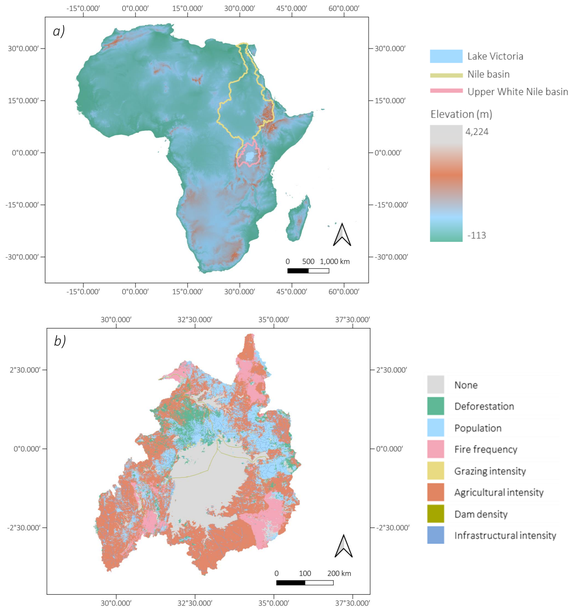


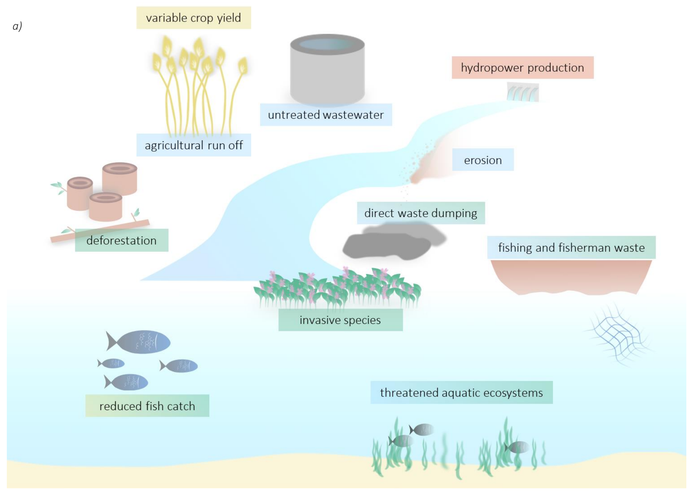
Figure 2: a) Map of the UWN basin; b) Co$tingNature map of the greatest relative pressures in the UWN basin

3. WEF NEXUS INDICATORS

- Employed semi-structured interviews to obtain stakeholder insights on the most significant environmental issues facing the basin (*Fig. 3a*)
- The CN analysis (*Fig. 2b*) illustrates the spatial distribution of pressures, whilst interviews show resulting impacts
- Findings were combined to develop WEF nexus indicators for the basin (*Fig. 3b*)
- This shows the priorities for future WEF nexus research and ensures research is fit-for-purpose in addressing the most pressing challenges

Figure 3: a) Results from stakeholder interviews; b) Proposed WEF nexus indicators and their occurrence in stakeholder interviews. Stakeholders include: Association of Fishers and Lake Users of Uganda (ALUFU); Uganda Electricity Generation Company Limited (UEGC); Academia (Ac.); National Water & Sewerage Corporation (NWSC); Nile Basin Initiative (NBI; Uganda Police Marine (UPM); Ministry of Agriculture, Animal Industry and Fisheries (MAIIF); Ministry of Water and Environment (MWE) in Uganda

a)



b)

	ALUFU	UEGC	Ac.	NWSC	NBI	UPM	MAIIF	MWE	%
River flow		■	■		■	■	■	■	75
Lake levels		■	■		■	■	■	■	75
Total nitrogen	■		■	■	■	■		■	75
Total phosphorus	■		■	■	■	■		■	75
Sediment transport	■		■		■	■	■		63
Dissolved oxygen	■		■		■	■			50
Hydropower energy		■			■		■		38
Energy demand		■					■		25
Energy access		■							13
Crop yield							■		13
Fisheries yield	■		■	■		■	■	■	75
Irrigation water					■		■	■	38
Food demand							■		13
Food access							■		13
Aquatic biodiversity		■	■	■	■		■	■	75
Eutrophication				■				■	38
Land degradation	■		■	■	■	■	■		75
Invasive fish	■		■			■	■	■	63
Invasive plants			■			■	■		38
%	37	32	63	32	53	53	74	47	

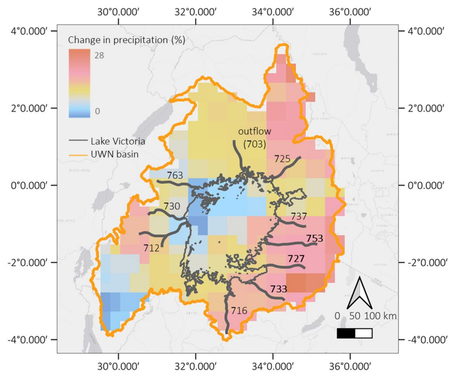
% 91 – 100, 81 – 90, 71 – 80, 61 – 70, 51 – 60, 41 – 50, 31 – 40, 21 – 30, 11 – 20, 0 – 10

4. CLIMATE CHANGE IMPACTS

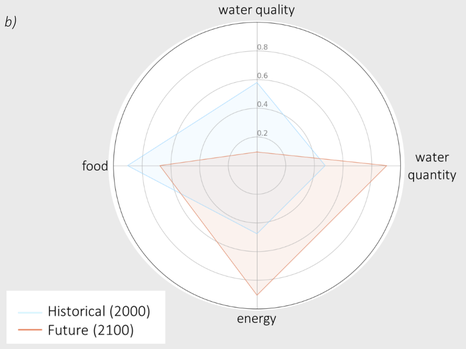
a)

Impact of climate change (%): 91 – 100, 81 – 90, 71 – 80, 61 – 70, 51 – 60, 41 – 50, 31 – 40, 21 – 30, 11 – 20, 0 – 10

	Channel									
	763	730	712	716	733	727	753	737	725	703
Nitrogen	45	42	39	35	46	47	53	35	38	50
Phosphorus	60	52	46	43	54	46	53	39	36	53
Sediment	31	2	14	60	59	58	69	37	14	51
Flow	36	27	28	48	59	72	67	52	51	41
Average	43	31	32	47	55	56	60	41	35	49



b)



c)

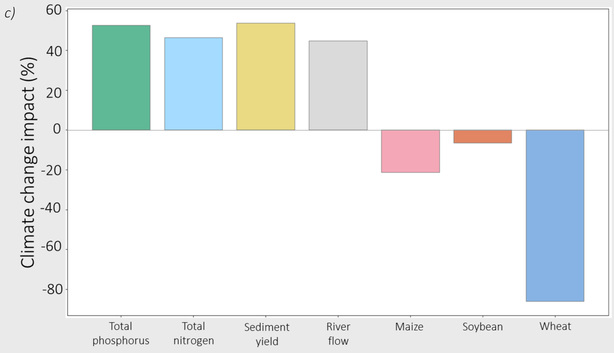


Figure 4: a) Impact of climate change (%) across the different channels in the UWN basin, showing both inflows and the outflow (channel 703); b) Normalised WEF nexus indicators across the entire basin under historical (2000) and future (2100) scenarios; c) Climate change impacts (%) on different component of the WEF nexus indicators across the entire basin

- Historical (1971-2000) and future (2071-2100) simulations using 5 GCMs from the bias-corrected CMIP6 climate forcing data under SSP5-RCP8.5 conditions (Nkwasa, A. et al, 2022a; 2022b)
- Undertook SWAT+ (Soil and Water Assessment Tool) simulations for water quantity, water quality, and crop yield
- Results indicate heterogenous changes in water quality and quantity across the basin (*Fig. 4a*)
- Climate change impacts will likely result in increases in water flow and energy production and decreases water quality and crops, as seen in the normalised WEF indicators (*Fig. 4b*) and in the % impact of climate change (*Fig. 4b*)

Nkwasa, A. et al (2022b). https://doi.org/10.1007/s10113-022-02008-9
Nkwasa, A. et al (2022b). https://doi.org/10.1016/j.ejrh.2022.101152

5. CONCLUSIONS

- Stakeholder interviews provide important insights and can ensure research is fit-for-purpose
- WEF nexus indicators must include water quality and environmental variables in order to address the WEF challenges in the UWN basin
- Modelling tools such as SWAT+ can be used to understand the changes in a subset of the proposed indicators
- Climate change will impact WEF nexus resources, indicating a:
  - ✓ Increase in water flow and hydropower production
  - ✗ Decrease in water quality and crop yield
- Spatial patterns of the changes in water quantity and quality correspond to precipitation patterns

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