Deliverable 6.5

Second Progress Report

Grant Agreement nº: 956623

Project full title: Inventive forecasting tools for adapting water quality management to a new climate

Project acronym: inventWater

Type of deliverable: report

Planned date of deliverable: 29 February 2024

Actual submission date: 29 February 2024

Target Audience: Public

Authors: Rafael Marcé and Daniel Mercado-Bettín

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1. General progress

1.1 Scientific progress and training events

The inventWater Early Stage Researchers (ESRs) are progressing in their respective research programmes following their Career Development Plans. Since the date of submission of the First Progress Report (31 March 2022) to date, there are 9 peer-reviewed scientific manuscripts published; and ESRs have led 43 oral presentations and 35 poster presentations in national and international conferences. In addition, 2 tools/softwares are being developed as an output of the project.

ESRs have participated in four technical training events following the Grant Agreement (GA), organised by the DkIT (Dundalk Institute of Technology), VUB (Vrije Universiteit Brussel), RUB (Ruhr University Bochum) and AU (Aarhus University) respectively. The topic being “Big data for water quality management”, “Modelling water quality under global change”, “Managing water in complex anthropogenic landscapes”, and “Entrepreneurship, pitching, and media interactions”. See Appendix 1 for details on each training event.

ESRs have been leading 15 outreach and communication activities and events, and have proven engagement in social media, blog posts, articles and press releases through 64 interactions and posts. A diverse target audience including the general public have been reached by using outcomes from the different projects of inventWater: children in elementary and secondary schools, young scientists, students from other fields at the university level, public in restaurants and bars (Pint of Science), policy makers, environmental professionals, international organization, industries, and big audiences (during a TV program).

Deviations from the original workplan

About the deviations to the original Workplan to date, the most relevant deviation is that two ESRs presented particular circumstances related to their

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health that obliged them to switch from on-site secondment to “virtual secondment”:

ESR-4 have experienced health issues in the past year and a half. This requires frequent check-ups at the doctor, and doing so while being in another country would be very challenging. Together with his supervisors notified to coordination that doing his 2nd secondment planned in CA (Climate Analytics) remotely, with a potential short-term visit at some point, will be very helpful for him, as he can continue his recovery while working at the same time. They proposed to keep the content of the original plan, and do the secondment between January 2024 till April 2024 (same duration) with a plan for frequent virtual interactions and progress metings. He will try to also make a visit, for about 2 weeks towards the end of the secondment, so they can assess the progress achieved and have the possibility to meet other colleagues at CA. CA informed that “conducting the secondment remotely is totally fine. We agree with the idea of having a meeting to refine the topic, but also to discuss the modalities of the secondment and expectations regarding meetings”. A Secondment Agreement was signed and it’s attached in the Annex. The coordination notified this situation to the PO.

ESR-1 is also experiencing health issues, and she has been on sick leave since 25th January 2024. The sick leave is expected to continue at least until April with possibility to reach until October 2024. Thus, the expected end date of the PhD project is now 31st March 2026. Regarding a 2-month secondment at VUB, the student will do the secondment in January and February 2025 in a virtual format. The coordination notified this situation to the PO.

A relevant event during this period has been the moving of the coordinator to a new institution (from ICRA to CSIC-CEAB). However, this change was implemented with no impacts on project execution.

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1.2 Deliverables and milestones

Here is the full list of deliverables submitted and milestones achieved from 31st March 2022 to 29th February 2024

Deliverable (D) or milestone (MS)	Due date (month)	Status
MS3 Project Check (meeting between REA and consortium)	15	Completed
D4.5 Report on Network-wide training event 2	16	Completed
D5.7 ESRs blog entry on training activity 2	16	Completed
D1.1 Improved models to forecast the status of water quality in rivers, lakes and reservoirs.	21	Completed
D4.10 2nd bi-annual report on ESR training progress	21	Completed
D2.1 Tailored forecasting workflows for different time scales in industry and management.	21	Completed
D5.4 Press releases for first group of local outreach events	21	Completed
D4.6 Report on Network-wide training event 3	21	Completed
D5.8 ESRs blog entry on training activity 3	21	Completed
D3.1 Adaptation measures for a future-proof water quality.	25	Completed
D4.11 3rd bi-annual report on ESR training progress	25	Completed
D1.2 Assessment of current and future impacts on regional and global scales.	27	Completed
D4.7 Report on Network-wide training event 4	31	Completed
D4.12 4th bi-annual report on ESR training progress	31	Completed
D5.9 ESRs blog entry on training activity 4	31	Completed
D1.3 Innovative set of indicators which combine remote sensing information and modelling results	33	Completed

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D4.8 Report on Network-wide training event 5	35	Completed
D5.10 ESRs blog entry on training activity 5	35	Completed
MS4 Completion of technical training	35	Completed
D2.2 Using forecasting to define preventive action plans and adaptive monitoring strategies.	36	Completed
D4.13 5th bi-annual report on ESR training progress	36	Completed
D6.5 2nd progress report	36	Completed

Small deviation from the original plan for deliverables was related to delays in recruitment process and visa applications. Deliverables 1.1, 4.10, 4.11, 1.2, 1.3, 4.7, 4.12, 5.9 and 2.2 were slightly delayed, but their submission date was re-scheduled in agreement with the EU Project Officer well before the deadline, so no formal situation of pending deliverables was originated.

2. Recruitment strategy

This section does not apply to the phase of the project.

3. Career development plan for each recruited researcher

A summary of the drafting of all Career Development Plans (CDPs) was included in the First Report and all the details can be found in Deliverable 4.1. The CDPs are a living document according to the needs of each ESR and the progress of each project. This progress is periodically assessed with the 6-months ESR progress reports and no report raised any relevant deviation from the original CDP. The consecution of the objectives stated in the different CDPs will be assessed during the last whole-network activity of the netwrok in August 2024, where ESR will be interviewed in the light of the original CDPs and the actual fulfillment of the objectives stated there.

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4. Management of the project

4.1 Management, meetings, and involvement of researchers

ESRs have participated in four technical training events from 31 March 2022 to 29 February 2024: (i) “Big data for water quality management” held on 13th-17th June 2022 at Dundalk Institute of Technology, (ii) “Modelling water quality under global change” held on 10th-14th October 2022 at Vrije Universiteit Brussel, (iii) “Managing water in complex anthropogenic landscapes” held on 18th-22nd September 2023 at Ruhr University Bochum, and (iv) “Entrepreneurship, pitching, and media interactions” help on 24th-25th January 2024 at Aarhus University.

Four Supervisory Board meetings have been held during this time, held remotely via video conferencing (26th May 2023) and onsite during the training events (15th June 2022, 12th October 2022, 19th September 2023). This has been done following the GA, having at least 2 SB meetings per year. Agenda and minutes have been produced and sent to all the consortium for these four SB meetings.

At the first Training School, ESRs were requested to nominate a representative to attend future inventWater SB meetings. This position will last for a 1-year period, with a new representative nominated at the end of each tenure. Maud Siebers was the first representative, and after one year, Floran Clopin took over.

Multiple minor changes in the timing of the secondments have been suggested by the beneficiaries and communicated to the Project Officer, who asked for a detailed table with all the changes from the original plan. To date, two versions of the table have been sent updating all the changes.

All financial payments have been made by the coordinator as required under the grant agreement.

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4.2 Identification of risks

Risk	Description of Risk	WP	Proposed mitigation measures	Status
R1	Delay in recruitment	6	Applying early and comprehensive dissemination of vacancies. Re-advertisement if necessary.	Does not apply to this report
R2	ESR dropping out	All	Employing motivated and independent students. Providing ESRs with research directions, good management practices, organised research environment and positive work ethos. Re-advertise and recruit new ESR.	No reported issues
R3	Scientific Misconduct	All	Scientific Misconduct Strategy Detailed in Consortium Agreement	No reported issues.
R4	Recruitment Gender Imbalance	6	Recruitment strategy in place to ensure Gender Balance. Engage positive discrimination to ensure gender balance.	Does not apply in this report
R5	ESR issues with	1-4	Dealt with first by	Changes in Supervision

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	supervisory team		Supervisory Team. If not resolved, pass to the SB	due to supervisors leaving science, retiring, changing institutions or restrictions in time for supervision. All these have been communicated to the PO. The main supervisor of ESR1 left academia, Katrin Bieger and Hans Estrup took over Dennis Trolle; The main supervisor of ESR4 has now more time restrictions for supervising, Ann van Griensven took over Wim Thiery; the main supervisor of ESR7 retired in 2023, Suzanne Linnane took over Eleanor Jennings. Additional supervisors have been added to the supervisory teams of ESR4, ESR7, ESR9, ESR10, ESR13, to add more technical expertise need it in the project. Most of these details were added in the last amendment of the GA.
R6	Inefficient communication within network. Unsatisfactory supervision	1-4	Promoting strong and effective formal and non-formal communication at all levels. Definition of strict co-supervision	No reported issues.

This project has received funding from the European Union`s Horizon 2020 research and innovation programme under the Marie Skłodowska-Curie grant agreement No 956623

			arrangements	
R7	Poor ESR progress	1-4	Progress Monitoring System in place. Regular meetings with team	Reported issues on the three last bi-annual training report D4.13 for ESR-15. Mitigation measures already into place.
R8	Training Event Unsatisfactory	4	All ESRs will provide an assessment of the success of each Training Event. Feedback will be used to address any ESR concerns and further develop	No reported issues.
R9	Inadequacy of research and training activities	4	Initial Analysis of Training Needs, annual implementation of Career development plan. Frequent status assessments, inventWater midterm review.	No reported issues.
R10	Low data quality or unavailable data	1-3	inventWater will use data from long established sites with established QA/QC procedures that have substantial archives available to the network. ISIMIP and Copernicus data are already available.	No reported issues.
R11	Too complex numerical analyses and modeling	1-3	Supervisory team very experienced and aware of the challenges ahead.	No reported issues.

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	exercises		Extensive computing power in the network.	
R12	Mismatch between spatial and temporal scales in model chains	1-3	Modular structure of the workflows, with plenty of possibilities for averaging. Training activities including multiple models to know respective limits.	No reported issues.
R13	Loss of leadership	6	In addition to the Coordinator, Martina Floerke (RUB) will serve as substitute leader. Both have permanent positions and network management experience.	No reported issues. There was a change in the coordinator institution, but this didn’t affect the leadership of the project.

4.3 Ethical issues

An agreement was made with the 4 non-EU institutions involved in inventWater at the time of the First Progress Report.

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5. Communication Activities and Dissemination outputs

Here it's the full list of **communication and outreach activities** led by the ESRs during the whole time of the project:

Type	**Title**	**Place/ Journal**	**Target Audience**	**Date**	**Additional information**	**ESR ID**
Outreach activity	Marine Institute Ireland Open Day	Newport, Ireland	General public	03/28/2023'	Outreach activity for primary schools.	12
Website	A Typical Day for an ESR	inventWater webpage	General public	04/04/2023'	Describing the life of an ESR on the west coast of Ireland	12
Social Media	Climate change effects on Atlantic salmon	Twitter NoWPaS / France	Scientific community and general public	02/03/2022'	Climate change effects on Atlantic salmon @NoWPaS 2022	12
Social Media	Climate change effects on Atlantic salmon	Twitter NoWPaS / Norway	Scientific community and general public	07/03/2023'	Climate change effects on Atlantic salmon @NoWPaS	12

This project has received funding from the European Union`s Horizon 2020 research and innovation programme under the Marie Skłodowska-Curie grant agreement No 956623

					2023	
Social Media	NA	LinkedIn (link)	Scientific community, international organisations and the general public	07/10/2023’	The Marine Institute Open Day	12
Other	Member of NoWPaS 2024 committee	https://nowpas.eu/current/	Scienfitic community, international organisation and the general public	04/01/2023’	Member of the 2023 committee	12
Website	NoWPaS 2024 WebSite	https://nowpas.-wordpress.-com/	Scienfitic community, policy makers	2023/2024	Updating NoWPaS Website	12
Other	NoWPaS 2024 Keynote Organisation	https://nowpas.-wordpress.-com/	Scientific community, policy makers	2023/2024	Inviting and organising Keynotes	12
Outreach activity	Transition year students	Marine Institute Ireland	General public	2023/2024	Chatting to Transition-Year Students about do-	12

This project has received funding from the European Union`s Horizon 2020 research and innovation programme under the Marie Skłodowska-Curie grant agreement No 956623

					ing a PhD in Biology	
Out-reach activity	Effect of extreme precipitatation events on total phosphorus (TP) concentrations in rivers	RUB	RUB Uni-versity community	16-10-2023’	Bochum, Germany	2
Press release	Interview with RUB press office and published news in RUB website	RUB press	RUB Uni-versity community	20-10-2023’	https://news.rub.de/wissenschaft/2023-10-20-ingenieurhydrologie-starkregenereignisse-verschlechtern-die-wasserqualitaet-von-fluessen	2
Out-reach activity	Swat conference 2023	linkedin	public	1685577600	NA	1
Social Media	NA	twitter	public	NA	NA	1

This project has received funding from the European Union`s Horizon 2020 research and innovation programme under the Marie Skłodowska-Curie grant agreement No 956623

Out-reach activity	NA	pintof-science	public	NA	yet to confirm the dates	1
Out-reach activity	ISIMIP- Procalis workshop	linkedin & Prague	public	1685577600	NA	1
Out-reach activity	Collaboration with Wateritech	linkedin	public	1690848000	NA	1
Article	GW-flow swat+ coupled model	Environ-mental Model-ling and Software	public	1698796800	submitted and ac-cepted	1
Out-reach activity	Poster presenta-tion ITN, Ireland	linkedin & Dun-dalk	public	1654041600	NA	1
Out-reach activity	Greenland sum-mer school, Nuuk, Greenland	linkedin & Nuuk	public	1661990400	NA	1
Web-site	SITES AquaNet summer experi-ment success-fully finished	News | SITES	general public, sci-entific com-munity	21/09/2022’	https:// www.-field-sites.se/i/a32250806/2022/	8

This project has received funding from the European Union`s Horizon 2020 research and innovation programme under the Marie Skłodowska-Curie grant agreement No 956623

Out-reach activity	El clima está cambiando, el agua también, y tú, ... qué cam-biarías si pudieras ver el futuro?	Euro-pean Re-searcher s` Night	general public	29/09/202 2’	Girona, Spain	8
Other	The Aquatic Crystall Ball: De-coding the Fu-ture of Freshwa-ter in a Shifting Climate	The Marie Curie Alumni Associa-tion Blog	general public, pol-icy makers, scientific community	06/07/202 3’	The Aquatic Crystal Ball: | The Marie Curie Alumni Associa-tion Blog | Jul, 2023 | Medium	8
Article	European Year of Youth: three young MSCA re-searchers help-ing to build a brighter future for generations to come!	Euro-pean Comis-sion Website	Scientific community, policy mak-ers, inter-national or-ganiza-tions, and the general public	01/01/202 2’	Published by Euro-pean Re-search Executive Agency (REA)	14

This project has received funding from the European Union`s Horizon 2020 research and innovation programme under the Marie Skłodowska-Curie grant agreement No 956623

Web-site	Annika Schlemm: Hydrologist, ecol-ogist, and con-servationist	Personal website	Scientific community, policy mak-ers, inter-national or-ganiza-tions, and the general public	01/01/202 2’	NA	14
Social Media	Today is #wom-eninscience day!	LinkedIn	Scientific community, policy mak-ers, inter-national or-ganiza-tions, and the general public	02/01/202 2’	Published by Euro-pean Re-search Executive Agency (REA)	14
Social Media	Research trip to Uganda	Twitter (X)	Scientific community, policy mak-ers, inter-national or-ganiza-tions, and the general public	08/01/202 2’	NA	14
Article	Brussels training week “Modelling water quality un-der global change”	invent-Water website	Scientific community, policy mak-ers, inter-national or-ganiza-tions, and the general public	11/01/202 2’	NA	14

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Social Media	Research trip to the USA	Twitter (X)	Scientific community, policy makers, international organizations, and the general public	11/01/2022’	NA	14
Outreach activity	Meet the Researcher	International German School brussels (iDBS)	General public	01/01/2024’	Done with Prometeruse	14
Article	Nurturing Entrepreneurship at The Kitchen	inventWater website	Scientific community, policy makers, international organizations, and the general public	02/01/2024’	NA	14
Article	We support #WomenInSTEM!	LinkedIn	Scientific community, policy makers, international organizations, and the general public	02/01/2024’	Published by European Research Executive Agency (REA)	14

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Article	Today we celebrate International #WomenInScience Day	LinkIn	Scientific community, policy makers, international organizations, and the general public	02/01/2024’	Begoña Arano, Head of Department Marie Skłodowska-Curie Actions	14
Article	We support #WomenInSTEM!	Instagram	Scientific community, policy makers, international organizations, and the general public	02/01/2024’	EU Science	14
Social Media	InventWater Dundalk training and Dublin pre-meeting activity	Twitter	Scientific community and general public	14.06.2022	NA	13
Website	Ireland training	inventWater blog	Scientific community	20.06.2022	NA	13
Social Media	SIBECOL-AIL meeting	Twitter	Scientific community and general public	04.07.2022	NA	13
Social Media	Seminar at the RHMA - University of Chile	Twitter	Scientific community and general	30.03.2023	NA	13

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			public			
Out-reach activity	The role of water in the carbon cy-cle (in Spanish)	Pint of Science	General public (re-gional ac-tivity - Girona, Spain)	23.05.202 3	NA	13
Social Media	ASLO congress	Twitter	Scientific community and general public	10.06.202 3	NA	13
Social Media	GLEON23 meet-ing	Twitter	Scientific community and general public	27.06.202 3	NA	13
Social Media	GLEON23 meet-ing	Twitter	Scientific community and general public	28.06.202 3	NA	13
Article	How can reser-voirs buffer cli-mate change im-pacts on down-stream water quality?	Science of the Total En-viron-ment	All audi-ences	12/20/202 3’	https:// doi.org/ 10.1016/ j.sci-totenv.20 23.16946 0	10
Social Media	New article allert	TWITTER	All audi-ences	12/01/202 3’	https://x.-com/ nakulopa/ status/ 17408438 97943978	10

This project has received funding from the European Union`s Horizon 2020 research and innovation programme under the Marie Skłodowska-Curie grant agreement No 956623

					233?s=20	
Article	the welcome re-treat @Digital sau	Invent-water blog	General Public	01/01/2022’	NA	5
Out-reach activity	The value of wa-ter: at the croassroads be-tween climate change, scarcity and political ecol-ogy	Seminar organ-ised dur-ing PhD trip in Italy	General public	09/01/2022’	Organizer	5
Social Media	PhD trip post	Linkedin	General public	11/01/2022’	NA	5
Social Media	Advanced trainign in Brus-sels	Linkedin	Scientific Community	11/01/2023’	NA	5
Social Media	My secondment and different conferences	Linkedin	Scientific Community	06/01/2023’	NA	5
Social Media	PROCLIAS-ISIMIP Webinar water quality in a changing world	Linkedin	Scientific Community	06/01/2023’	NA	5
Web-site	MARINA-MULTI	Wa-genin-gen Uni-versity	Scientific Community	09/01/2023’	NA	5

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		and Research				
Social Media	Exploring Innovative Water Management in Anthropogenic Landscapes!-Bochum	Linkedin	General public	10/01/2023’	NA	5
Outreach activity	Exploring Innovative Water Management in Anthropogenic Landscapes!-Bochum	Inventwater blog	Scientific Community	10/01/2023’	NA	5
Outreach activity	Recent advancement in water quality indicators for eutrophication in global freshwater lakes	National University of Singapore	Science community, Policy community, Development banks	June 22-23 2023	A workshop on water-food security	6
Outreach activity	Recent advancement in water quality indicators for eutrophication in global freshwater lakes	Ministry of Environment, Water and Agriculture, Saudi Arabia,	Policy makers, International Organizations	06/12/2023’	A workshop on valuing water	6

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		World Bank				
Outreach activity	Global Lake Assessment	Global Sustainable Development Congress, Times Higher Education	Science comunity, Policy community, Education community, General public	May 30-31 2023	Global Sustainable Development Congress	6
Outreach activity	Global water resources assessment	International Atomic Energy Agency	Science community, Policy community, UN organizations	July 3-7 2023	International Symposium on Isotope Hydrology	6
Outreach activity	Project at LVFO	Lake Victoria Fisheries Organisation	Science and Policy community, representatives of the nile basin initiative	5th Aptil 2023	Collaboration and identification of new opportunities towards better water quality management	6

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Social Media	Paper exposure	LinkedIn	Science, policy and other environmental professionals network	07/08/2023’	Social media post	6
Social Media	GLEON experience	LinkedIn	Science, policy and other environmental professionals network	07/08/2023’	Social media post	6
Outreach activity	Global indicators and local insights on water quality status and changes	Water Security Group, International Institute of Applied Systems Analysis	Science community	16th Jan 2024	Oral presentation about my research to invite discussions and collaboration about the topic	6
Outreach activity	Water quantity and quality modeling embedded in nexus assessment and management	College of Management and Economics, Tianjin University	Science community	NA	NA	6

This project has received funding from the European Union`s Horizon 2020 research and innovation programme under the Marie Skłodowska-Curie grant agreement No 956623

Outreach activity	Water quantity and quality modeling embedded in nexus assessment and management	School of Engineering, West-Lake University	Science community	NA	NA	6
Article	FISCHERS HITZE: Die Klimaerwärmung macht Ökosystemen besonders zu schaffen, die bisher wenig Beachtung fanden: den Seen. Binnenfischer bemerken bereits einen tiefgreifenden Wandel. Forschende versuchen zu verstehen, was unter der Wasseroberfläche passiert	Greenpeace maagzine	general public	06/01/2023’	NA	9
Social Media	Tweets and retweets of conference participation	Twitter	general public	07/01/2023’	NA	9

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Out-reach activity	GLEON new membership drive	Annual Meeting of the African Great Lakes Stake-holder Network	scientific community, policy mak-ers	02/01/2024’	NA	9
Out-reach activity	Festival of Frend-ship 2023	Denny high school	general public	10/06/2023’	Lake pre-diction game were part of this ac-tivity for the girls with a range in ages from 4 to 18.	11
Social Media	NA	Twitter	general public	10/06/2023’	post about out-reach ac-tivity	11
Social Media	NA	Linkdin	general public	10/06/2023’	post about out-reach ac-tivity	11
Social Media	NA	Twitter	general public	16/05/2023’	post about phd sympo-sium talk at the uni-versity of	11

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					Stirling	
Social Media	NA	Linkdin	general public	16/05/2023’	post about phd sympo-sium talk at the uni-versity of Stirling	11
Social Media	NA	Twitter	general public	27/06/2023’	post about the GLEON 2023 meeting and in-ventWa-ter ESRs reunite	11
Social Media	NA	Twitter	general public	27/06/2023’	post about the GLEON 2023 meeting and my study poster presenta-tion	11
Social Media	NA	Linkdin	general public	27/06/2023’	post about the GLEON 2023 meeting and my study poster	11

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					presenta-tion	
Out-reach activity	SIEC Meet the Scientists	Univer-sity of Stirling	general public	30/10/2023’	Lake pre-diction game were part of this ac-tivity for the girls with a range in ages from 4 to 18.	11
Social Media	2023 inventWa-ter flashback post	Twitter	general public	28/12/2023’	Post about the inven-tWtaer activities during year of 2023	11
Social Media	2024 inventWa-ter flashback post	Linkdin	general public	28/12/2023’	Post about the inven-tWtaer activities during year of 2023	11
Social Media	NA	Twitter	general public	30/8/2023’	Post about in-ventWa-ter retreat in	11

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					Bochum	
Social Media	NA	Linkdin	general public	30/8/2023’	Post about inventWater retreat in Bochum	11
Outreach activity	Girl Guides Science fair	Denny High School, Scotland	General public, kids aged 4 till 18	10/06/2023’	A computer model was made to show kids about lake modelling.	3
Outreach activity	SIEC Young Pathfinder's 'Meet the Scientists'	Stirling University	General public, high school kids	31-10-2023’	Presentation on lake modelling	3
Social Media	Young Pathfinders event	X (twitter)/ Linkedin	Scientific community	31-10-2023’	Explaination on what we presented	3
Social Media	Blog post	X (twitter)	Scientific community	29-09-2023’	-	3
Social Media	Presentation at SEFS	X (twitter)	Scientific community	20-06-2023’	Quick info on my presentation at SEFS	3

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Social Media	Girl Guides Sci-enc fair	X (twit-ter)/ Linkedin	Scientific community	10/06/2023’	Tweet on our out-reach ac-tivity	3
Social Media	Lake model - vis-ual representa-tion	X (twit-ter)	Scientific community	31-05-2023’	Gif on my model vis-ual repre-sentation used for outreach	3
Social Media	Workshop Art and Science	X (twit-ter)	Scientific community	11/04/2023’	-	3
Social Media	Reposting invent-Water	X (twit-ter)	Scientific community	2021/2022/2023’	Reposting important tweets from the iventWa-ter ac-count	3
Social Media	First InventWater Meeting	LinkedIn	Scientific community/ non aca-demics	10/01/2021’	NA	3
Social Media	Blog post invet-nwater	LinkedIn	Scientific community/ non aca-demics	06/20/2022’	NA	3

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Outreach activity	Breaking the Wall of Unsafe Drinking Water	MSCA Falling Walls Lab pitch competition, Paris, France	General public and administrative authorities of different sectors: university, European comission, industry	05/01/2022’	NA	7
Outreach activity	PhD overview	Science Week Event at DkIT, Ireland	Academia, other departments within my institution, and prospective students	05/01/2023’	NA	7
Outreach activity	Podcast on climate change deniers	Oxfam	General public	03/01/2023’	Assisted a few students in the preparation of a podcast episode for Oxfam on the topic of climate deniers	4
Social Media	Drought conditions and impacts in South America	LinkedIn	General public	03/01/2023’	NA	4

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Social Media	Drought conditions and impacts in Maghreb region and Turkey	LinkedIn	General public	03/01/2023’	NA	4
Social Media	Navigating climate skepticism amid global challenges	LinkedIn	General public	03/01/2023’	NA	4
Press release	Many tourists, too little water	DeMorgen	General public	07/01/2023’	Interview for De Morgen on the relationship between water scarcity and tourism.	4

The Twitter (X) and LinkedIn accounts of inventWater (@invent_water and inventWater MSCA ITN) has been active in the last 2 years showing updates about the project. Also, six blogs have been produced based on the inputs of the projects, led by the ESRs (https://inventwater.eu/news/)

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Here it's a list of all **dissemination outputs** led by the ESRs during the whole time of the project:

Type	**Title**	**Journal/ Conference**	**Target Audience**	**Date**	**Additional information**	**ESR ID**
Paper	Future Climate Change is Projected to lead to increased freshwater growth potential and changes in pace-of-life in Atlantic salmon Salmo salar	TBD	Scientific community and management	06/23/2023'	NA	12
Oral presentation	ESR-12: Employing ISIMIP projections to model the phenology, production, and distribution of diadromous fish populations	International Workshop of PhDs and Postdoctoral Fellows on Anadromous Salmonids (NoWPAS) 2022	Scientific community	03/01/2022'	Presentation of the inventWater ESR12 project for the NoWPaS attendees.	12

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Oral presentation	ESR-12: Employing ISIMIP projections to model the phenology, production, and distribution of diadromous fish populations	Cross-sectoral ISIMIP-PROCLIAS workshop	Scientific community	05/18/2022’	Presentation of the inventWater ESR12 project for the ISIMIP-PROCLIAS attendees.	12
Oral presentation	Future Climate Change is Projected to lead to increased freshwater growth potential and changes in pace-of-life in Atlantic salmon Salmo salar	The Burrishoole Catchment Workshop	Scientific community	11/29/2022’	Presentation of first paper	12
Poster	Future Climate Change is Projected to lead to increased freshwater growth potential and changes in pace-of-life in Atlantic salmon Salmo salar	The Burrishoole Catchment Workshop	Scientific community	11/29/2022’	Poster of first paper	12
Poster	ESR-12: Employing ISIMIP projections to model the phenology, production, and	inventWater Welcome Retreat	Scientific community	01/17/2022’	Presentation of ESR 12 Project - Life-cycle	12

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	distribution of diadromous fish populations				of Atlantic salmon and anthropogenic impacts	
Oral presentation	Science Pitch	inventWater Welcome Retreat	Scientific community	01/17/2022’	Presentation of science pitch for working on climate change effects on Atlantic salmon	12
Poster	Future Climate Change is Projected to lead to increased freshwater growth potential and changes in pace-of-life in Atlantic salmon Salmo salar	inventWater Dundalk	Scientific community	06/13/2022’	Presentation of first paper progress	12
Poster	ESR-12: Employing ISIMIP projections to model the phenology, production, and distribution of diadromous fish populations	inventWater Project Offiser Meeting	Scientific community	06/21/2022’	Presentation of ESR12 Project and first paper progress	12

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Oral presentation	Future Climate Change is Projected to lead to increased freshwater growth potential and changes in pace-of-life in Atlantic salmon Salmo salar	Wild Atlantic salmon Conference	Scientific community, policy makers, and the general public	04/25/2023’	Presentation of first paper with findings for 350 attendees from most sectors relevant to the topic.	12
Oral presentation	Future Climate Change is Projected to lead to increased freshwater growth potential and changes in pace-of-life in Atlantic salmon Salmo salar	EPOS Stirling	Scientific community	05/03/2023’	Presentation of first paper for EPOS group at University of Stirling	12
Deliverable	Deliverable D3.1 Identifying Adaptation Scenarios Relevant For Water Quality Management	InventWater Deliverable	Scientific community, policy makers	03/10/2023’	NA	12

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Paper	Future Climate Change is Projected to lead to increased freshwater growth potential and changes in pace-of-life in Atlantic salmon Salmo salar	Journal of Fish Biology	Scientific community	10/31/2023’	NA	12
Oral presentation	InventWater Aarhus Pitching	InventWater Aarhus	Scientific community	01/26/2024’	NA	12
Oral presentation	Deliverable D2.2 Using forecasting to define preventive action plans and adaptive monitoring strategies	InvenrWater Deliverable	Scientific community, policy makers	02/09/2024’	NA	12
Oral presentation	NoWPaS Density Dependent Regulation of Survival, Growth, and Dispersal in Juvenile Atlantic Salmon	NoWPaS Scotland 2024	Scientific community	02/28/2024’	NA	12

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Paper	Brief Communi-catons: Density Dependent Regu-lation of Survival, Growth, and Dis-persal in Juvenile Atlantic Salmon	in prep. / internal revisions	Scientific commu-nity	TBD	NA	12
Paper	Interaction Ef-fects of Climate Change and Ge-netic Introgres-sion on Growth of Juvenile Atlantic Salmon	in prep. / internal revisions	Scientific commu-nity	TBD	NA	12
Paper	The Effects of Cli-mate Change on Growth in Juve-nile Atlantic salmon; An Anal-ysis on Trans-Eu-ropean Scale	In prep.	Scientific commu-nity	TBD	NA	12
Oral presen-tation	Presentation for the Marine Insti-tute Board on Cllimate Chaange Effects on At-lantic salmon	Marine In-stitute Ire-land	Scientific commu-nity	Autumn 2024	NA	12
Oral presen-tation	Marine Institute Lunchtime Semi-nar	Marine In-stitute Ire-land	Scientific commu-nity and Manage-ment	02/14/202 4’	NA	12

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Poster	Machine learning methods integrating climate and water monitoring data to support modelling future water quality in lakes and reservoirs over decades	inventWater Training week	inventWater project staffs	06/15/2022’	Dundalk Ireland	2
Oral presentation	Effect of extreme precipitatation events on total phosphorus (TP) concentrations in rivers	Tag der Hydrologie Conference	Conference attendies (scientific community and practitioners)	03/22/2023’	Bochum Germany	2
Oral presentation	Effect of extreme precipitatation events on total phosphorus (TP) concentrations in rivers	UFZ	Researchers in UFZ	04/19/2023’	Magdeburg Germany	2
Oral presentation	Statuss quo of PhD project	RUB	inventWater project staffs	19-09-2023’	Bochum, Germany	2
Tool	Establishing SWAT+ as a hydrological modelling tool in Denmark	2023 International SWAT Confer-	scientific community	28th June 2023	NA	1

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		ence & Work-shops, Aarhus, Denmark				
Oral presen-tation	Hydrological Sim-ulation of a Tem-perate Water-shed in Central Denmark Using SWAT+	2023 In-terna-tional SWAT Confer-ence & Work-shops, Aarhus, Denmark	scientific commu-nity, pol-icy mak-ers	28th June 2023	NA	1
Poster	A new generation of coupled water-shed-lake water quality models operating at mul-tiple scales.	DKIT, Dundalk, Ireland	scientific commu-nity	15th June 2022	NA	1
Deliver-able	D1.1	Invent water	scientific commu-nity, pub-lic	29th no-vember 2022	NA	1
Deliver-able	D1.2	Invent water	scientific commu-nity, pub-lic	20th May 2023	NA	1
Oral presen-tation	Climate change Effects on Nature and Society in	Aarhus university & Univer-sity of	scientific commu-nity, pub-lic	31st Au-gust 2022	NA	1

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	the Arctic.	Greenland				
Oral presentation	Understanding the impact of run-off variability on dissolved organic matter for better management of lakes devoted to drinking water supply	ASLO Aquatic Sciences Meeting	scientific community, international organizations	05/06/2023’	NA	8
Oral presentation	Understanding the impact of run-off variability on DBP’s precursors for better management of lakes devoted to drinking water supply	The Water Disinfection, Byproducts and Health Gordon Research Seminar	scientific community, international organizations	29/07/2023’	NA	8
Poster	Understanding the impact of run-off variability on DBP’s precursors for better management of lakes devoted to drinking water supply	The Water Disinfection, Byproducts and Health Gordon Research Conference	scientific community, international organizations	02/08/2023’	NA	8
Oral presentation	Minimising trade-offs within the water-energy-food-environment nexus un-	International Conference on Water,	Scientific community, policy makers	05/01/2022’	In Portalegre, Portugal	14

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	der climate change	Energy, Food and Sustainability				
Poster	Including water quality in the water-energy-food nexus: An Upper White Nile case study	inventWater Training Week 2022 in Dundalk “Big Data for Water Quality Management”	Scientific community	06/01/2022’	In Dundalk, Ireland	14
Oral presentation	Minimising trade-offs within the water-energy-food-environment nexus under climate change	US-Africa Sustainable Food Systems through water-energy-food AccelNet-Project Launch	Scientific community, policy makers	10/01/2022’	In Penn State University, USA	14
Oral presentation	Addressing the water-energy-food nexus in the Upper White Nile basin	Vrije Universiteit Brussel HYDR (Hydrology and Hydraulic Engineering) department seminar	Scientific community	01/01/2023’	In Brussels, Belgium	14

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Deliverable	Identifying adaptation scenarios relevant to the water quality sector	inventWater's Deliverable D.3 report	Scientific community, policy makers	02/01/2023'	NA	14
Oral presentation	The Impacts of Climate Change on the Water-Energy-Food-Environment (WEFE) Nexus in the Upper White Nile basin: A Lake Victoria Case Study	JOOUST-VLIR IUC Project (Management of Natural Resources of Lake Victoria Basin) meeting	Scientific community, policy makers	03/01/2023'	In Kisumu, Kenya, but presented online	14
Oral presentation	The impacts of climate change on the water-energy-food (WEF) nexus in the Upper White Nile basin: A Lake Victoria case study	UNESCO International Conference on Climate Risk, Vulnerability and Resilience Building	Scientific community, policy makers, international organizations	04/01/2023'	In Paris, France	14
Oral presentation	The impacts of climate change on the water-energy-food (WEF) nexus in the Upper White Nile basin: A Lake Victoria case study	Enabel Conference "Is climate change adaptation all about water?"	Scientific community, policy makers, international organizations	04/01/2023'	In Brussels, Belgium	14

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Poster	Including water quality in the water-energy-food nexus: An Upper White Nile case study	European Geosciences Union conference	Scientific community, policy makers, international organizations	04/01/2023’	In Vienna, Austria	14
Oral presentation	Incorporating stakeholder feedback into the modelling concept: A case study of the Lake Victoria basin	ISIMIP-PROCLIAS cross-sectoral workshop	Scientific community	06/01/2023’	In Prague, Czech Republic	14
Oral presentation	The Impacts of Climate Change on the Water-Energy-Food-Environment Nexus	Nile Basin Initiative 7th Development forum "Deepening Nile cooperation: Accelerating the Achievement of SDGs in a Changing Climate”	Scientific community, policy makers, international organizations	09/01/2023’	In Kampala, Uganda, but presented online	14
Poster	Including water quality in the water-energy-food nexus: An Upper White Nile case	Swiss Climate Summer School on the cli-	Scientific community	09/01/2023’	In Ascona, Switzerland	14

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	study	mate-water-energy-food nexus				
Poster	The impacts of climate change on the Water-Energy-Food-Environment (WEFE) nexus in the Upper White Nile basin: A Lake Victoria case study	WCRP Open Science Conference	Scientific community, policy makers, international organizations	10/01/2023’	In Kigali, Rwanda, but presented online	14
Oral presentation	Minimising trade-offs within the water-energy-food-environment nexus under climate change	Vrije Universiteit Brussel, Department of Water and Climate, Surface Water Team meeting	Scientific community	11/01/2023’	In Brussels, Belgium	14
Deliverable	Development of innovative global indicators for water quality status and changes	inventWater’s Deliverable D.1.3 report	Scientific community, policy makers	11/01/2023’	NA	14
Oral presentation	Empowering Sustainable Decision-Making in the Lake Victoria Basin: Bridging Data, Models,	inventWater Training Week "Entrepreneurship and	Scientific community	01/01/2024’	In Aarhus, Denmark	14

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	and Community Knowledge	Pitching" at Aarhus University				
Paper	Developing meaningful water-energy-food-environment (WEFE) nexus indicators with stakeholders: A Lake Victoria case study	Science of the Total Environment	Scientific community	01/31/2024’	Accepted for publication	14
Paper	Detection and attribution of changes in river flow and sediment loads in the Nile basin	Climate Change	Scientific community	01/31/2024’	In final stage of reviews	14
Poster	ESR13: Forecasting feedbacks between the climate system and carbon dynamics in lakes and reservoirs under adaptation scenarios.	InventWater welcome retreat	InventWater community and other guests.	17.01.2022	NA	13
Oral presentation	Re-assessing the role of reservoirs as carbon sinks along the land-to-ocean continuum.	SIBECOL-AIL meeting 2022	Scientific community (international congress)	04.07.2022	NA	13

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Poster	ESR13: The role of reservoirs as carbon sinks along the land-to-ocean continuum.	ANAEE summer school	Scientific community (international course)	28.09.2022	NA	13
Deliverable	Deliverable D.3.: Identifying adaptation scenarios relevant for water quality management.	inventWater	InventWater community.	03.03.2023	NA	13
Oral presentation	Modelling global carbon burial: Current status and challenges.	Department of Civil Engineering at the University of Chile (Hydric Resorces and Environment)	Students and faculty members	30.03.2023	NA	13
Oral presentation	Modelling global carbon burial along the Land-Ocean Aquatic Continuum (LOAC): Current status and challenges.	ASLO	Scientific community (international congress)	09.06.2023	NA	13

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Poster	Modelling global carbon burial along the Land-Ocean Aquatic Continuum (LOAC): Current status and challenges.	GLEON	Scientific community (international congress)	26.06.2023	NA	13
Poster	Assessing the sustainability of Germany nutrient pollution regulations under changing climate conditions	SWAT Conference 2023	Scientific Community	06/28/2013’	NA	10
Paper	How can reservoirs buffer climate change impacts on downstream water quality?	Science of the Total Environment	All audiences	12/20/2023’	Published	10
Oral presentation	Solutions for existing and future challenges in water governance	EGU2022	Scientific Community	05/27/2022’	NA	10
Oral presentation	Solutions for existing and future challenges in water governance	SIL100	Scientific Community	08/09/2022’	NA	10
Oral presentation	Overview of the Germany Water Sector following a training with the with the Ger-	ASAM Department	Scientific	09/05/2022’	NA	10

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	many Association for water, waste water and waste (DWA)					
Oral presentation	Can a reservoir alter climate change impacts on nutrient pollution?	ASAM Department	Scientific	08/21/2023’	NA	10
Poster	Adaptattion measures based on smart nutirnet management at the catchment scale	SIL 2022	scientific community	08/01/2022’	NA	15
Deliverable	identifying adaptation scenarios relevant for water quality management	NA	scientific community, policy makers, internatinal organiwations	02/01/2023’	NA	15
Oral presentation	systematic review of modeling tools assessing the nutrient flows from land to surface water and their effects on lake ecosystems	ASLO 2023	scientific community	06/01/2023’	NA	15

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Poster	systematic review of modeling tools assessing the nutrient flows from land to surface water and their effects on lake ecosystems	Gleon 2023	scientific community	06/01/2023’	NA	15
Poster	Current trends in multi-pollutant problems of water systems from land-based sectors	SENSE Symposium	Scientific Community	06/02/2022’	NA	5
Poster	Innovative forecasting approaches to assess future trends in pollutant flows from land to water systems for advancing sectoral water quality service	InventWater Advanced Training School in Dundalk	Scientific Community	13-17 June 2022’	NA	5
Oral presentation	The value of water: at the croassroads between climate change, scarcity and political ecology	Seminar organised during PhD trip in Italy	General public	09/01/2022’	Organizer	5
Deliver-	Improved models	Deliver-	Public re-	11/01/202	Deliver-	5

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able	to forecast the status of water quality in rivers, lakes and reservoirs	able 1.1	port	2’	able 1.1	
Poster	Sources of multiple pollutants in coastal waters worldwide	NAC 2023	Scientific Community	03/01/2023’	NA	5
Poster	Future coastal water pollution under global change: multi-pollutant modeling	EGU 2023	Scientific Community	04/01/2023’	NA	5
Deliverable	Assessment of current and future impacts on regional and global scales	Deliverable 1.2	Public report	05/01/2023’	Delvierable 1.2	5
Oral presentation	Current and future trends in pollutant flows from land to water systems	IIASA WAT Seminar	Scientific Community	06/01/2023’	NA	5
Paper	Causes of coastal waters pollution with nutrients, chemicals and plastics worldwide	Marine Pollution Bulletin	Scientific Community	01/01/2024’	published	5
Oral presen-	Ten years of MARINA modeling:	EGU 2024	Scientific Commu-	04/01/2024’	submitted abstract-	5

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tation	Multi-pollutant hotspots and their sources under global change		nity		first author	
Oral presentation	The Water Quality Protocol for Model Intercomparisons Under Climate Change Impacts	EGU 2024	Scientific Community	04/01/2024’	second author	5
Oral presentation	Global plastic export by rivers: large differences in trends between microplastics and macroplastics	EGU 2024	Scientific Community	04/01/2024’	second author	5
Oral presentation	Domestic waste management strategies to reduce future river export of macro- and microplastics to the coastal waters of Africa	EGU 2024	Scientific Community	04/01/2024’	second author	5
Paper	Recent advancement in water quality indicators for eutrophication in global freshwater lakes	Environmental Research Letters	scientific community	06/13/2023’	https://doi.org/10.1088/1748-9326/acd071	6

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Poster	Comprehensive indicators for eutrophication dynamics and water quality status in global freshwater lakes	NAC 2023	Scientists of earth and environmental sciences	23-24 June 2023	https://nacgeo.nl/	6
Poster	Recent advancement in water quality indicators for eutrophication in global freshwater lakes	EGU 2023	Geoscientists	24-28 June 2023	https://meetingorganizer.copernicus.org/EGU23/EGU23-7565.html	6
Poster	Assessing eutrophication indicators in lake basins for water quality management	GLEON 2023	Limnologists	25th - 30th June 2023	https://gleon.org/sites/default/files/uploaded/GLEON2023-Poland-Abstract-Booklet_final_2.pdf	6
Oral presentation	A simple model for predicting oxygen depletion of Lakes under Climate Change	36th Congress of the International Society of Limnology	scientific community	08/01/2022’	NA	9

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Oral presentation	Combining forecasting tools and adaptive monitoring strategies for fast reaction plans for aquatic ecosystems at risk.	Biological and Environmental Sciences Workshop, University of Stirling	scientific community	10/01/2022’	NA	9
Poster	A simple model for predicting oxygen depletion of Lakes under Climate Change	GLEON 2022	scientific community	10/01/2022’	NA	9
Oral presentation	A simple model for predicting oxygen depletion of Lakes under Climate Change	Department of Lake Research meeting, UFZ	scientific community	02/01/2023’	NA	9
Oral presentation	EezyPeezyISIOxy: Worldwide impact of eutrophication and climate change on lake hypoxia	ISIMIP Lake Sector writing paper workshop	scientific community	03/01/2023’	NA	9
Poster	Evaluating synchrony among neighboring reservoirs through high frequency data	HIGRADE Conference 2023	scientific community	05/01/2023’	NA	9
Oral presen-	A simple model for predicting	The Association for	scientific commu-	06/01/2023’	NA	9

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tation	oxygen depletion of Lakes under Climate Change	the Sciences of Limnology and Oceanography (ASLO) 2023 Aquatic Sciences Meeting	nity			
Poster	Evaluating synchrony among neighboring reservoirs through high frequency data	GLEON 2023	scientific community	06/01/2023’	NA	9
Paper	A simple model for predicting oxygen depletion of Lakes under Climate Change	Inland Waters	scientific community	06/01/2023’	accepted 04/01/2024	9
Poster	A simple model for predicting oxygen depletion of Lakes under Climate Change	Annual Meeting of the African Great Lakes Stakeholder Network	scientific community, policy makers	02/01/2024’	NA	9
Deliverable	IDENTIFYING ADAPTATION SCENARIOS RELEVANT TO THE	NA	General public	28/02/2023’	Chapter "Deoxygenation and adap-	11

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	WATER QUALITY SECTOR WP3, D3.2				tation measures in lakes and reser-voirs" was written by me.	
Oral presen-tation	Phd title: Adapta-tion strategies against progress-ing anoxia in lakes	University of Stirling PhD sym-posium 2022	Scientific commu-nity	11/05/2022’	2-minute flash talk as 1st year PhD student/ partici-pant: BES depart-ment members	11
Oral presen-tation	Impacts of Global Warming on Hy-polimnetic Dis-solved Oxygen Dynamics in Lakes: A Case Study of Lake Erken	University of Stirling PhD sym-posium 2023	Scientific commu-nity	16/05/2023’	15-minute talk for 2nd year PhD stu-dent/ par-ticipant: BES de-partment members	11
Oral presen-tation	Phd title	Mini work-shop wa-ter /earth observa-tion	Scientific commu-nity	10/19/2022’	Atten-dees: EPOS re-search group members	11
Oral presen-	Phd title	FNS Inter-disciplin-ary PGR	Scientific commu-nity	27/04/2022’	Atten-dees: about 15	11

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tation		network-ing event			PhD students from the faculty of natural science	
Oral presentation	Phd title	EPOS(Earth and Planetary Observation Research Group)	Scientific community	04/05/2023’	Update about my model after my first secondment at Uppsala University	11
Poster	Phd title	PhD symposium 2022	Scientific community	11/05/2022’	An annual symposium at the University of Stirling	11
Tool	Lake prediction game	NA	General public	01/06/2023’	A computer game for-predicting algae in the future	11
Poster	Phd title	1st inventWater retreat	Scientific community	15/01/2022’	NA	11
Poster	Phd title	2nd inventWater retreat	Scientific community	09/06/2022’	NA	11

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Oral presentation	Introduction to estimating of uncertainty in modeling	EO PhD workshop	Scientific community	31/03/2023’	GLUE method introduction and showing my work results	11
Poster	Phd title	GLEON2023	Scientific community	27/06/2023’	Mainly about the Lake Erken	11
Oral presentation	Developed oxygen model (case study: Lake Erken)	Germany inventWater retreat	Scientific community	19/09/2023’	Rcorded video	11
Poster	Project overview	Welcome retreat inventWater	Colleagues	10/01/2021’	NA	3
Oral presentation	Project presentation	PhD Symposium 2022	Academics, Colleagues	05/01/2022’	NA	3
Oral presentation	Project presentation	Trainingweek Dundalk	Colleagues	06/01/2022’	NA	3
Poster	Improving forecasts of phytoplankton blooms using satellite imaging	GLEON, USA	Scientific community	October/ Novermber 2022’	NA	3
Oral	Testing the limits	SEFS,	Scietific	06/01/202	NA	3

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presen-tation	of a process-based lake ecosystem model on simulating chlorophyll a	Newcastle	commu-nity	3’		
Poster	Testing the limits of a process-based lake ecosystem model on simulating chlorophyll a	GLEON, Poland	Scientific commu-nity	06/01/2023’	NA	3
Oral presen-tation	Presenting my work in the de-partment	Depart-ment UFZ, Ger-many	Scientific commu-nity	07/01/2022’	NA	3
Oral presen-tation	ISIMIP findings	InventWa-ter Bochum training-week	Col-leagues	09/01/2023’	NA	3
Oral presen-tation	BES seminar	BES de-partment, Stirling University	Col-leagues	08/25/2023’	NA	3
Oral presen-tation	A modelling fore-casting frame-work to support decision making on the precursors and formation on Trihalomethanes (THMs) in Ireland	Annual Meeting of the Irish Freshwa-ter Sci-ences As-sociation, University College	NA	NA	NA	7

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		Dublin (UCD), Dublin, Ireland				
Poster	A modelling forecasting framework to support decision making on the precursors and formation on Trihalomethanes (THMs) in Ireland	InventWater training at DkIT, Ireland.	inventWater network, academia	June 2022.	NA	7
Oral presentation	A modelling forecasting framework to support decision making on the precursors and formation on Trihalomethanes (THMs) in Ireland and Sweden	AGU Fall Meeting 2022 at Chicago, Illinois, USA)	Academia and general public	12/01/2022’	NA	7
Oral presentation	Near-term forecasting of water temperature at lakes and reservoirs and its implications on management	Internal DkIT CFES meeting	Colleagues, co-workers and supervisors within the centre of research	12/01/2023’	NA	7

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Oral presentation	How to decrease large scale discrepancies between GCM/RCM pairs in the next EURO-CORDEX runs	EURO-CORDEX General Assembly	Scientific community	01/01/2022’	Based on the work I did in my master thesis	4
Oral presentation	Implementing sectoral water usage in the Community Earth System Model for projecting future water resource availability	EGU22	Scientific community	05/01/2022’	NA	4
Poster	Incorporating sectoral water usage in the Community Earth System Model	Oxford Land Surface Modelling Summit	Scientific community	09/01/2022’	NA	4
Poster	Incorporating sectoral water usage in the Community Earth System Model	Belgian contributions to Earth Sciences in a Changing World	Scientific community	11/01/2022’	NA	4
Poster	Sectoral water usage in the Community Earth System Model (CESM)	EGU23	Scientific community	05/01/2023’	NA	4
Oral presen-	Sectoral water usage in the	Seminar at Hydrol-	Scientific commu-	06/01/2023’	NA	4

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tation	Community Earth System Model	ogy and Hydraulic Engineering Department, at VUB	nity			
Paper	Mechanisms behind large-scale inconsistencies between regional and global climate model-based projections over Europe	Climate Dynamics Journal	Scientific community	10/01/2022’	Published paper based on the work I did in my master thesis.	4
Code repository	Understand and correct population data spatial inconsistencies in ISIMIP2 protocol	https://github.com/VUB-HYDR/isimip2b_population_correction	Scientific community	11/01/2022’	NA	4
Code repository	Changes to the CTSM code repository (as part of the incorporation of the sectoral water usage in CESM model)	https://github.com/TaranuDev/CTSM	Scientific community	Apr 2022 - Now	https://github.com/ES-COMP/CTSM/pull/1975	4

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Code repository	Changes to the MOSART code repository (as part of the incorporation of the sectoral water usage in CESM model)	https://github.com/TaranuDev/MOSART	Scientific community	Apr 2022 - Now	https://github.com/ESCOMP/MOSART/pull/63	4
Code repository	Changes to the CMEPS code repository (as part of the incorporation of the sectoral water usage in CESM model)	https://github.com/TaranuDev/CMEPS	Scientific community	Apr 2022 - Now	https://github.com/ESCOMP/CMEPS/pull/351	4
Code repository	Changes to the CPL7 code repository (as part of the incorporation of the sectoral water usage in CESM model)	https://github.com/TaranuDev/CPL7	Scientific community	Apr 2022 - Now	https://github.com/ESCOMP/CESM_CPL7andDataComps/pull/23	4
Deliverable	D1.1 Improved models to forecast the status of water quality in rivers, lakes and reservoirs	NA	NA	11/01/2022’	Deliverable D1.1 for the inventWater project	4

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Deliver-able	D1.2 Assessment of current and fu-ture impacts on regional and global scales	NA	NA	03/01/2023’	Deliver-able D1.2 for the in-ventWa-ter project	4

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6. Impact of the Action

6.1 Impact on recruited researchers

The participation of the ESRs in the inventWater program has had transformative impacts on their professional development and contributions to the field of water quality management. Engaging in this interdisciplinary training network has exposed the ESRs to cutting-edge advancements in climate science, data analytics, hydrology, and freshwater ecology, fostering a holistic understanding of the complexities involved in addressing water quality challenges. Through hands-on experiences and real-world applications, ESRs have develop practical skills in the design and implementation of inventive water quality forecasting tools.

One significant impact lies in the unique and diverse skill set that the ESRs have acquire, enabling them to bridge gaps between different fields and translate technical knowledge into actionable solutions. As they engage with new ecological, water quality and meteorological data products and modeling tools, ESRs will be at the forefront of producing reliable forecasts for lake and river water quality on both regional and global scales. This not only positions them as experts in their respective domains but also empowers them to contribute meaningfully to water management practices, thereby playing a crucial role in safeguarding ecosystems and the services they provide.

6.2 Impact on institutions

The participation of the ESRs in the inventWater program is not only a transformative experience for the individual researchers but also holds significant potential for positive impacts on the institutions they are affiliated with. Institutions hosting these ESRs have benefitted from enhanced visibility and recognition within the scientific community, particularly in the field of water quality management. The collaborative nature of the program fosters a net-

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work of experts, providing the institution with opportunities for valuable partnerships and collaborations.

In terms of research capacity, the institutions have gained access to cutting-edge developments in climate science, data analytics, and interdisciplinary research methodologies. The knowledge and expertise brought in by the ESRs have contributed to the institution's research profile and elevate its standing as a hub for innovative research in the water sector. This influx of expertise can lead to the development of new research avenues and projects, further strengthening the institution's position as a leader in environmental and water sciences.

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7. Summary of the advances of the 15 projects so far.

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ESR 1

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Scientific Summary for ESR1: A new generation of coupled watershed-lake water quality models operating at multiple scales

Since the last century, there has been a decrease in the water quality of lakes and reservoirs around the world because of multiple stressors such as climate change, increased demand for water abstraction, and high nutrient levels caused by agricultural expansion and point sources. To quantify the streamflow response to multiple stressors at the catchment scale and compare the performance of SWAT+ forced by reanalysis data and local weather data, we applied SWAT+ to the groundwater dominated Gudenå catchment in Denmark (figure 1).

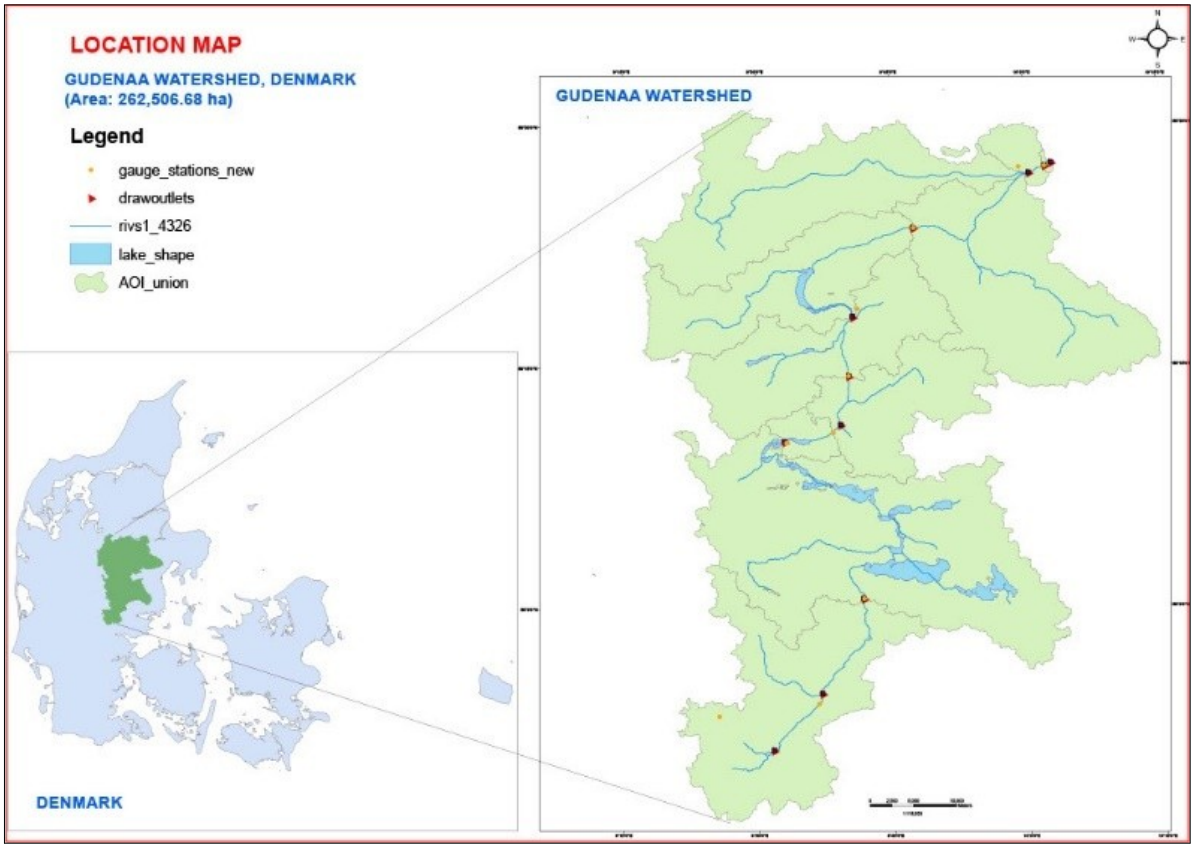


Figure 1: River Gudenå, the longest river in Denmark, and its catchment area.

The overall objective of this study is to develop a multi-model-chain, which is transferable to any other location in the world and predict the impacts of future climate on hydrology and water quality. The specific objectives of the study are to develop an impact modelling chain, which will be applied:

(1) To assess whether globally available gridded ERA5 data or observations from weather stations outperform each other when a hydrological model is calibrated for an area of interest (Study 1).

(2) To acquire climate model ensembles formed by ISIMIP3bs combinations, downscaled to the scale of watersheds, for the quantification of hydrological impacts of climate change simulated using SWAT+ (Study 2).

(3) To test the ability of reservoirs and reservoir operations to mitigate the impacts of climate change using SWAT+ with a focus on flood management (Study 3).

Study 1:

We assessed the performance of two SWAT+ model setups. In the first setup, runoff is routed from the upslope to the floodplain areas of a subbasin before it reaches the stream. In the second SWAT+ setup, runoff from hydrological response units (HRUs) is summed up at the subbasin level and added directly to the stream. A DDS (dynamic dimensional search)-based approach that enables auto-calibration of SWAT+ parameters was used. The model includes key components of natural and managed landscapes (figure 2, adapted from (Abbas and Xuan 2019)).

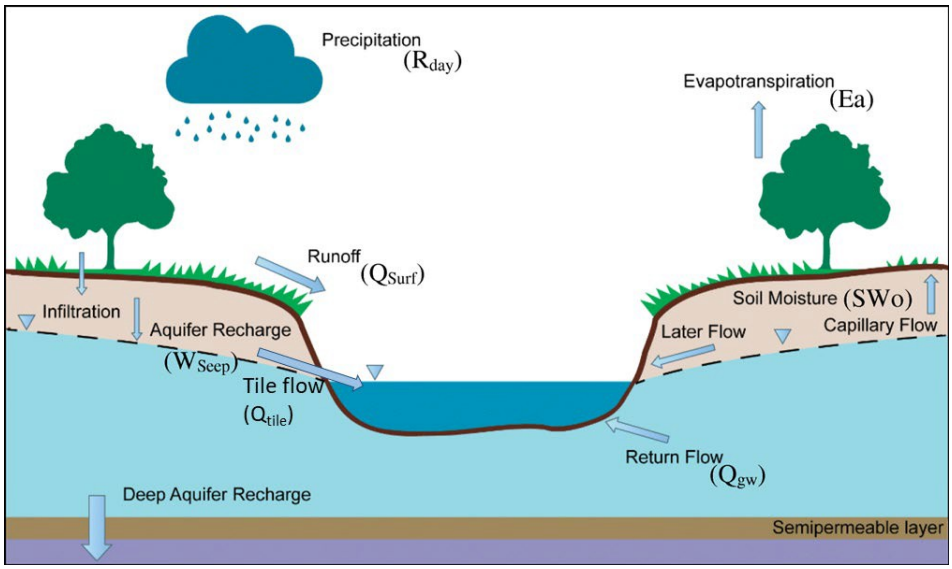


Figure 2: Key hydrological components included in the hydrological cycle simulated by SWAT+.

Initially, both models demonstrated unsatisfactory statistical performance for the temporal pattern of the streamflow, mainly because they simulated too little baseflow. Considerable improvements in the model performance were achieved through careful evaluation of the simulated water balance and manual adjustment of selected parameters. Furthermore, we worked on improving the representation of tile-drained cropland and groundwater processes. We implemented tile drainage for agricultural land use type on soils consisting of >8% clay and on slopes of <2% at the tiled depth of 1000 mm according to the normal practice in the area. Concerning groundwater processes, aquifer connections were studied, and two shallow aquifers were introduced; one slow and one fast aquifer to simulate the baseflow. Finally, plant growth was analyzed to make sure that the simulated Leaf Area Indices and biomass of all plants were as expected during the season.

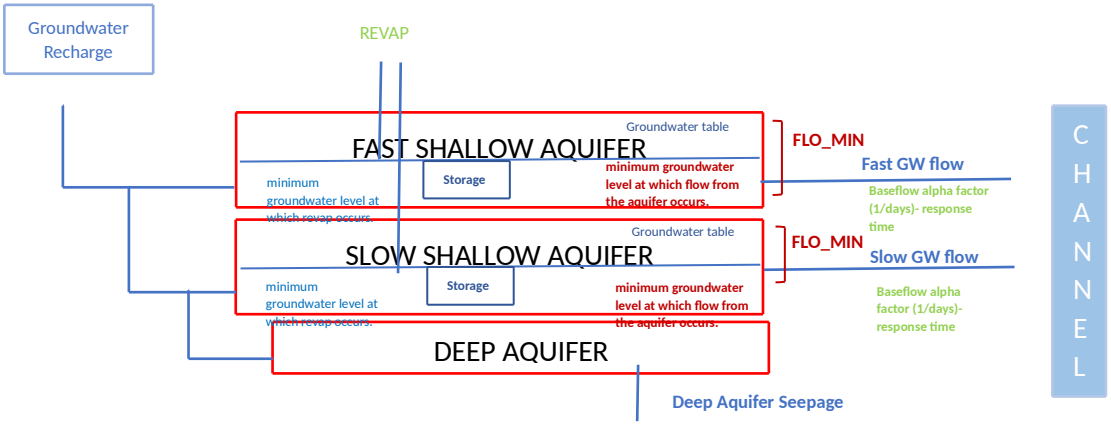


Figure 3: Representation of setup with two shallow aquifers.

After the parameterization, the calibration for both models (forced by ERA5 and DMI data) for the period 2000-2010 was done, resulting in satisfactory performance ($0.50 < NSE \leq 0.65$). Validation of the models for the period 2011-2020 is ongoing. Accordingly, Study 1 is nearly complete. The draft manuscript is 30-40% complete, including the spatial and temporal analysis of climatic data, as well as the study area and methodological description.

Studies 2 and 3:

The download of the climate ensemble data for Study 2 has already been prepared, so once the final version of the models from Study 1 is available, Study 2 can be completed within 2 months. The reservoir analyses for Study 3 were done during the first secondment at VUB in January and February 2023, so an estimated 40% of the work for Study 3 has been completed. Drafting of the manuscripts for Studies 2 and 3 will begin in the second half of 2024.

ESR 2

This project has received funding from the European Union`s Horizon 2020 research and innovation programme under the Marie Skłodowska-Curie grant agreement No 956623

Project summary

Ammanuel Bekele
ESR2

Research Progress

Initially, a study was conducted to assess the impact of extreme weather on riverine total phosphorus (TP) concentration. This investigation integrated meteorological, hydrological, and water quality data from the Moehne and Erft rivers. The resulting manuscript detailing the findings is prepared for submission and is slated for submission in February 2024.

Secondly, a collaborative research work was undertaken during my secondment at UFZ, in collaboration with a post-doctoral researcher. The research project has been successfully concluded, culminating in the submission of a manuscript to the Journal of Cleaner Production. Titled 'Climate Warming Effects in Stratified Reservoirs: A Comprehensive Assessment of Machine Learning Techniques versus Process Models in Thermal Structure Projections,' the study evaluated the efficiency of various machine learning and deep learning models, including Random Forest, Extreme Gradient Boosting, and Long Short-Term Memory (LSTM), compared to the CE-QUAL W2 process-based model. The objective was to predict daily reservoir water temperatures at various depths within the Rappbode reservoir. The ML and deep learning models were assessed using both historical and projected future climatic predictor inputs. The manuscript is currently under review.

Thirdly, a study has been started to analyse the future projection of TP loadings for the world's 100 largest lakes under three different RCP-SSP scenarios. The preparation of drivers as input data for future water quality scenario modelling has been completed. This encompassed data on population, livestock, sanitation, fertilizer application rates, cropland area, and atmospheric deposition for various future Shared Socioeconomic Pathway (SSP) scenarios. The subsequent steps involve integrating these drivers with hydrological model outputs from the WaterGAP3 model, which drive the water quality model (anticipated soon). Subsequently, the WorldQual model will be utilized to simulate future TP loadings according to various RCP-SSP combinations. The outcomes will inform the drafting of a manuscript and subsequent publication of the scenario simulation results.

Secondments and trainings

The three secondments occurred in Silkeborg, Denmark, Magdeburg, Germany, and Wageningen, Netherlands, collectively amounting to eight months spent away from my host institute. Each secondment proved fruitful in obtaining substantial assistance from the

supervisors at the respective locations. Remarkably, one of these secondments resulted in a collaborative study evolving into a published paper.

The trainings organized by the inventWater project, along with participation in other scientific conferences, also played a role in facilitating knowledge transfer and enhancing presentation skills.

ESR 3

This project has received funding from the European Union`s Horizon 2020 research and innovation programme under the Marie Skłodowska-Curie grant agreement No 956623

ESR-3: Project summary (7th of February 2024)

Maud Siebers

University of Stirling

Title: Improving forecasts of algal blooms using high frequency satellite imaging and process-based modelling techniques.

The plan for this thesis will be 4 chapters that will shed a light on the potential of combining earth observation measurements with process-based modelling to improve forecasts of algal blooms in both short- and long-term scenarios.

Chapter 1: Assessing the impact frequency of input data on simulating phytoplankton blooms in UK lakes.

The chapter is focused on setting up and implementing the process-based model GLM-AED. The aim is to set up the 1-D ecosystem model with default values and calibrate two or three parameters based on temperature and chlorophyll data available in the selected case study lakes. Next, the same process will be repeated with lower frequency calibration data. The comparison between different frequencies of data will give us insight. Next to calibration, the effect of low frequency input data on the simulation capabilities of the model will be assessed. This will lead to a publication that will set up my further work for forecasting and the use of earth observation in combination with modelling.

So, far I have run the model for Esthwaite, and I am interpreting the results for this chapter. This includes the analysis of frequency in the calibration of the model, as well as the input data of the model. Next to that, I have set up the framework of the paper, have made figures and are in more advanced stages of this chapter.

Chapter 2: Near-real time detection and monitoring of phytoplankton blooms in UK lakes using Sentinel-2 MSI observations.

The aim of this second chapter is to create an optimised, validated and quality-controlled time-series satellite water quality data (e.g., chlorophyll, turbidity) for selected lakes and reservoirs. The idea is to improve forecasts by using satellite (in combination with in-situ) to calibrate and validate the model. In this study we are quantifying the uncertainties that come with using earth observation data, as well as the uncertainties resulting from using it in process based modelling. Eventually, we will be evaluating if the advantage of having higher frequency data is worth the added uncertainty that earth observation brings. The goal is for this the be published as a paper in corporation with Mortimer Werther and Daniel Odermatt from EAWAG, Switzerland.

So, far I have started the search for the best atmospheric correction and chlorophyll a algorithm for each of the lakes, as well as finding the match ups in the data. Next to that, a plan is formed to use conformal prediction as a means to determine uncertainty in the earth observation data. The goal is to get this paper out by the end of my secondment at EAWAG (in 3 months).

Chapter 3: Scenario based forecasting of phytoplankton blooms through the assimilation of near real time satellite observations in process-based model GLM-AED to inform management decisions.

In chapter 3, the goal is to use the model set-up in chapter 2 with earth observation data (chl-a, temperature). The assimilation of two novel approaches will bring the research a step closer to improve forecasting of phytoplankton blooms. The chapter will focus on the Alton reservoir in the

UK, managed by Anglian water, and later may include Esthwaite Water as a natural lake as well. The objective is for this paper to naturally flow from chapter 2, to determine how well the model in combination with earth observation can be used for management decisions in the form of future scenarios. These future scenarios include short-term and long-term timescales on nutrient and meteorology impacts and other scenarios discussed with Anglian water management. The outputs will lead to publication.

So far, I have started to model Alton Water Reservoir during my secondment at Anglain Water. There are currently problems with data scarcity that will need to be solved, but are discussed with Anglian, as well as solutions will be found. Further work on this chapter is dependent on efforts completed in chapter 1 and 2 and is therefore halted for now. There is ongoing discussion with Anglian Water on progress as well as data.

Chapter 4: The effect of forecasted ISIMIP climate scenarios on phytoplankton blooms using GLMAED in UK lakes.

In chapter 4, the aim is to extend the working set-up with climate scenarios from now until 2100 and investigate the effect on UK lake phytoplankton biomass. The focus is on effect of climate; therefore, the inflow volume and inflowing nutrients will be kept constant to current levels. The first set up of this will be on individual lakes, with the goal to create a gradient over the whole United Kingdom. This will shed a light on which part of the area is affected most heavily by a changing climate. This will lead to publication.

So far, I have run and interpreted all climate scenarios using the model for Esthwaite Water in the UK lake district. The idea of a gradient over the whole of the UK is still in the plans, therefore this work has not been finalised yet. If due to time constraint these efforts will be to big, a decision will be made to focus on only the local lakes that have been modelled so far. Still, there is need for more research and possible development in this work.

Thesis in full - Discussion chapter: Improving forecasts of phytoplankton blooms using a 1-D lake ecosystem model and high frequency earth observations.

The main thesis goal posed will be answered in the discussion chapter. Which will touch upon the feasibility and usability of forecasting algal blooms using models and the combination with earth observation. Lastly, it will summarise what could be done in future work and what is still needed for it to succeed. As this is based on inputs from all chapters, no work has been done to realise this.

ESR 4

This project has received funding from the European Union`s Horizon 2020 research and innovation programme under the Marie Skłodowska-Curie grant agreement No 956623

A short summary of the current progress

ESR4: Incorporating water management in an Earth System Model for improved climate, impact and adaptation modelling

By Ioan Sabin Taranu

I embarked on my PhD journey at the Vrije University of Brussels (VUB), Belgium, on November 1, 2021. My initial background in Physics and Climate Science, while useful, required further enhancement to grasp the principles of water management, and the structure and functioning of the Community Earth System Model (CESM) I aimed to refine.

In the initial months, I dedicated myself to comprehensive literature review to assimilate the current state of the art in modeling human water management within Global Hydrological and Earth System Models. This period was crucial for identifying the prevailing challenges in the field and pinpointing a specific, worthwhile problem to tackle.

By the end of February 2022, after thorough deliberation and multiple discussions with my supervisors, we converged on a project: integrating sectoral water use into the CESM. The CESM is a sophisticated tool designed to simulate the Earth's climate system, covering atmospheric, oceanic, cryospheric, and terrestrial processes. Despite its complexity and advanced capabilities, the model lacked certain elements, notably human water use.

The existing CESM framework included an irrigation module, but my task was to expand this to encompass additional water use sectors such as domestic, livestock, thermoelectric, manufacturing, and mining. I achieved this and also connected all sectors by introducing a competition algorithm, thereby enhancing the model's representation of human water use across various sectors.

This advancement enables the CESM to more accurately simulate the interactions between water demand and supply, as well as water scarcity at both regional and global scales, under different climate change scenarios. The technical demands of this project were substantial, involving intricate model development, rigorous testing, validation, and analysis.

Our efforts culminated in the integration of this development into the official CESM version (currently in progress), reflecting the significant interest our work has garnered within CESM community. Moreover, we have documented our findings and submitted a paper to Geoscientific Model Development (GMD), a leading journal in our field. The paper was submitted in February 2024, so almost 2 years after we begin the work on this project.

This project also sparked a realization about the oversimplified nature of current models in representing sectoral competition for water, especially under conditions of scarcity due to droughts. Inspired by this gap, I am now developing a novel framework for water allocation among competing sectors, aiming to provide valuable insights into the socio-economic impacts of water scarcity and support the formulation of optimal drought management strategies at various governmental levels. This tool promises broad applicability, from informing on water scarcity's effects on socio-economic stability to aiding in the creation of effective water management and policy-making strategies.

In addition to my main research activities, I also did the following:

- Published as first author a paper on my Master thesis research which was very well received by the community: Taranu, I.S., Somot, S., Alias, A. et al. Mechanisms behind large-scale inconsistencies between regional and global climate model-based projections over Europe. Clim Dyn 60, 3813–3838 (2023). https://doi.org/10.1007/s00382-022-06540-6
- Co-author of a book for the 5-th National Communication of the Republic of Moldova to the UNFCCC: Climate Change Impacts, Risks and Vulnerabilities in the Republic of Moldova: Observed Trends and Future Projections, ISBN: 978-9975-166-92-8, 2023.
- Co-author on 2 articles currently in progress on topics related to intergenerational water scarcity and impacts of irrigation scenarios on the climate.
- Completed a secondment in Austria (3 months) at the International Institute for Applied Systems Analysis (IIASA), in USA (1 month) at the National Center for Atmospheric Research, in Germany (currently in progress, remotely) at Climate Analytics.
- Participated at a Summer School on Earth System Modelling in Boulder, Colorado, USA.
- Participated at a number of inventWater workshops
- Assisted in teaching for courses at my university on Land Climate Dynamics and Environmental Programming
- Presented my work at a number of international (EGU, CORDEX), national (Belgian Science Contribution), and internal conferences and seminars (VUB, IIASA, NCAR).

While there were a few significant challenges here and there, I am quite satisfied with the progress I have made so far, and I am confident that I will be able to defend my thesis well and on time. I also feel very grateful that I am part of the inventWater project. While we have more responsibilities than a typical PhD student, we also have more opportunities. I was able to meet many nice researchers this way, some of which I even befriended. I am looking forward to the remaining of my PhD, to what I will learn and to the research I am yet to do!

ESR 5

This project has received funding from the European Union`s Horizon 2020 research and innovation programme under the Marie Skłodowska-Curie grant agreement No 956623

Summary of progress – ESR 5 – January 2024

Coastal water pollution is a threat to the economy, the ecosystem, and human health. My PhD project research aims to address this issue by assessing trends in flows of various pollutants from land-based sectors to water systems at the sub-basin scale worldwide. The study revolves around four research questions, focusing on current trends, future projections, and the extent of pollution exceeding desired targets for clean water. The research contributes to the development of a comprehensive multi-pollution modelling framework to support water pollution control and achieve unsustainable development goals 6 (clean water and sanitation) and 14 (life below water). The initial focus has been on current and future pollution levels, examining multiple sources and pollutants, and developing the MARINA-Multi global model (version 4) (first two research questions).

Answering RQ1: what are the present trends in flows of multiple pollutants from land-based sectors to water systems at the sub-basin scale globally?

I completed the initial manuscript, addressing research question one, which has been published in the Elsevier journal "Marine Pollution Bulletin" under the title "Causes of Coastal Waters Pollution with Nutrients, Chemicals, and Plastics Worldwide." In this research, I quantified global river exports of nutrients, chemicals, and plastics to coastal seas by source and sub-basin for the recent past (2010). To do so, we developed the MARINA-Multi model (version 4) that covers 10,226 sub-basins. This model integrates the approaches of the point sources (Strokal et al., 2021a) and diffuse sources (Li et al., 2022) for inputs of pollutants to rivers. our model explicitly distinguishes between inorganic and organic forms of nitrogen and phosphorus in rivers from point and diffuse sources, which was not done in the previous model versions. Our model is expanded to macroplastics from mismanaged plastic waste (diffuse source) and diclofenac from sewage (point source), which differs from the previous marina models furthermore, our model is expanded to river exports of pollutants in which river retention is considered. The model used the updated removal efficiencies for microplastics, macroplastics, triclosan, and diclofenac during treatment (Micella et al., 2024). Results of this published manuscript demonstrate that already in 2010 89% of the global population lived in areas that are affected by multiple pollutants. I showed that globally, rivers exported approximately 40,000 kton of nitrogen, 1,800 kton of phosphorus, 45 kton of microplastics, 490 kton of macroplastics, 400 tons of triclosan and 220 tons of diclofenac to coastal waters in the recent past. approximately 75% of these contaminants are exported by

rivers to the Atlantic and Pacific oceans. Diffuse sources were dominant and accounted for 95-100% of the nitrogen (agricultural) and macroplastics (mismanaged garbage) in the rivers. Point sources (sewage) were dominant and accounted for 40-95% of phosphorus and microplastics in coastal waters. almost 45% of global surface sub-basin areas were identified as multi-pollutant hotspots. these areas accommodated 89% of the world's population.

Answering RQ2: what are the future trends in flows of multiple pollutants from land-based sectors to water systems at the sub-basin scale worldwide?

I am currently working on preparing the final version of my second manuscript in which I include answers to research question two. Now, the paper is with my co-authors for revision. I intend to submit this manuscript in the next few months of the year 2024. In this manuscript, I further developed the marina-multi model (version 4) for future applications under a combination of scenarios for multiple pollutants. These scenarios are based on the RCPs (representative concentration pathways) and SSPs (shared socio-economic pathways) combination and developed further for multiple pollutants. This second manuscript will be about future water pollution at the global scale, with a particular focus on new hotspots of pollution such as Africa and the Indian Ocean.

Other activities and future research Steps

Additionally, I have already co-authored three articles on the topic of water quality. One of these articles, titled "Water Pollution and Agriculture: Multi-Pollutant Perspectives," has recently been published in the journal Frontiers of Agricultural Science and Engineering. This article aligns well with the research scope of my work. The second article has been submitted to a journal, and the third article will be submitted soon.

I am currently drafting the plan for my third manuscript, which will focus on Sustainable Development Goal (SDG) 14 (Life Below Water).

Furthermore, I am actively involved in the ISIMIP (The Inter-Sectoral Impact Model Intercomparison Project) consortium and associated water quality sector. I co-organized the second water quality workshop in August 2023 and co-coordinated the effort with the ISIMIP fast-track initiative for large-scale water quality simulations. My activities within this sector also involve the development and updates of the water quality protocol and technical support of the community. I am also planning to submit my model runs to the sector, which is a great opportunity for me to extend my networking and enhance my collaboration skills.

ESR 6

This project has received funding from the European Union`s Horizon 2020 research and innovation programme under the Marie Skłodowska-Curie grant agreement No 956623

New indicators for global impacts on lake water quality to support management and policy making

1. Defining the research problem

Eutrophication is a critical issue that leads to enhanced algal growth effecting aquatic water quality and ecology. Lakes are increasingly vulnerable to the impacts of eutrophication due to the rising nutrients release from human activities and is further aggravated by climate change. Monitoring data on water quality constituents such as total nitrogen, total phosphorus and chlorophyll-a are often integral to understanding the long-term nutrient inputs and resulting dynamics in lakes. The in-situ data are widely used as indicators to track the progress of monitoring and management efforts to control eutrophication. However, globally there is a lack of adequate spatial and temporal distribution of this monitoring data. The issue is more prominent in the world's developing regions which are also the primary hotspots for future population growth and economic development. High requirement of funding and resources (e.g., personnel, infrastructure) allocation constrain the dramatic expansion of the in-lake monitoring. Yet, it is important to understand what and how anthropogenic nutrient emissions effect lakes in all climatic and development patterns. It paves the way towards effective water quality management and long-term policy making.

The PhD research aims to address the gap by development of different types of indicators (e.g., population growth, wastewater discharge) that can be used as proxies to diversify water quality monitoring. The main goal is to develop quantitative methods and data for diverse indicators that go beyond in-situ water quality and reflect anthropogenic activities, socio-economic conditions and climate change within the lake basin. They can further assist integrated water quality management at appropriate spatial scales and management levels. Integration of different aspects to characterize water quality and management can allow to understand lake eutrophication in a holistic manner. The following provides a summary of the progress achieved in this PhD research using two main outcomes: (i) a review and synthesis of the diverse indicators for global freshwater lakes using a causal network assessment; (ii) development of an integrated modeling framework to assess and identify the critical (most important) indicators.

2. Identification of the potential set of eutrophication indicators in global freshwater lakes

The first phase in this research includes identifying the potential eutrophication indicators through a comprehensive literature review. A two-step methodology was used for the review. First, synthesis of the potential eutrophication indicators using existing studies on drivers-pressure-state-impact-response (DPSIR) framework. The main objective was to identify the main indicators and map their cause-effect interactions using a new conceptual causal network. Second, a detailed review of nutrient mechanisms associated with driver[1] and pressure[2] indicators to provide a holistic understanding of how they impact lake eutrophication dynamics. The review is published in Environmental Research Letters entitled "Recent advancement in water quality indicators for eutrophication in global freshwater lakes"[3].

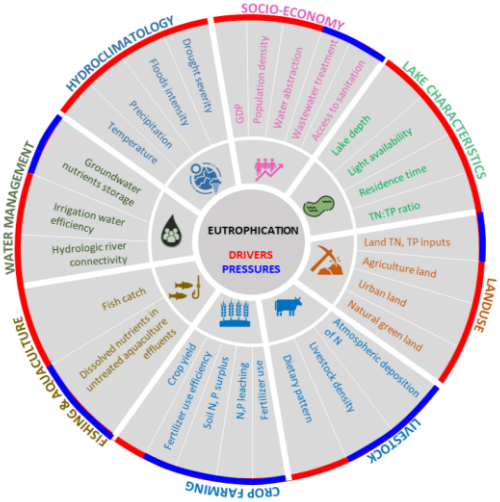


Figure 1: Overview of the indicators of drivers and pressures

The first result of the paper is a causal network, that includes a set of (58) potential eutrophication indicators and non-linear complexities of nutrients with climate, basin conditions (e.g. socio-economic development, point-source, diffuse source pollutants) and the lake systems. The interactions were mapped in a visual framework to identify interrelationships and feedback among the indicators, by dissecting causes and mechanisms of lake eutrophication. It offers an integrated approach, that can be used to study

[1] Activities within the basin (e.g., socioeconomic) and external factors (e.g. climate change) causing or worsening nutrients enrichment or both;
[2] Flows (e.g. fluxes and dynamics) of the nutrient emissions (e.g. point vs. diffuse) from specific sources and contributing sectors
[3] Keerthana Suresh et al 2023 Environ. Res. Lett. 18 063004. DOI :10.1088/1748-9326/acd071

interactions for specific cases and analyse the most important processes for eutrophication management. This can further help to guide decisions about the suitability and complexity of assessment methods, modeling and/or monitoring tools.

The second result is a holistic, interdisciplinary and systems analysis perspective of nutrient mechanisms for (30) driver and pressure indicators, identifying knowledge gaps and future research directions. These indicators are categorised across seven cross-cutting themes: (i) hydroclimatology, (ii) socio-economy, (iii) land use, (iv) lake characteristics, (v) crop farming and livestock, (vi) hydrology and water management, and (vii) fishing and aquaculture. The diverse range of indicators represent the complexity of eutrophication and the need for an integrated approach to control and manage eutrophication. It is urgently required to increase the number of integrated impact studies for the indicators globally to support water quality management. They can help to assess management implications across regions and allow to apply the lessons learnt from developed areas to effectively benefit eutrophication management elsewhere. They are of utmost importance to policymakers, practitioners and decision-makers to set realistic water quality targets.

3. Development of an integrated modeling framework to identify critical indicators

To advance the quantitative assessments of indicators, we develop a new integrated modeling framework in the second phase of this PhD research. The framework combines a set of biophysical models of land use and nutrient emissions (GLOBIOM), hydrology (CWatM) and nutrient transport model (MARINA) to estimate nitrogen(N) and phosphorus(P) loadings to lakes. It consists of one-way coupling of these models with set-up in R programming environment. First, simulations are run independently for CWatM and GLOBIOM to feed the inputs into the MARINA model for outputs. Thereafter, the set-up in R is used to process the model outputs from CWatM, GLOBIOM, and other socio-economic data to simulate the nutrient loads to the lake using MARINA model. In summary, CWatM provides the hydrological data, GLOBIOM provides land use and agricultural nitrogen inputs and the MARINA model quantifies the annual nutrient loadings to the lakes by different pollution sources at sub-basin scale. The key strength of the framework is its potential to assess the sources of nitrogen and phosphorus pollution, which is crucial to identifying dominant drivers and pressures at diverse scales (e.g., basin scale, regional and global).

The modeling framework is applied to a case of the Lake Victoria basin for the year 2000 and 2015 to quantify the near-current changes of nitrogen and phosphorus loads and their contributing sources at a sub-basin scale. The main objective is to analyze and assess nutrient pollution by dominant sources to enable systematic identification of the critical indicators relevant to the case study. Results indicate urbanization and agricultural intensification as the main drivers of nutrient loadings to Lake Victoria. There is a total increase of 15% and 55% for dissolved nitrogen and phosphorus respectively from 2000 to 2015, with 70% contribution from diffuse sources. The impact of the changing nutrient inputs from different sources on nutrient loads to lakes is evaluated using one-at-a-time sensitivity analysis technique. The sensitivities are used as proxies to assign importance for different indicators. The critical indicators are more diverse for nitrogen loading than phosphorus loading. Hydrology, land use, crop and livestock production as well as population connected to the sewerage system are likely the main indicators of nitrogen pollution, while crop and livestock productions are the indicators of phosphorus pollution. Although the critical indicators identified in this study are specific to the Lake Victoria basin, this study establishes the foundation for application to diverse contexts and conditions globally. A manuscript is under preparation to summarize the development and implementation of the integrated modeling framework.

4. Future vision of the research

The set of critical indicators summarized in section 3 using the modeling framework is only applicable to the selected case study, while the methodology is applicable elsewhere. The implementation of the modeling framework is a useful first illustration and offers a methodological template for future applications and improvements. The next phase of this research will expand the application to a global scale to represent the diverse socio-economic, biogeochemical and climatic conditions. This includes analysis of a wider number of indicators (identified in the review), development of quantitative index to evaluate their relative importance and interactions. We aim to explicitly connect the lake system characteristics with the nutrient emissions and anthropogenic influences in the connected basin. To achieve this, statistical and machine learning methods will be explored to leverage the combination of modelled results, remote sensing information and in-situ data. The ultimate goal of this PhD research is to contribute to new and improved ways to monitor and manage the lake water quality by development of an assessment framework for (critical) eutrophication indicators that is easy to quantify, reliable, transferable and feasible for practical applications.

ESR 7

This project has received funding from the European Union`s Horizon 2020 research and innovation programme under the Marie Skłodowska-Curie grant agreement No 956623

Summary of my PhD project (Ricardo Paiz; ESR No. 7)

Maintaining the health of aquatic systems is an essential component of sustainable management, however, degradation of water quality and aquatic habitat continues to challenge scientists and policymakers. To support mitigation and restoration efforts, forecasting and modelling techniques are required to capture the complex trajectories that water systems display in response to multiple stressors. Water quality forecasts, for instance, can be beneficial for industrial activities, environmental strategies, and climate change adaptation. However, challenges exist in providing solutions in many areas including the drinking water sector. This sector has faced challenges in northern Europe, particularly in Ireland and Sweden related to (1) water quality deterioration due to increased levels of dissolved organic carbon (DOC) in rivers and lakes, and (2) increasing concentrations of disinfection by-products (DBPs) in drinking water supply networks.

These two issues are intrinsically linked; when water containing high levels of DOC drains into rivers and lakes that are used as sources for drinking water, the formation of DBPs during treatment is prone**.** DBPs are mainly formed via chemical reactions with organic matter during water disinfection treatment and they are recognized to have negative implications on human health. Some DBPs are known to be carcinogenic and cytotoxic when users are exposed to long-term drinking water consumption. Some of the most common (and most regulated) DBPs are the trihalomethanes (THMs) which represent an important health concern in Ireland and Sweden. Therefore, monitoring DOC levels in water sources is crucial for the drinking water sector as it is considered an important precursor of DBPs. However, an increase in DOC exports from catchments to water bodies also presents negative implications for the environment which can be independent of the water use. For instance, high DOC loads from catchments can affect physical and biological cycles in rivers and lakes, ultimately affecting ecosystem biodiversity. An increase in water DOC can also reduce the penetration of sunlight radiation to deeper layers in lakes and reservoirs, modifying biological cycles.

To address both THM breaches and environmental degradation, a range of mitigation measures are required to be implemented. The aim of these measures is focused mainly on the protection of sources, raw water quality, and treatment improvement; where we have identified opportunities for water quality forecasts to support decision-making as part of this PhD.

Within this context, we are developing a near-term forecasting framework that currently has the capacity to produce decadal predictions of DOC levels in river catchments draining into water sources. We have done this (1) by using two water models GLWF and GLM that are driven by climate projections and monitoring data from the study areas; (2) by applying novel forecasting techniques based on statistics (e.g. Bayesian statistics) and likelihood estimations; (3) to then estimate the uncertainty of our predictions, putting them in context either for drinking water or environmental protection managers. We emphasize on the uncertainty when communicating our findings to stakeholders in the study sites so they can better understand the predictions and make more informed decisions.

The study sites where we are testing this framework are:

(1) the Burrishoole catchment located in County Mayo, Western Ireland, where we have simulated decadal levels of DOC entering Lough Feeagh as an exercise to inform Irish drinking water supply; and where additional opportunities rise to mitigate environmental degradation threatening important biodiversity including fish populations, which are an important native ecological trait of the region.

(2) the Lake Malaren catchment in Sweden, where we have simulated future changes of water quality including DOC loads entering the water supply of Stockholm providing indications of the potential impacts on drinking water.

To date, we have produced decadal predictions of water quality including DOC concentrations and loads in rivers and lakes for the study sites in Ireland and Sweden. This has been proven beneficial mostly for policymakers and environmental agencies, since with this information, they can have a better picture of how the water quality most likely will change in the intermediate and long term. Regulations can be structured with more information by using forecasts provided by the framework, enabling managers to draft proposals and strategies for water and environmental protection more accurately. This can ultimately have potential impacts on funding allocation with significant savings in the long term at local to regional levels.

Some applications for water treatment and environmental protection, however, require a higher temporal resolution than decadal predictions of future water quality. Therefore, we are currently increasing the resolution of our water quality forecasts, from decadal to daily predictions. We are doing this in Western Ireland at the Burrishoole catchment, where we are working in collaboration with the Marine Institute and managers to implement a daily water quality framework. We have made significant progress on this; now having the capacity to produce successful daily forecasts (up to 34-days in advance) for some water parameters already (e.g. temperature) in the main lake of the catchment. This has been done by deploying and incorporating for the first time in Europe a frontier forecasting mechanism into our framework: Forecasting Lake and Reservoir Ecosystem system (FLARE) developed by Virginia Tech (USA). This is proving to be very beneficial for the managers to anticipate important ecological dynamics in the short-term in the catchment. For instance, with this information they are able to estimate more accurately how Atlantic salmon, European Eel, and brown trout fish populations migrate in the region in response to climate variability.

By using water quality forecasts in water and environmental management, we aim that managers can anticipate important dynamics triggered by changes in climate and human activities. So that, better mitigation actions can be taken in both the short and the long term benefiting not only the drinking water (by a reduction of DBPs in water supplies) and environmental protection sectors but other related fields that also require attention. We estimate that the framework we are developing has the potential not only to support decision-making but can also benefit economic channels related to mitigation actions taken at different scales. Therefore, we expect to have a final product that can be a practical, scalable, and applicable tool for (but not limited to) Sweden and Ireland.

ESR 8

This project has received funding from the European Union`s Horizon 2020 research and innovation programme under the Marie Skłodowska-Curie grant agreement No 956623

ESR8: Production of water quality forecasting tools for better management of lakes devoted to drinking water supply

Based on the following objectives of this project, three out of four specific objectives will be described.

Develop a forecasting tool to support water management, decision-making, and planning, from catchment to treatment, to mitigate the increasing impact of climate variability on the formation of DBPs.

– Identify the extent to which different weather patterns and DOM proxies in catchments and lakes are key drivers of DBP formation. (100%)
– Using a mesocosms approach in lake waters, investigate the effect of different run-off scenarios in DOM on the formation of DBPs. (100%)
– Apply a combination of dynamic and other numerical modelling methods to forecast DBP's precursors in raw waters on a short time scale. (50%)
– Generate a decision-support tool that integrates DBP's precursor forecasts with reservoir and/or treatment management scenarios that will serve to project the formation of DBPs. (0%).

The work that has been developed is divided into two main activities: a)Experimental/laboratory work and b) Modelling work as is shown in Figure 1.

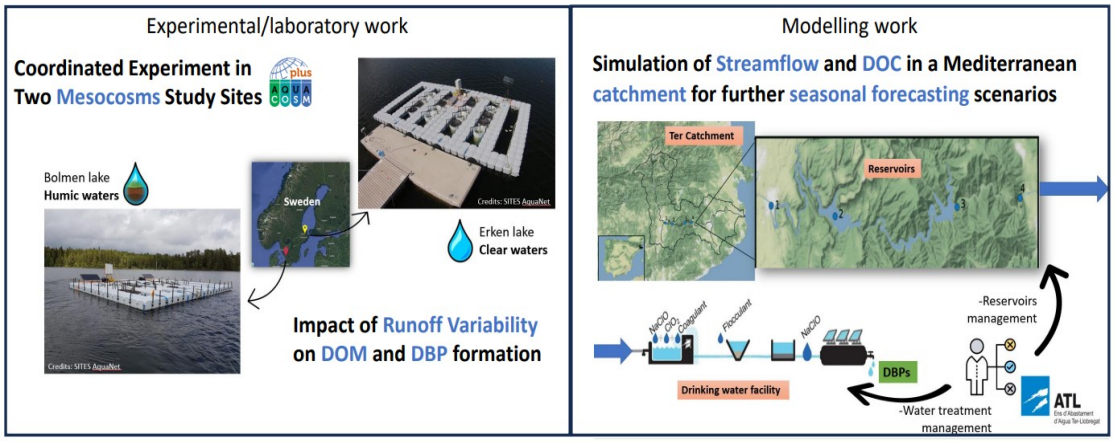


Figure 1. Timeline and status of the ESR8 project

a)Experimental/laboratory work: Results showed primarily site-specific changes in DBP precursors (Figure 2), and some were strongly dependent on runoff variability. Higher formation potential of haloacetonitrile (HANs) was observed for intermediate and continuous pulse events in the clear-water mesocosms, closely associated with freshly produced protein-like DOM enhanced by light availability. In contrast, trihalomethanes (THMs) were associated with humic-like DOM and showed no significant differences among pulse events in the brown-water mesocosms. The elevated concentration of bromide in the clear mesocosms played a crucial role in the speciation and concentrations of DBPs. These findings contribute to understanding the impact of changing precipitation patterns on DBP dynamics, providing

insights for monitoring, and controlling the mobilization and changes of DBP precursors in catchments and lakes. The manuscript is ready to be submitted.

b)Modelling work: The mediterranean catchment Ter was studied and modelled applying the model PERSiST to simulate streamflow and the model INCA-C (https://incamodels.org/) to simulate DOC concentrations (Figure 2) at daily basis for a calibration period of 11 years (2010-2020). Results are shown in Figure 3, where the streamflow simulations present satisfactory good of fit statistics when comparing them against the observations, On the other hand, DOC simulations show underestimated values compared to the observations.

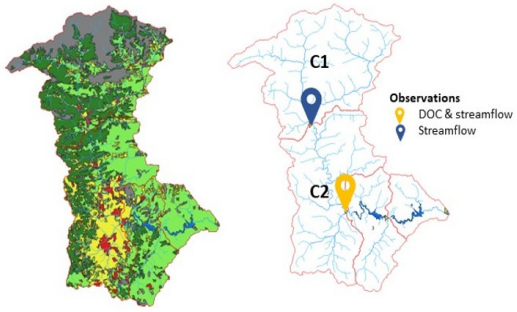
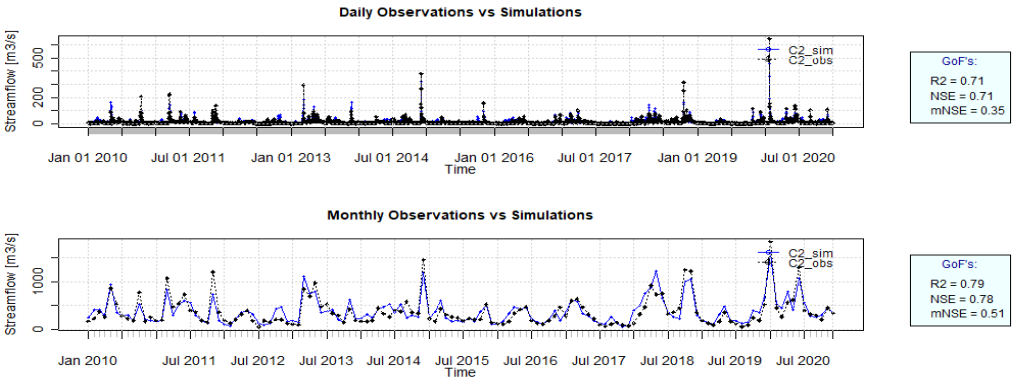


Figure 2. Ter catchment structure showing land cover (left) and sub-catchments configuration (right)



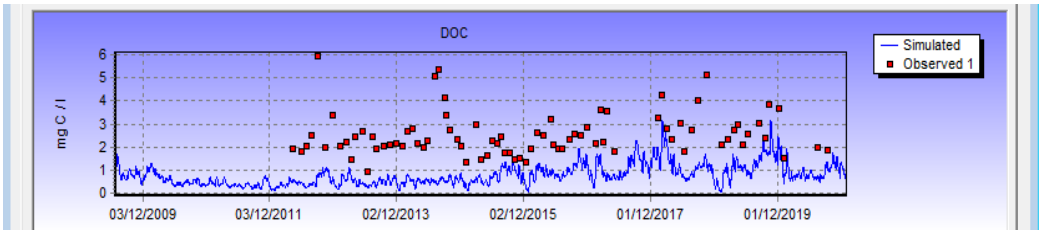


Figure 3. Simulation results of hydrology (streamflow) (upper) and DOC (bottom) at the Ter catchment.

Once the simulation of the INCA-C model is satisfactoctory, seasonal forecasts will be preformed using meteorological data provided by Copernicus (https://climate.copernicus.eu/seasonal-forecasts).

ESR 9

This project has received funding from the European Union`s Horizon 2020 research and innovation programme under the Marie Skłodowska-Curie grant agreement No 956623

ESR 9 Project Summary

My project so far has incorporated many opportunities for me to grow, in terms of my scientific capabilities, skills acquisition, and scientific network.

Research

To date, I have authored a manuscript titled ‘A simple model for predicting oxygen depletion of lakes under climate change’ (DOI: 10.1080/20442041.2024.2306113), which focuses on the depletion of oxygen in temperate lake hypolimnia. This paper will serve as the first chapter of my PhD thesis. The subsequent chapter for my thesis, currently in the process of being written, revolves around a manuscript titled 'Standard Phytoplankton Model: A Novel Lake Ecological Modeling Approach.' This work is an endeavor to streamline the parameterization requirements for implementing the ecological Aquatic Eco-Dynamics (AED) tool by introducing a transferable standardized process-based modeling concept and was collaboratively developed with fellow PhD students from Tsinghua University, the University of Girona, and Stirling University (ESR 3), as well as scientists from the Helmholtz Centre for Environmental Research (UFZ). The proposed final chapter of my thesis will be focused on deciphering adaptive monitoring of lakes and delineating reaction schemes. The current goal for this study is to conduct a literature review of documented water quality management strategies, spanning short-term to long-term approaches. Additionally, we aim to leverage monitoring data provided by our project collaborators, the Ruhrverband, to analyze the management strategies they have implemented.

In addition to the studies integral to my thesis, I actively engage in collaborative initiatives with researchers beyond the UFZ, with the goal of scientific output. Firstly, we recently submitted a paper, ‘Temperatures and hypolimnetic oxygen in German lakes - observations, future trends and adaption potential’, led by Dr. Robert Schwefel of the Leibniz-Institute of Freshwater Ecology and Inland Fisheries (IGB). Here, we assessed the impacts of climate change on German lakes, focusing on temperature, stratification, and hypolimnetic oxygen using observational data and the simple oxygen depletion model developed in my published manuscript. The second research project I am involved in is a Global Lake Ecology Observatory Network (GLEON) initiative which investigates the challenges of open data and data harmonization in aquatic sciences. In this context, we conducted a survey to unravel the perspectives of professionals in the water research sector. The manuscript is currently in the finalization stage, with the intention of submitting it in the first half of the year Furthermore, my involvement in another GLEON project centers on deducing the effects of climate change on the progression of hypolimnetic oxygen concentration. Our aim is to systematically analyze potential human impacts on hypoxia globally, comparing the effects of eutrophication (oligotrophic vs. eutrophic) and global change (observed climate vs. counterfactual climate). We are still generating results for this endeavor, and anticipate to start writing a manuscript in the coming months.

Training

During my time as an ESR I have actively engaged in diverse training activities that have significantly enhanced my capabilities to fulfill the requirements for the project. Beyond the specialized training events organized for ESRs in inventWater, I have enrolled in courses provided by UFZ's graduate school, HIGRADE (Helmholtz Interdisciplinary GRADuate School for Environmental Research). These courses span a spectrum from technical topics like 'Navigating Core Concepts of Statistics' to soft skills offerings such as 'Good Scientific Practice.' Complementing the in-house training at UFZ, I have expanded my

knowledge by participating in courses hosted by other esteemed universities. Examples include 'Applied Limnology and Modeling of Lakes and Reservoirs' from the Technical University of Braunschweig and 'Communicating with Confidence and Accuracy - Voice and Body Coaching' from the Otto von Guericke University Magdeburg. Additionally, I have undergone hands-on training encompassing water quality monitoring and fieldwork techniques. I've also gained proficiency in utilizing R-Studio for modeling and graphics generation, as well as aquatic modeling skills using the General Lake Model (GLM). Furthermore, I regularly meet with my supervisor to discuss research goals, receive guidance on necessary training, and identify contacts for fulfilling those training needs.

Networking

Throughout my PhD program, I have actively participated in numerous networking events, fostering valuable connections within the academic community across diverse geographical locations. At the UFZ, my engagement extends to attending scientific presentations during Lake Research department meetings and the house-wide Seminar: Water & Environment series. This proactive involvement allows me to explore potential synergies between the presenters' work and my ongoing research endeavors. To amplify these networking opportunities, I've also taken part in events specifically designed to connect PhD students in the environmental sciences field. Notable instances include my participation in the HIGRADE conference in 2023, where I presented a poster, and the PhD Student Event organized by the Technical University of Dresden Faculty of Environmental Sciences. These experiences have been instrumental in broadening my professional network and enhancing collaborative possibilities within the academic field.

Furthermore, my engagement in external networking activities has been driven by active participation in international conferences. For instance, my involvement in GLEON, which encompasses attendance at the past two in-person meetings and one online meeting, has provided me with valuable access to professionals engaged in diverse facets of lake research across various stages of their career paths, ranging from graduate students to esteemed professors. This involvement has extended to being elected as a GLEON Student Association Co-Chair, enabling collaborative work with students from different countries and those possessing expertise in various fields related to lakes. Through GLEON, I've not only contributed to scientific endeavors, as mentioned earlier, but also expanded my network internationally. Additionally, I have attended two other notable international conferences—the 36th Congress of the International Society of Limnology (2022) and the Association for the Sciences of Limnology and Oceanography (ASLO) Aquatic Sciences Meeting (2023). Notably, the former conference led to the establishment of a collaborative working relationship with Dr. Schwefel.

ESR 10

This project has received funding from the European Union`s Horizon 2020 research and innovation programme under the Marie Skłodowska-Curie grant agreement No 956623

Status report ESR10: Solutions for existing and future challenges in water governance.

Publications	
(Nakulopa et al., 2024)[1]	https://doi.org/10.1016/j.scitotenv.2023.169460 Abstract: Reservoirs regulate water flow and pollutant transport in catchments. However, climate change can significantly impact their ability to perform this function. This study analyzed a multi-decadal time series of data to examine the complex relationship between climate and nutrient pollution trends in the Möhne reservoir catchment. The study aimed at understanding the effect of the reservoir on downstream nutrient pollution in the face of a changing climate. The analysis revealed that upstream nutrient concentrations were higher than downstream, indicating a general nutrient-trapping effect of the reservoir. Upstream stations exhibited a declining trend in total nitrogen (TN) and total phosphorus (TP) concentrations. This was due to improved wastewater management and reduced nutrient mobilization resulting from decreasing surface runoff and streamflow. At the downstream station, whereas TN concentrations decreased, TP concentrations mildly increased. These opposite downstream trends were likely due to rising temperatures and declining dissolved oxygen concentration within the reservoir, which might have favoured nitrogen denitrification and internal phosphorus loading, causing the decline and increase in downstream TN and TP concentrations, respectively. The contrasting downstream TN and TP trends alter the nutrient stoichiometry, which can profoundly affect the ecosystem's biogeochemical functioning. Therefore, in a warming climate, reservoirs may modulate nitrogen and phosphorus nutrients differently, leading to ecological discontinuities along river networks due to changes in TN-to-TP ratios. The study highlights the need to develop adaptable and precise nutrient pollution management strategies in reservoir catchments to address the challenges of climate change effectively.
(Nakulopa et al., 2022)[2]	https://doi.org/10.1175/JHM-D-21-0106.1 Abstract: The Rwenzori Mountains, in southwest Uganda, are prone to precipitation-related hazards such as flash floods and landslides. These natural hazards highly impact the lives and livelihoods of the people living in the region. However, our understanding of the precipitation patterns and their impact on related hazardous events and/or agricultural productivity is hampered by a dearth of in situ precipitation observations. Here, we propose an evaluation of gridded precipitation products as potential candidates for filling this hiatus. We evaluate three state-of-the-art gridded products, the ERA5 reanalysis, IMERG satellite observations, and a simulation from the convection-permitting climate model (CPM), COSMO-CLM, for their ability to represent precipitation totals, timing, and precipitation probability density function. The evaluation is performed against observations from 11-gauge stations that provide at least 2.5 years of hourly and half-hourly data, recorded between 2011 and 2016. Results indicate a poor performance of ERA5 with a persistent wet bias, mostly for stations in the rain shadow of the mountains. IMERG gives the best representation of the precipitation totals as indicated by bias score comparisons. The CPM outperforms both ERA5 and IMERG in representing the probability density function, while both IMERG and the CPM have a good skill in capturing precipitation seasonal and diurnal cycles. The better performance of CPM is attributable to its higher resolution. This study highlights the potential of using IMERG and CPM precipitation estimates for hydrological and impact modeling over the Rwenzori Mountains, preferring IMERG for precipitation totals and CPM for precipitation extremes.

[1] Nakulopa, F., Bärlund, I., Borchardt, D., 2024. How a reservoir modulates downstream water quality under declining upstream loading and progressing climate change. Science of The Total Environment 912, 169460. https://doi.org/10.1016/j.scitotenv.2023.169460

[2] Nakulopa, F., Vanderkelen, I., Walle, J.V. de, Lipzig, N.P.M. van, Tabari, H., Jacobs, L., Tweheyo, C., Dewitte, O., Thiery, W., 2022. Evaluation of High-Resolution Precipitation Products over the Rwenzori Mountains (Uganda). Journal of Hydrometeorology 23, 747–768. https://doi.org/10.1175/JHM-D-21-0106.1

Conferences	EGU General Assembly 2022: Vienna Austria Gave a talk. Title: Solutions for existing and future challenges in water governance 36th Congress of the International Society of Limnology - SIL 100 Berlin -2022. A talk: Title: Solutions for existing and future challenges in water governance 2023 SWAT Conference: A poster: Assessing the sustainability of Germany nutrient pollution regulations under changing climate conditions
Internal presentations	Department presentation: Overview of the Germany Water Sector following a training with the with the Germany Association for water, waste water and waste (DWA) – September 5, 2022. Can a reservoir alter climate change impacts on nutrient pollution? – August 21, 2023 IP Seminar Poster presentation:
External professional training	Understanding the Germany Water Sector – The DWA Headquarters, Hennef – Germany: July 11-13, 2022
inventWater Training schools	1. Welcome retreat – January 2022 2. Big data for water quality management – June 2022 3. Modelling water quality under global change – October 2022 4. Managing water in complex anthropogenic landscapes – September 2023 5. Entrepreneurship, pitching, and media interactions – January 2024
Courses Attended	1. Making an Impact as an Effective Researcher – By Helmholtz Graduate School, "HGS-HIRe for FAIR". 01st – 3rd .11.2022 2. Good Scientific Practice (for doctoral researchers) – By UFZ. 3rd – 4th .11.2021 3. Applied Limnology and Modelling of Lakes and Reservoirs (Angewandte Limnologie und Modellierung von Seen und Talsperren) – TU Braunschweig. 21st – 25th .03.2022 4. Natural controls and human impacts on catchments and streams - water quantity, quality and ecosystems – By TRACER School. 22nd – 26th .08.2022 5. Doing your PhD at the UFZ – By UFZ. 21st - 22nd ·10. 2021
Research Stays	Vrije Universiteit Brussel October – December 2022. Lab Visited: Prof. Ann van Griensven. Attended courses and workshops on the understanding and the usage of the model. SWAT+ model setup ICRA and CEAB September - December 2023. Lab visited: Prof. Rafael Marce' Manuscript writing SWAT+ model improvement and analysis Big Climate data handling

ESR 11

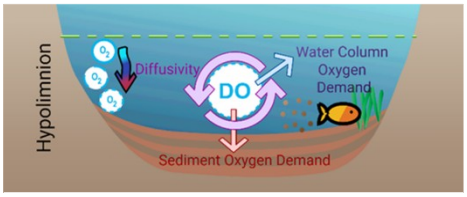
This project has received funding from the European Union`s Horizon 2020 research and innovation programme under the Marie Skłodowska-Curie grant agreement No 956623

invent water

Summary of ESR11 project

Adaptation strategies against progressing anoxia in lakes

Mahtab Yaghouti



Lakes provide very critical ecosystem services for us. They are highly vulnerable water resources to climate change. Dissolved oxygen (DO), as a fundamental water quality indicator, has been used for many years as a classifier of lake condition and health. In this study, a one-dimensional DO model has been developed to simulate the changes in oxygen levels in the hypolimnion profile during the summer stratification and will be used to explore factors impacting the influence of different pressures on hypolimnetic oxygen concentrations. This model has been applied in Lake Erken, a mesotrophic, medium-sized lake with daily water temperature and DO profile data available over 4 years (2019-2022). The hypolimnion in this study has been identified in the deep zone of the lake with a thickness of 7.25 m, and well below the photic zone. This part of the lake lacks an oxygen source, making it highly susceptible to becoming anoxic. The dynamics of oxygen in the hypolimnion are related to oxygen transfer as a function of thermal diffusivity and oxygen consumption in the water column and sediment and is also influenced by the morphology (Fig. 1). Over the observed years, the DO vertical diffusion coefficient was estimated from the hypolimnetic temperature profile.

This model was calibrated in 2020 and 2021 and validated separately in 2019 and 2022. Testing various combinations of model parameters, 16 different parameter sets (oxygen consumption rates from sediment and water column) were selected with volumetric hypolimnetic oxygen depletion rate in the range of 0.5-0.6 mg L^{-1} d^{-1}, according to their acceptable performance in simulating DO profiles (<1 mg L^{-1}) during the calibration period. The validation was carried out for a polymictic year (2019) and a dimictic year (2022). The validation process showed that the model's performance in simulating DO profiles in dimictic years (0.89-1.46 mg L^{-1}) is better than in polymictic ones (1.63-2.28 mg L^{-1}).

Simulation results (water temperature profiles and vertical diffusivity coefficients) from the ISIMIP2b data, using the hydrodynamic lake model, GOTM, were obtained under 4 General Circulation Models (GCMs: GFDL, HadGEM2, IPSL, and MIROC) and 3 Representative Concentration Pathways (RCPs: RCP2.6, RCP6.0, and RCP8.5) and the historical scenario (Ayala et al., 2020) and used to drive the DO model. Fig. 2 displays the fluctuation of hypolimnetic DO in May-Sep under all scenarios.

The result of uncertainty partitioning showed that 71%-72% of the total uncertainty comes from the GCM selected, 27%-28% comes from the parameter selections, and less than 1% originates from the interactions of GCMs and parameter selections in simulating the average of hypolimnetic DO in May-Sep in all historical and future scenarios. These months (May-Sep) were selected because during this time of year, the lake is more likely to become deoxygenated.

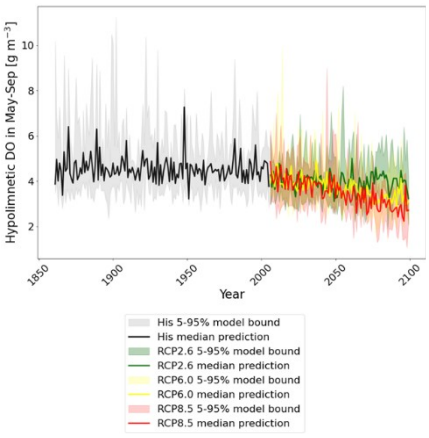


Fig. 2. Simulation of hypolimnetic dissolved oxygen in May-Sep under historical and future scenarios

Four factors were identified that could be affected by climate change and could impact hypolimnetic DO. These were, the onset DO concentration, the diffusivity coefficient, the length of stratification, and the deoxygenation temperature correction coefficient, Attribution analyses were carried out to identify the contribution of each potential driver to the increase in deoxygenation over 80 years (2020-2099). The attribution test indicated that the decreasing trend in hypolimnetic DO under RCP6.0 and RCP8.5 is due to the increasing trend in the DO stratification period, but no trend was detected for RCP2.6.

Given these climate change pressures on hypolimnetic DO, maintaining the current hypolimnetic DO condition in the future would require a reduction in the overall oxygen depletion rate. The amount of reduction is highly dependent on the scenario defined; for RCP8.5 a 0.15 mg L^{-1} reduction in consumption rate is needed to maintain the same average May-Sep hypolimnetic DO value in 2020-2029 as in 2090-2099.

A second sub-project focuses on how atmospheric wind stilling influences the progression of deoxygenation in Lake Erken. On a global scale, from 1973 to 2010, there was a decreasing trend in wind speed known as the wind stilling phenomenon. Initial analyses of available meteorological data have been carried out on the long historical meteorological dataset (1960-2017) that was available on Malma islet located in Lake Erken from Moras et al (2019).

We examined the trends of wind speed and air temperature simultaneously. These two factors play critical roles in the thermal stratification pattern and consequently in hypolimnetic DO dynamics. Over a decade, the decreasing slope in wind speed is 0.14 m s^{-1} $decade^{-1}$, and the increasing slope in air temperature is 0.34 °C decade-1 (Fig 3). The wind speed decline equates to an approximately 8.5% reduction in wind energy, which would impact the length of thermal stratification and therefore hypolimnetic deoxygenation. The next step is to analyse the comparative impacts of the historic wind decline and air temperature rise on hypolimnetic DO for Lake Erken.

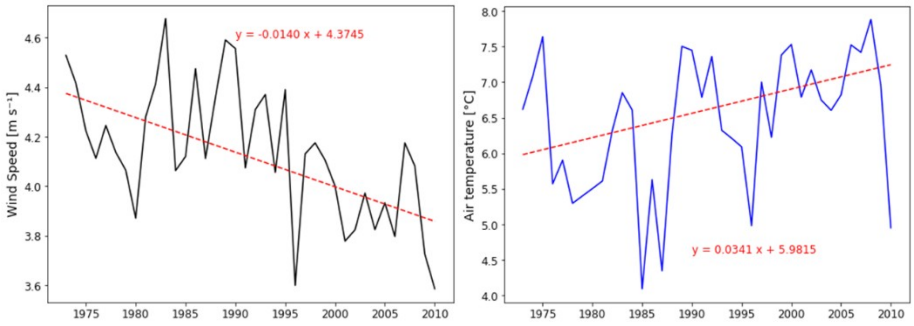


Fig 3. Annual wind speed and air temperature fluctuations and their detected trendlines

ESR 12

This project has received funding from the European Union`s Horizon 2020 research and innovation programme under the Marie Skłodowska-Curie grant agreement No 956623

ESR 12: Employing ISIMIP projections to model the phenology, production, and distribution of diadromous fish – A summary

The title of my PhD project ‘Employing ISIMIP projections to model the phenology, production, and distribution of diadromous fish’ cover a wide range of climate related questions and hypotheses. My project is located at the Marine Institute Research Station on the Burrishoole River system. The long-term monitoring in the Burrishoole catchment encompasses three diadromous fish species, the two anadromous species Atlantic salmon *Salmo salar* Linnaeus 1758 and brown trout *Salmo trutta* Linnaeus 1758, and the catadromous species European eel *Anguilla Anguilla* Linnaeus 1758.

The core objective of the PhD is to use data from The Inter-Sectoral Impact Model Intercomparison Project (*i.e.*, ISIMIP) joint projections of ‘Shared Socioeconomic Pathways’ (*i.e.*, SSP) and ‘Representative concentration pathways’ (*i.e.*, RCP), to further understand the ecology of diadromous fish in response to global warming. The first objective was to establish a model capable of forecasting environmental drivers relevant to one or more of these diadromous fish species.

In lotic freshwater ecosystems, three fundamental drivers have been the focal point of previously reported ecological studies on diadromous fish. In short, stream temperature, stream flow, and productivity (*e.g.*, primary, secondary, and tertiary) are all key determinants of phenology, production, and distribution of diadromous fish. The first step towards bridging ecological models of phenology, production and distribution of diadromous fish was to derive a method to downscale data from the ISIMIP 3A repository and predict stream temperatures.

The first goal was to provide the most accurate statistical model for predicting stream temperature using the atmospheric drivers available from the ISIMIP phase 3A repository. In this process, linear regression models, stepwise linear regression models, seasonal autoregressive moving average models, random-forest models, extreme gradient boosting models, feed-forward neural networks, and recurrent neural networks were constructed and validated to achieve the most accurate predictions of stream temperature.

The next step was to establish a link between temperature and phenology, productivity and/or distribution of diadromous fish. This was achieved using a metric known as degree day, often seen in studies applied in agronomy and entomology. The degree day metric has been shown to have a strong linear correlation to growth in immature fish and requires only knowledge of i) length at age, and ii) temperature.

A more detailed description of the model workflow can be found in Rinaldo *et al.*, (2023), which shows how the ISIMIP framework may be coupled with a long short-term neural network to predict stream temperatures and a degree day model to provide growth projections for juvenile Atlantic salmon.

Whilst the model workflow of Rinaldo *et al.*, (2023) appears to provide decent estimates of growth in juvenile Atlantic salmon, the precision of the model may be improved upon at the cost of generalisability. By expanding on the workflow, the second paper (in prep.) attempts to quantify the impact of genetic introgression from farmed Atlantic salmon on wild Atlantic salmon populations. In addition to the original methodology of Rinaldo *et al.*, (2023), the improved growth model incorporates density dependence, stream flow, and genetic effects.

The third paper (in prep.) is a collaborative paper applying the methodology of Rinaldo *et al.*, (2023) at a trans-European scale. The collaboration involves 16 researchers from institutions across Europe, such as Norway, Sweden, Denmark, Finland, Scotland, England, Ireland, France, and Spain. The paper is planned to be the focus during the secondment at Potsdam Institute for Climate Impact Research.

Lastly, a brief communication (in prep.) on density dependence of juvenile Atlantic salmon across an entire freshwater part of the salmon's life cycle, building on a number of earlier studies that focussed on early life history following emergence, is nearing completion (currently internal revision). The brief communication will most likely be submitted to the Special Issue Proceedings of salmonids Symposium in Ecology of Freshwater Fish which was held in Mallorca Spain in 2023.

ESR 13

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Project 13: The role of reservoirs as carbon sinks along the land to ocean aquatic continuum: a modelling approach.

ESR 13: Daniela Henry
Supervisors: Rafaél Marcé, Núria Catalán y Biel Obrador

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1 Goals

The main goal of this work is to address the role of reservoirs as carbon (C) sinks, determining their capacity to sequester and store C, as well as to study the stability of such C within the sediments in comparison to other depositional environments along the land to ocean aquatic continuum (LOAC), using a modelling approach. Thus, we have established four specific objectives:

- **Objective 1:** Determine the current state of C burial modelling in order to identify the best means and resources available to build, implement and validate a global process-based model which integrates different depositional environments in its parametrization.
- **Objective 2:** Study the influence of reservoirs over the buried organic carbon (OC) across the LOAC.
- **Objective 3:** Evaluate the effect of dam decommisioning (or abandonment) on reservoir's OC burial efficiency.
- **Objective 4:** Analyze the impact of dam infrastructure and climate over buried OC under diverse scenarios (e.g. with or without the presence of reservoirs, under optimistic or conservative climate scenarios).

To accomplish the goal of the project, it has been decided to implement a mechanistic global model able to simulate the transport and processing of OC across different ecosystems of the LOAC: lakes, reservoirs, floodplains and coastal ecosystems. This model will allow to study various past and future scenarios, in order to understand how reservoirs have or will impact the transport and burial of OC.

2 Project tasks and advances

The project has been organized in four main tasks: literature review, model implementation, scenario analysis, and thesis writing and submission. So far, the main advances have focused on the first two.

2.1 Literature review

As all scientific studies, the first step is to found a theoretical framework to establish relevant hypotheses and to support them. In particular, this study relies more strongly in this task because it covers a broad range of disciplines and because it does not generate new observations. For this, the literature search was separated in two different branches. The first one consisted of studying each of the depositional environments integrated in the model: lakes, reservoirs, floodplains and vegetated coastal ecosystems (mangroves, seagrasses and salt marshes), and comprehend how carbon burial has been approached in the past at different temporal and spatial scales. This review was fundamental to acknowledge the gaps and challenges of global C modelling, to define which type of model fits the best

the needs of the study, and to determine processes parametrization to be used for each component of the model. The second branch of this literature review was to gather OC burial rates from diverse aquatic ecosystems around the world in order to create a robust database. From this complete review, an article has been submitted to the journal "Earth Science Reviews".

2.2 Model implementation

To prove the thesis hypotheses and simulate different climatic scenarios, a global steady state process-based OC burial model is the tool which is being implemented. The implementation of such tool has been the most time demanding task and it is still in progress. The model simulates C transport and processing across different ecosystems of the LOAC. It requires geo-referenced spatial maps as inputs. Those maps provide the location of each ecosystem, some of their properties such as water depth, volume and residence time, and also information about sediment input, its organic carbon content, and some other sediment properties. Maps are either taken directly from open source repositories or produced, when necessary. The model follows the fate of C throughout the river network and incorporates the most relevant processes of C transformation within inland and coastal waters (sedimentation, burial and mineralization), until it reaches the ocean. The model workflow is shown in Figure 1.

On the subject of processes parametrization, each environment is addressed differently according to the data available in the literature and with what has been previous done in similar studies. Regarding model implementation, Python and R are the programming languages used. The model is based on another model developed by ICRA colleagues (Font et al., 2019), and modified according to the project needs. The model code has been created and used for other purposes, but it has been proved suitable to be adapted for global C transport and processing. For model validation, model outputs will be compared to outputs from previous global studies of sediment transport to the oceans and C emissions. Additionally, also burial rates data collected from the literature is going to be used for further validation.

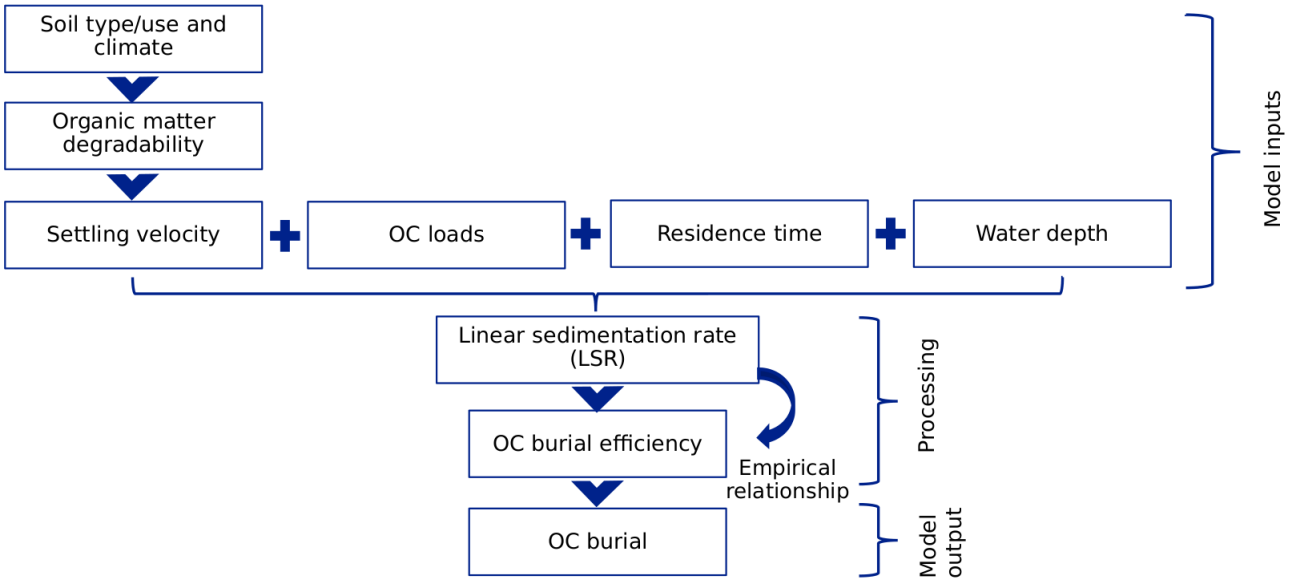

Figure 1: Model workflow.

Up to date, the model has been successfully implemented for lakes and reservoirs. Currently, we are working on the integration of coastal ecosystems. Once the model is completely implemented, it will be use to simulate several scenarios in the experimental phase. Scenarios will be established in order to answer quantitatively and/or qualitatively the following questions:

- How much C stays in the reservoir?
- How much C reaches the ocean?

- How much *Blue Carbon* is displaced because of reservoirs?
- How much C can be classified as new anthropogenic sink?
- How much C can be lost when dams are removed (dam decommissioning)?
- How much C can be lost with drawdowns during dam operation?
- Which anthropogenic perturbances affect C burial the most, degradation of coastal ecosystems or dam infrastructure?
- How all these aspects are affected by climate change?

References

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ESR 14

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Project Summary: Forecasting trade-offs between the food-energy-water-environment nexus and opportunities for adaptation

Annika Schlemm, ESR 14

The project "Forecasting trade-offs between the food-energy-water-environment nexus and opportunities for adaptation" investigate the interlinkages and interdependencies within the water-energy-food-environment (WEFE) nexus in the Upper White Nile (UWN) basin in East Africa. This region, crucial for sustaining essential ecosystem services and supporting the livelihoods of millions, faces escalating environmental pressures due to rapid population growth, urbanisation, and land use changes, all exacerbated by the looming threats of climate change. Understanding the interconnectedness of the WEFE nexus and the potential impacts of future climate scenarios is paramount for devising effective adaptation strategies. Thus far, the project has focused on investigating the current WEFE challenges and needs within the UWN basin, leveraging extensive stakeholder engagements and employing the Co$tingNature ecosystem services (ES) mapping tool. These interactions with local stakeholders have been instrumental in not only identifying key ES and current challenges, but also for integrating invaluable local knowledge into the decision-making process to reduce the disconnect between the production and use of scientific knowledge.

In the first chapter of the project, a valuation and mapping of ecosystem services (ES) within the UWN basin is currently underway, building upon the insights gathered from stakeholder interviews across Uganda, Kenya, and Tanzania and employing the ES mapping tool Co$tingNature. The results have provided insights into which ES are most important to locals within the basin (namely water provision, aquatic biodiversity, artisanal fisheries, and crop production), and in which instances the valuation of ES by stakeholders and Co$tingNature are in agreement (such as culture-based tourism, environmental quality, and nature-based tourism), and in conflict (such as carbon sequestration, commercial timber, and water provision). In addition, this work develops a WEFE nexus and ES framework that provides a novel perspective on the classification and mapping of ES, demonstrating the dominance of environmental related ES within the basin. This chapter aims to provide a comprehensive understanding of the spatial distribution and significance of ES in the basin, incorporating both biophysical assessments and participatory methodologies to capture the diverse cultural and social values attached to these services. This work is being completed, which will be summarised in a paper that will be submitted to the journal *Ecosystem Services*.

In the subsequent chapter, the project delves deeper into the refinement of WEFE nexus indicators through continued stakeholder engagements and a thorough review of existing WEFE nexus models. By integrating stakeholder feedback and local knowledge, the chapter has developed relevant and context specific WEFE indicators that accurately reflect the complexities of WEFE nexus challenges in the UWN basin. The findings highlight the importance of declining water quality and aquatic ecosystem health as a result of deforestation and increasing agricultural intensity, with stakeholders expressing concerns for the uncertain impacts from climate change. Furthermore, a review of current WEFE nexus modelling tools reveal how they tend to be insufficient in addressing the most pressing environmental challenges within the basin, with a significant gap regarding the inclusion of water quality and aquatic ecosystem indicators. Subsequently, these findings are combined to guide the development of WEFE nexus indicators that have the potential to spatially model the trade-offs within the WEFE nexus in the UWN basin under climate change scenarios. This work provides an example of how incorporating local stakeholder’s values and concerns can contribute to the development of

meaningful indicators that are fit-for-purpose and respond to the actual local needs. This has been summarised in a paper that is currently in the second round of reviews in the journal *Science of the Total Environment*.

The third chapter, which is also currently underway, moves towards the application of the refined WEFE indicators developed in the previous chapter. Leveraging modelling approaches such as the Soil and Water Assessment Toil (SWAT+) and Ecopath with Ecosim (EwE), this phase aims to explore WEFE nexus hotspots within the UWN basin. Hydrological model SWAT+ outputs will feed into ecological model EwE, enabling an analysis of the interactions between water, energy, food, and environmental resources supporting the identification of areas where trade-offs are most pronounced. This application not only underscores the importance of stakeholder involvement in model application, but also lays the groundwork for future steps in implementing Nature-based Solutions (NbS) to mitigate WEFE nexus trade-offs.

Looking ahead, the fourth chapter will focus on implementing NbS into the coupled models to explore future changes in the WEFE nexus under climate change scenarios. Partnering with The Nature Conservancy (TNC) and utilising the SWAT+ and EwE modelling framework, this chapter seeks to advance the understanding of the impact of NbS on the WEFE nexus, particularly within the context of the UWN in East Africa. This chapter will not only involve the integration of NbS into modelling frameworks, but also stakeholder engagement to ensure the relevance and applicability of proposed NbS interventions. By incorporating local knowledge into the development and implementation of NbS, the project aims to generate actionable insights that contribute to building resilience and sustainability in the region.

In addition to research activities, I have actively participated in conferences, workshops, summer schools, and outreach activities to disseminate findings, engage with researchers and policymakers, and foster collaboration. Notable events include presenting research at the Nile Basin Initiative 7th Development forum, International Conference on Water, Energy, Food and Sustainability, UNESCO International Conference on Climate Risk, Vulnerability and Resilience Building, and the European Geosciences Union conference, among others. Through poster presentations, oral presentations, and networking opportunities at these events, I have shared research outcomes, exchanged ideas, and built networks with researchers and stakeholders across diverse sectors. These engagements play a crucial role in expanding the reach and impact of the project, facilitating knowledge exchange, and contributing to the broader discourse on sustainable development and climate change adaptation in East Africa.

ESR 15

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ESR 15: Adaptation measures based on smart nutrient management at the catchment scale for future-proof water quality

I am Floran Clopin, currently pursuing my PhD project titled "Adaptation measures based on smart nutrient management at the catchment scale for future-proof water quality" at Wageningen University and Research (WUR) in the Netherlands. My educational background in Biodiversity Conservation and Restoration, along with Management and Restoration of Nature, led me to embark on this journey in Water Management with this PhD.

Commencing on October 1, 2021, my research focuses on developing modelling tools to assess and understand nutrient dynamics and pollution at a catchment scale, intending to enhance the water quality management of lakes and reservoirs. Initially, my project was emphasized around a catchment study case in Ukraine, utilizing the MARINA and PCLake models. However, due to geopolitical circumstances, I redirected my focus to the Rappbode Reservoir System in collaboration with the Helmholtz Centre for Environmental Research (UFZ) in Magdeburg.

During my first year, I dedicated time to refining my proposal and enhancing my skills through courses offered at WUR and training sessions organized by InventWater. These covered a range of topics, including Research Data Management, Systematic Literature Review, Scientific Writing, and Water Quality Modelling. With inventWater, I participated in other training courses such as Big Data for Water Quality Management in Ireland and Modelling Water Quality under Global Change in Belgium. Additionally, I actively participated in international conferences such as SIL 2022 to expand my network and deepen my understanding of limnology.

In the second year of my PhD, my focus shifted to conducting a systematic literature review on integrated models for nutrient flows and lake ecological status worldwide. The goals of this paper are (1) to identify the attributes of current watershed models applied for the assessment of nutrient sources, flows, and loads; (2) to identify the attributes of current lake models applied for the assessment of water quality in lakes and reservoir; (3) to delineate the various configurations of model integration existing between watershed and lake/reservoir models and finally (4) to develop a decision support system aimed at guiding future modellers or researcher in the selection of appropriate models adapted to their specific research inquiries. Furthermore, this paper will be used for my project to select a suitable watershed model more adapted to my study case (Rappbode Reservoir). In addition to this research project, I participated in courses with WUR and inventWater such as Time and Project Management and Managing Water in complex anthropogenic landscapes (Germany). I performed my first secondment in NIOO (the Netherlands) where I started to work on my lake model, developed my network with new scientists, and continued to work on my first paper.

Finally, I went to two conferences: the Association for the Sciences of Limnology and Oceanography (ASLO) and the Global Lake Ecological Observatory Network (GLEON) where I again developed my network and knowledge. GLEON was for me, a very good opportunity to meet and collaborate with early-stage researchers working together on this systematic review.

As I enter the third year of my PhD, my primary goal is to finalize the review paper for submission to a journal by mid-March and to plan my secondment with the research institution of Blanes (CEAB) from mid-March to the end of June. I had the opportunity to participate in another inventWater training, focusing on Entrepreneurship, Pitching, and Media Interactions in Denmark.

Despite facing personal and professional challenges along the way, I remain committed to honing my skills and completing my PhD, by the end of 2025. Participating in the ITN project with InventWater has been an enriching experience, allowing me to collaborate with fellow researchers and build a strong network for advancing water quality management.

Floran Clopin

Annex 1: Sabin Taranu (ESR4) project, inventWater
Secondment Agreement between VUB and Climate Analytics

(Upon request, it's a confidential document)

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