Project Title	**Environmental Digital Twins for Sustainable Water Management**
University (where student will register)	University of Warwick
Which institution will the student be based at?	As above
Theme (Max. 2 selections)	Climate & Environmental Sustainability ☒ Organisms & Ecosystems ☒ Dynamic Earth ☐
Please explain how the project fits within the NERC remit	This project strongly aligns with the ***NERC Digital Strategy 2021-2030***. The vision of the proposed project is to create a robust frameworks and models for using data and digital technologies for environmental modelling and sustainable catchment management. We will capitalise upon the transformative potential of data and digital technologies, to make a step-change in design, operation, and maintenance of nature-based solutions for water and wastewater processing/treatment via development of Digital Twins (DTs). This project is also complimenting the recent ***IMFe report*** by ***NERC*** where the significance of developing DTs for environmental sciences was highlighted. Here, we aim to design a framework and develop the necessary tools for a digital twin model for natural capital water treatment assets. The project outcomes will facilitate effective adoption of nature-based solutions for water treatment and transitioning towards ***Net Zero*** targets for the Water Industry.
Supervisory team (including institution & email address	**PI: Dr Soroush Abolfathi** **Co-I: -Dr Sina Borzooei, Swedish Environmental Research Institute (external advisor)**

Project Highlights:

1. This project will develop digital twins for constructed wetlands (CWs) to model and assess the impacts of changing climate, hydrology, and biodiversity fluctuations on the overall performance and pollution removal efficiency of CWs.
2. Data assimilation and model integration techniques will be used to incorporate existing field-based data sets, CFD models, machine learning, and remote sensing data in DTs, and facilitate robust design, operation, and maintenance of CWs to enhance water quality and biodiversity.
3. Project outcomes aim to provide evidence and tools to inform policy development on sustainable water management and environmental monitoring, facilitate enhancing adoption of nature-based solutions for water treatment.

Overview (including 1 high quality image or figure):

The development of digital twins for the natural environment represents a crucial frontier in modern environmental science and sustainability efforts. These digital replicas, mirroring complex ecosystems, landscapes, and natural resources, offer transformative potential for understanding, managing, and preserving our planet's delicate ecosystems. Digital twins enable a comprehensive, real-time monitoring and modelling of natural systems, providing invaluable insights into dynamic processes like climate change, hydrology, and biodiversity fluctuations. By integrating data from various sources, such as satellite imagery, remote sensing, computational models, and environmental sensors, digital twins facilitate a holistic view of ecosystems, offering the ability to make informed decisions for conservation, pollution control, and water resource management. Digital twins empower proactive and efficient management by enabling scenario testing and forecasting, facilitating simulating the impact of various environmental stressors, human interventions, or climate change scenarios on ecosystems, which is vital for devising effective mitigation strategies and adapting to future challenges. Moreover, these digital tools can also enhance public engagement and awareness by visualizing complex environmental phenomena in an accessible manner, fostering a sense of shared responsibility for safeguarding our natural environments.

However, there exists a significant research gap in the field of digital twins for the natural environment. Development of high-fidelity digital twins for entire ecosystems remains a formidable task, as it demands a delicate balance between data accuracy and computational complexity. Current models often struggle to capture the full complexity of natural systems, including the intricate interactions between species, landforms, and environmental variables. Bridging this gap requires breakthroughs in data collection, machine learning, and computational modeling to create more accurate and responsive digital twins.

This project will develop digital twins for an integrated constructed wetlands to enhance its design and performance efficiency and facilitate informed decisions for conservation and resource management. The proposed DTs will be piloted for the UK flagship constructed wetland site located in Norfolk, where we have already established a living lab and collecting environmental, pollution, and climatic data. This project will integrate the data from our living lab, remote sensors, and numerical models to provide detailed information on the performance of CWs and inform optimal design, operation, and maintenance protocols for CWs. This project will provide crucial digital tools and data to help the UK Water Industry to transitioning towards Net Zero by facilitating wider and more reliable adoption of nature-based solutions.

Methodology:

This project will design and pilot digital twins of integrated CWs systems, providing invaluable insights into effects of dynamic processes such as climate change, hydrology, and biodiversity fluctuations on CWs performance. Design of DT involves multi-step process that combines data acquisition, modeling, and validation to create a comprehensive representation of the hydrological and environmental characteristics of CWs' catchment. By integrating data from various sources, including satellite imagery, remote sensors, and field-based environmental monitoring, this project will establish DTs of CWs to facilitate a holistic view of the performance of CWs in improving water quality and removing pollution. We will quantify the impacts of climate and land use on the case study CWs by adopting well-established SWAT model. CFD tools will be used to understand the effects of design and operational configurations. Advanced machine learning models will be used to derive predictive tools for environmental monitoring datasets.

Training and skills:

Students will be awarded CENTA2 Training Credits (CTCs) for participation in CENTA2-provided and 'free choice' external training. One CTC equates to 1⁄2 day session and students must accrue 100 CTCs across the three years of their PhD.

This research project provides comprehensive training in environmental science and computational modeling disciplines, covering topics such as environmental modeling, pollution transport and water quality modelling, advanced data science and predictive modeling, remote sensing, and field-based data collection. The successful applicant will gain practical experience by field-based survey of CWs, using advanced drone-based remote sensing and digital mapping technique. Training on analysis and modeling of large datasets will be provided to facilitate developing robust data collection and sharing protocols for developing agile DT for CWs.

Partners and collaboration (including CASE):
Further information on partners and collaboration (including CASE):

Possible timeline:

Year 1: will concentrate on setting up simulation and predictive tools for modeling the effects of climatic, hydrological, and environmental factors on the case study catchment in Norfolk. Well-established modeling tools such as SWAT model will be used to understand the effects of changing climate and anthropogenic activities on the catchment hydrology, and process-based numerical tools will be adopted for modelling the performance of the case study CWs in Norfolk.

Year 2: the project will progress to integrate simulation and predictive tools with real data generated from our living laboratory established for monitoring the UK flagship CWs in Norfolk. Digital twins of the CW will be generated based on field surveys, remote sensors, and models.

Year 3: the project will focus on scenario simulations to aid establishing robust data and evidence for optimised design, operation, and maintenance of CWs in changing climate and environmental conditions.

Further reading:

Blair, G., (2021). Digital twins of the natural environment. Patterns. Volume 2, Issue 10, 100359.

Siddorn, J., Blair, G., (2022). An Information Management Framework for Environmental Digital Twins (IMFe).

Lai, T., (2023). Digital cities: connected technology, connecting ecosystems. Volume 3, Ed. 2. AECOM https://digital.aecom.com/article/digital-cities-connected-technology-connecting-ecosystems

Mahdian, M., et al. (2023). Modelling impacts of climate change and anthropogenic activities on inflows and sediment loads of wetlands: case study of the Anzali wetland. Scientific Reports. Volume 13, 5399.

Further details:

Please add project/institutional contact details including a link to the application website if applicable

For informal inquiries about this project, you can email Dr Abolfathi (Soroush.Abolfathi@Warwick.ac.uk).