PHOTO: ADOBE STOCK

Digital Twins in Water and Lake management
数字孪生在水和湖泊管理中的应用

Noora Veijalainen, Leading hydrologist
努拉·韦亚莱宁，首席水文学家
noora.veijalainen@syke.fi
Marie Korppoo, Maiju Narikka
玛丽·科尔普奥，迈尤·纳里卡

Suomen ympäristökeskus
Finlands miljöcentral
Finnish Environment Institute
芬兰环境研究所

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Introduction
引言

- Challenges of water resources management require new solutions
  水资源管理面临多重挑战，亟需创新解决方案
- Flood,droughts, pollution and nutrient loading among the key issues
  洪水、干旱、污染与营养盐负荷等已成为关键议题
- Lake management includes specific challenges
  湖泊管理存在其特殊难点
- New digital solutions, including Digital Twins can be used to improve the management of water resources
  包括数字孪生在内的新兴数字化手段，可有效提升水资源管理水平
- Finnish Environment Institute(Syke) and Digital Waters Flagship(DIWA) project are working with Digital Twins in water resources
  芬兰环境研究所（Syke）与数字水域旗舰计划（DIWA）正致力于数字孪生技术在水资源领域的应用
- Cooperation with Europe and China
  持续开展与欧洲及中国的合作交流

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Digital-twin components
数字孪生构成要素

Physical twin
物理实体

River basin
流域

Observation
观察

Application
应用

Infrastructure
基础设施

Data
数据

Modelling
建模

Services
服务

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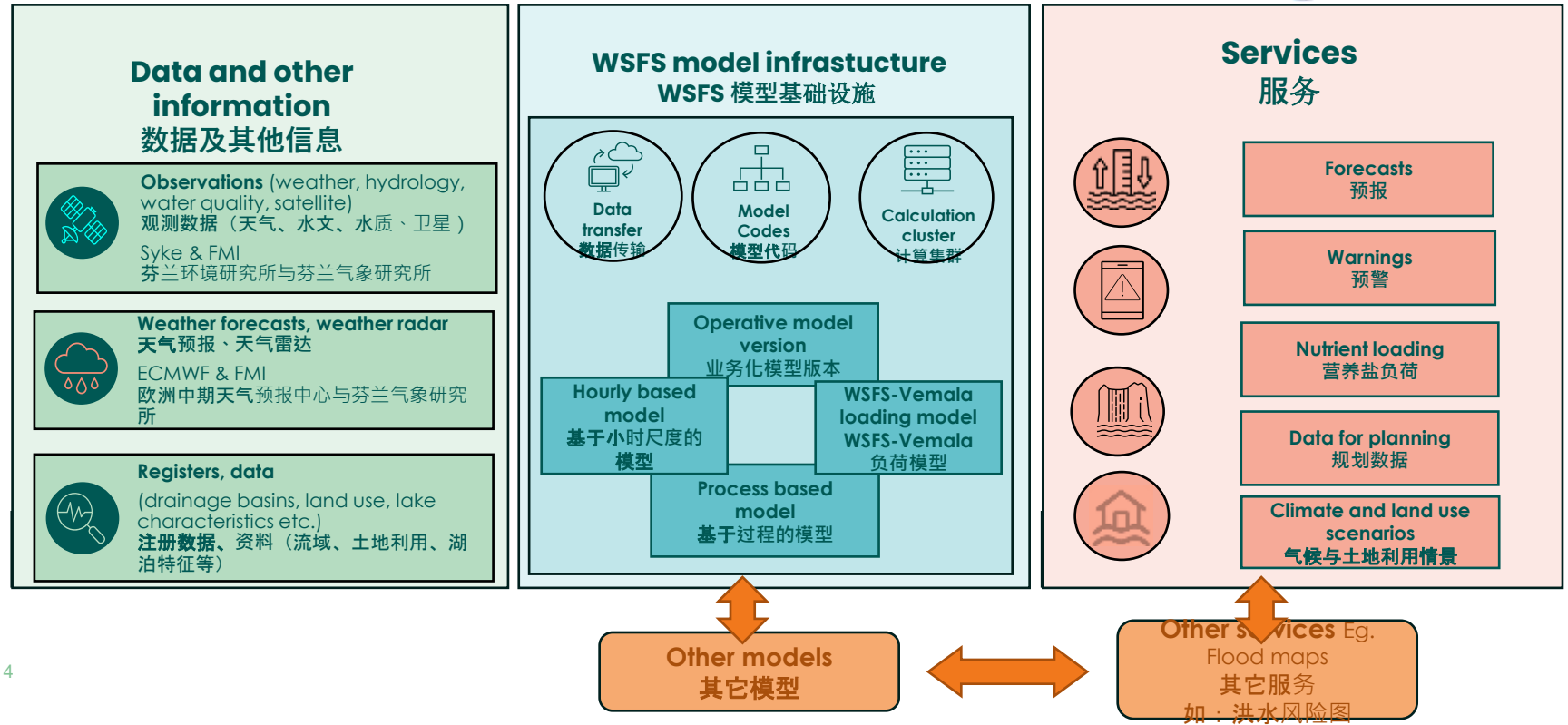
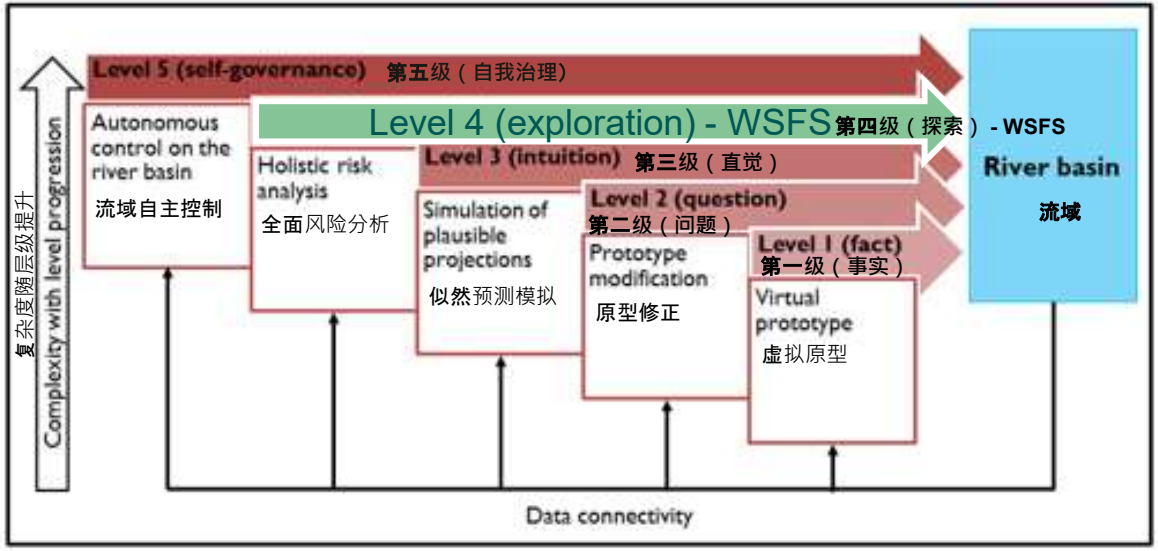
Digital twin: Watershed simulation and forecasting system WSFS in Finland
数字孪生：芬兰流域模拟与预报系统（WSFS）

FLOOD CENTRE



A schematic representation illustrating the progression of the digital twin's maturity level.
数字孪生成熟度水平进展示意图



Hydrology Research
水文学研究

流域数字孪生的蓝图概念化
Blueprint conceptualization for a river basin's digital twin

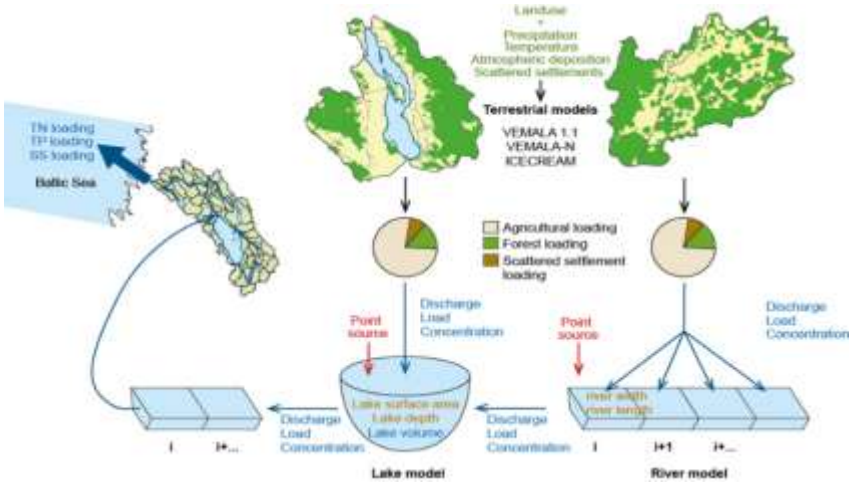
WSFS-Vemala
WSFS-Vemala 模型系统

Water quality and nutrient load model system for Finnish watersheds
用于芬兰流域的水质与营养盐负荷模型系统

- WSFS-Vemala is **part of Syke's Watershed simulation and forecasting system (WSFS)**
  WSFS-Vemala 是**芬兰环境研究所流域模拟与预报系统（WSFS）的一部分**
- Covers **entire Finland** with a **daily time-step**
  以日时间步长覆盖芬兰全境
- Nutrient loads simulated for over **200 000 sub-catchments**
  模拟超过**20万个子汇水区**的营养盐负荷
- Simulates water quality and quantity:
  模拟水质与水量指标：
  - Discharges, water levels, snow, soil moisture
    流量、水位、积雪、土壤湿度
  - Simulation of loading from various sources
    模拟不同来源的负荷输入
  - Nutrient processes, leaching and transport on land and in rivers and lakes
    涵盖营养盐过程及其在陆地、河流与湖泊中的淋溶与输移

WSFS-Vemala model scheme

WSFS-Vemala 模型架构



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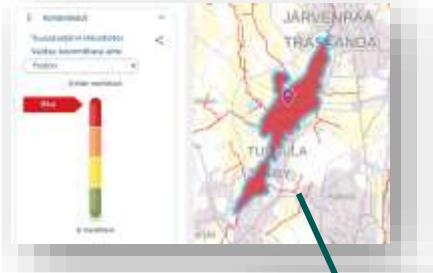
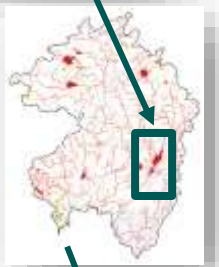
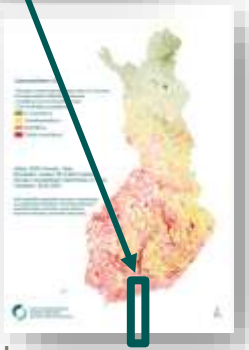
WSFS-Vemala results
WSFS-Vemala 成果应用







Lake or river level
湖泊或河流尺度

→ The magnitude of the nutrient load?
营养盐负荷量级如何？

→ The lake is affected by pressures, i.e. where does the load come from?
湖泊受哪些压力源影响，即负荷来源何处？

→ How do the amount of water and load vary on different time scales?
水量与负荷在不同时间尺度上如何变化？

Catchment area level
汇水区尺度

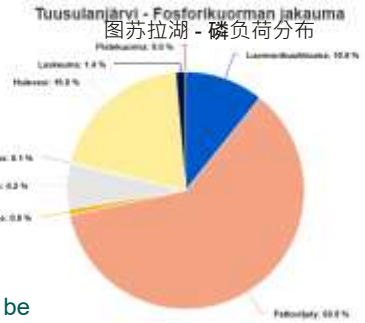
→ Catchment area planning, targeting measures to the area above
支持汇水区规划，针对性实施上游治理措施

→ Permitting, the impact of a new operator on downstream water bodies
用于审批评估，分析新项目对下游水体的潜在影响

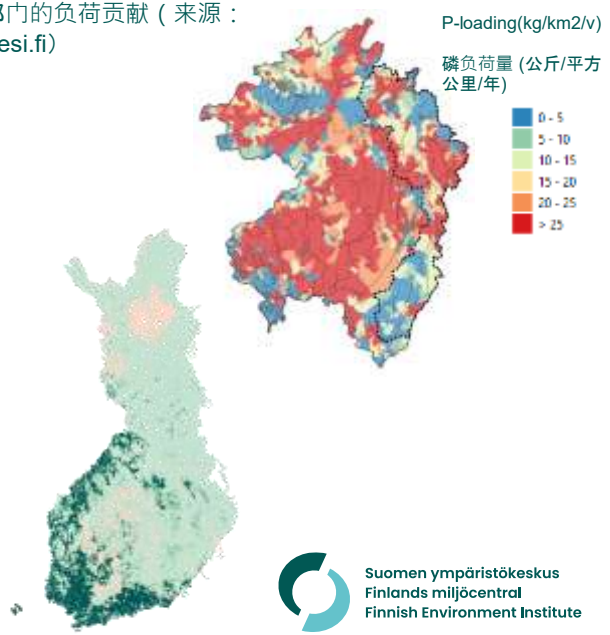
National level
国家尺度

→ Effectiveness of water management at the national level and improvement of the status of waters
评估国家层面水管理措施成效，推动水环境质量提升

→ FICOS, Land-Based Load, is a key input for marine modelling
陆源负荷系统（FICOS）**是海洋建模的关**键输入数据**来源**



Lake-specific load, different sectors can be specified (Source: Vesi.fi)
可针对特定湖泊解析不同**部**门的负荷贡献（来源：Vesi.fi）



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WSFS-Vemala use case example
WSFS-Vemala 应用案例

Sources of phosphorus load, current state
Vantaanjoki cathcment

Vantaanjoki 汇水区磷负荷来源现状分析

Phosphorus load from different sources relative to natural loading (%)

不同来源磷负荷相对于自然背景负荷的百分比（%）

Not significant	影响不显著
To be monitored	需持续监测
Significant	影响显著
Very significant	影响非常显著

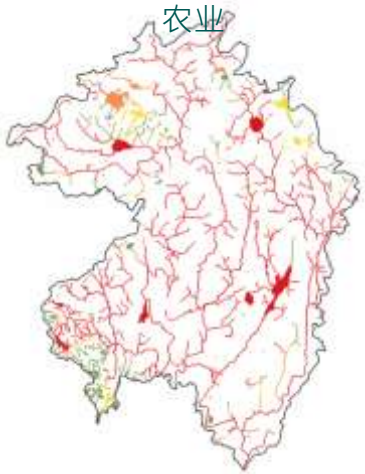
→ Identification of areas with largest loading
识别负荷最高的区域

→ Identification of sources of loading
解析负荷主要来源

→ Next step: Targeting water management measures to most relevant sectors and areas
下一步：针对关键部门和区域制定精准水管理措施

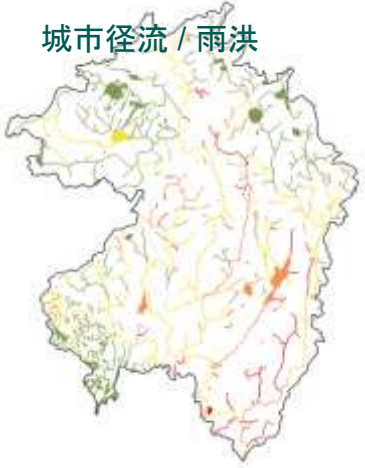
Source: WSFS-Vemala/Syke, 1/2024
数据来源：WSFS-Vemala / 芬兰环境研究所，2024年1月

Farming
农业

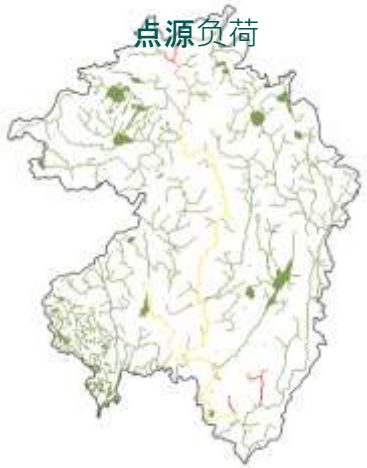


Forestry
林业

Urban runoff/ strom water
城市径流 / 雨洪

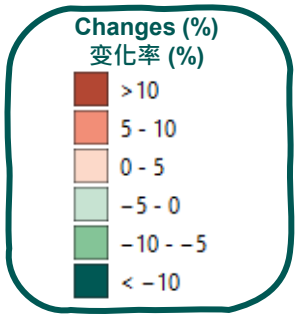


Point loading
点源负荷



Scenario examples: impact of actions and climate change
情景模拟示例：措施与气候变化的影响

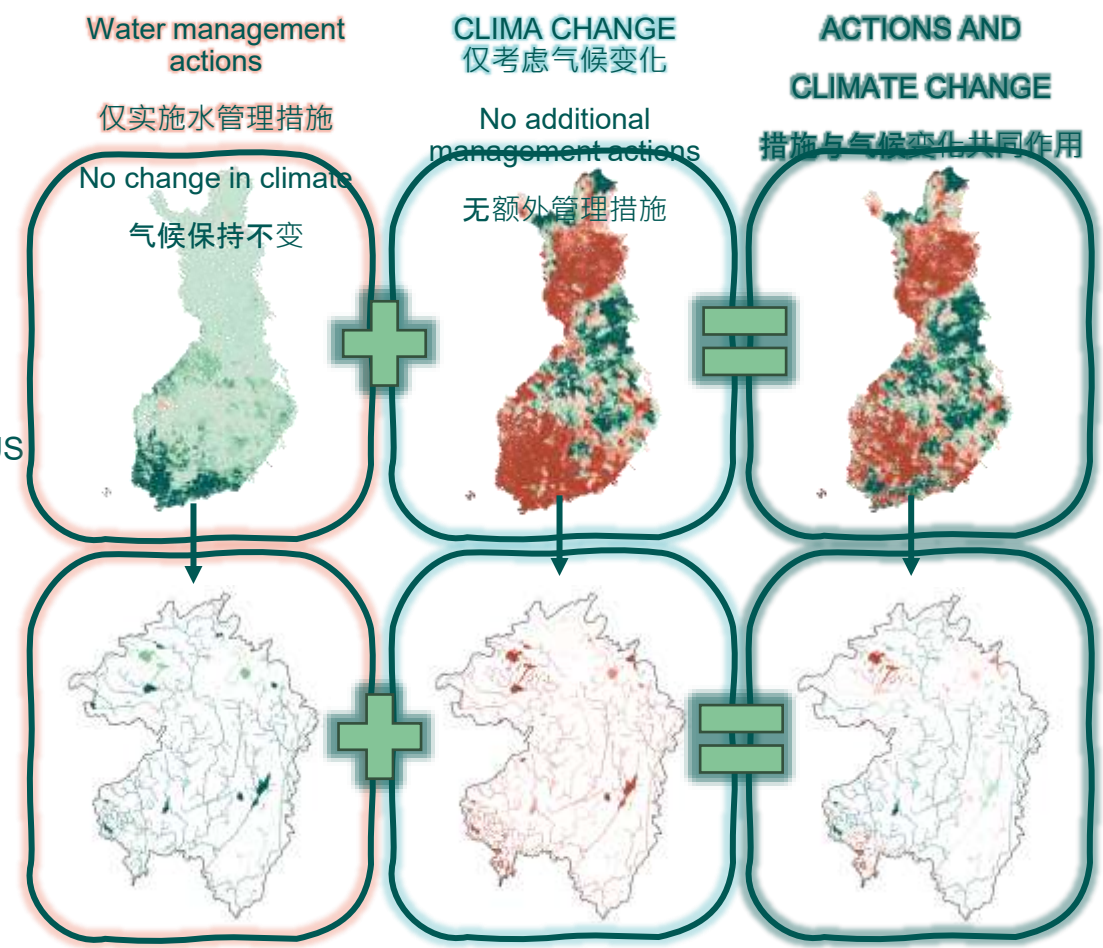
Example Vantaanjoki catchment
以 Vantaanjoki 汇水区为例



PHOSPHORUS

Total load

磷 – 总负荷



- → **Water management actions**: Management actions reduce loading
  水管理措施：实施措施可降低负荷
- → **Climate change without actions:** Increase in loading in most catchments
  无措施下的气候变化：多数汇水区负荷将上升
- → **Water management actions and climate change**: Several areas with increased loading (red) remain despite the actions
  水管理措施与气候变化叠加：部分区域（红色）即使采取措施负荷仍将增加

Source: WSFS-Vemala/Syke, 9/2024

数据来源：WSFS-Vemala / 芬兰环境研究所，2024年9月

→ NOTE! EXAMPLE WITH ONE CLIMATE SCENARIO. Uncertainty in climate change impacts remains high
注：本例基于单一气候情景。气候变化影响仍存在较大不确定性。

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Future developments towards full Digital Twin
迈向全面数字孪生的未来发展方向

- Modernisation of the model infrastructure
  推进模型基础设施现代化
- Development of visualisation tools and more interactive user interface for river and lake management
  开发河湖管理可视化工具与交互式用户界面
- Improvement in data sharing through APIs
  通过API提升数据共享能力
- Improvements in process models
  优化过程模型精度
- Integration of new data sources, e.g., satellites
  融合卫星等新型数据源
- Improvements of uncertainty estimations
  完善不确定性评估体系
- Increased automation and integration of AI methods
  加强自动化并融合人工智能方法
- Possible cooperation with China, Taihu Basin Authority on lake management with digital twins
  探索与中国太湖流域管理局就湖泊数字孪生管理开展合作

Summary
结语

- Digital twins integrate data, models, and services to provide a virtual representation of the water system
  数字孪生融合数据、模型与服务，构建水系统虚拟映射
  - aim to improve water management and security
    旨在提升水资源管理与安全保障水平
- WSFS, WSFS-Vemala models are national hydrological and nutrient loading models
  WSFS与WSFS-Vemala模型是国家层面的水文与营养盐负荷模型
  - Used for water and lake management, forecasting, operational planning, and research
    服务于河湖管理、预报预警、业务规划与科学研究
  - They fulfill most of the attributes of the digital twin concept
    已具备数字孪生概念的核心特征
  - Operating at multiple scales
    支持多尺度协同应用
  - Work is ongoing to improve the models and their usability
    持续优化模型性能与实用性

Contact information:
联系方式：
noora.veijalainen@syke.fi (WSFS and DIWA)

syke.fi/water
https://www.syke.fi/en/projects/diwa

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Finnish Environment Institute

Thank you!
谢谢您！

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