# AI driven Digital Twin for Water Management for Limpopo River Basin and Inclusive Integration with Citizen Science

IWMI

**Gaborone, Botswana**
**9–11 June 2025**

## Online Agenda

bit.ly/4jVtXgR

REPUBLIC OF BOTSWANA

LIMCOM
LIMPOPO WATERCOURSE COMMISSION

DIWASA

Supported by

CGIAR DIGITAL TRANSFORMATION

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In collaboration with

aws

Digital Earth AFRICA

Global Water Partnership Southern Africa

Microsoft

## Day 1

LIMPOPO
DIGITAL TWIN

### Digital Twin Hands on

Listening Session for Data Challenges

Digital Twin Concept

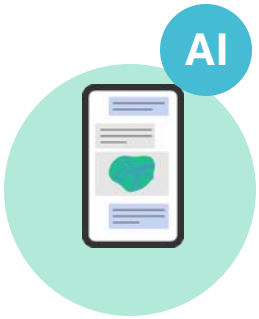
**Hands on:**

Water Availability

Irrigation Water Use

Droughts Index

## Day 2




### AI for Water Management

AI and Data Governance

101 generative AI

Prompt engineering

**Hands On:**

Limpopo

Water Copilot

## Day 3


### Citizen Science Co-designs

Creating trust on citizen science data

### Listening Session

Stakeholder consultation scaling opportunities


### DIWASA Training

Use cases from DEA

Tentative_schedule.docx

IWMI International Water Management Institute

# Digital Innovations for Water Secure Africa (DIWASA)

The project aims to enhance water security across scales in Africa through improved water data availability, accessibility, and institutional capacity and to leverage on innovative digital techniques for sustainable water resources management. It is structured as four pillars with user engagement and capacity development (Pillar 2) taking the bulk of the project budget. Within Pillar 1, the data products and tools developed under Phase I will be further enhanced and, more importantly, user application cases (use cases) developed together with end users.

Pillar 2 will involve activities that will help integrate the data layers and products into DEA and other ODC platforms. A fully dedicated Pillar 3 is included in the project to strengthen the integration of the datasets and tools in the Digital Earth Africa platform. Under Pillar 4, the prototype of river basin Digital Twin (for the Limpopo basin) will be developed to demonstrate the use of advanced technology in water resources decision-making.

https://www.iwmi.org/projects/diwasa/

February 2024 to January 2027

Active

**Locations**

Africa > Burkina Faso, Ghana, Kenya, Mozambique, South Africa, Uganda, Zambia, Zimbabwe

**Funders**

Helmsley Charitable Trust

**Partners**

Digital Earth Africa

**Project leader**

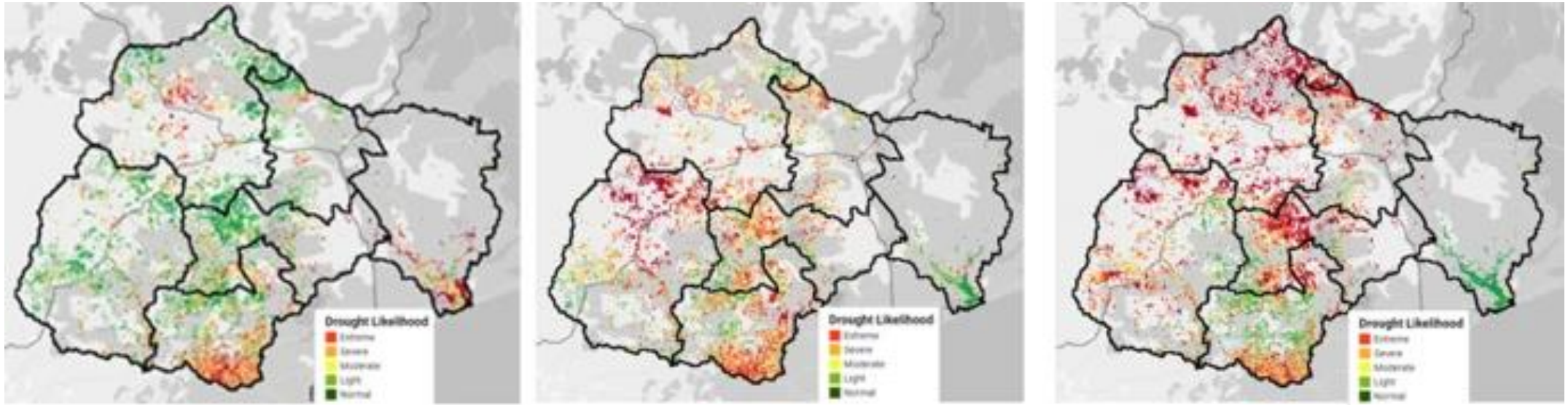
Abdulkarim Seid

**Team**

Mariangel Garcia Andarcia

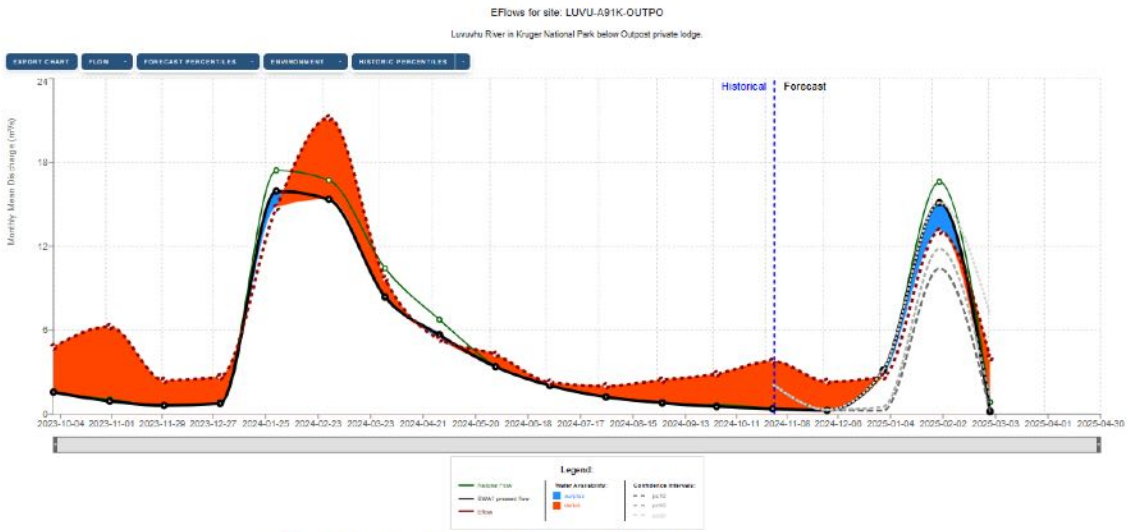
# Recent drought dynamics in the Limpopo River Basin


# Recent drought dynamics in the Limpopo River Basin



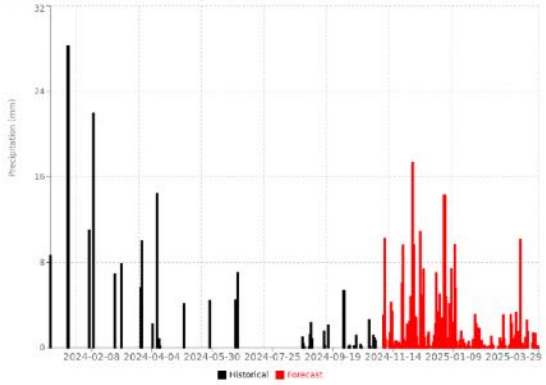

VCI of April 2022, 2023, and 2024 (left to right) for the Limpopo River Basin shows continued deterioration in vegetation conditions

# Analyzing Luvuvo River

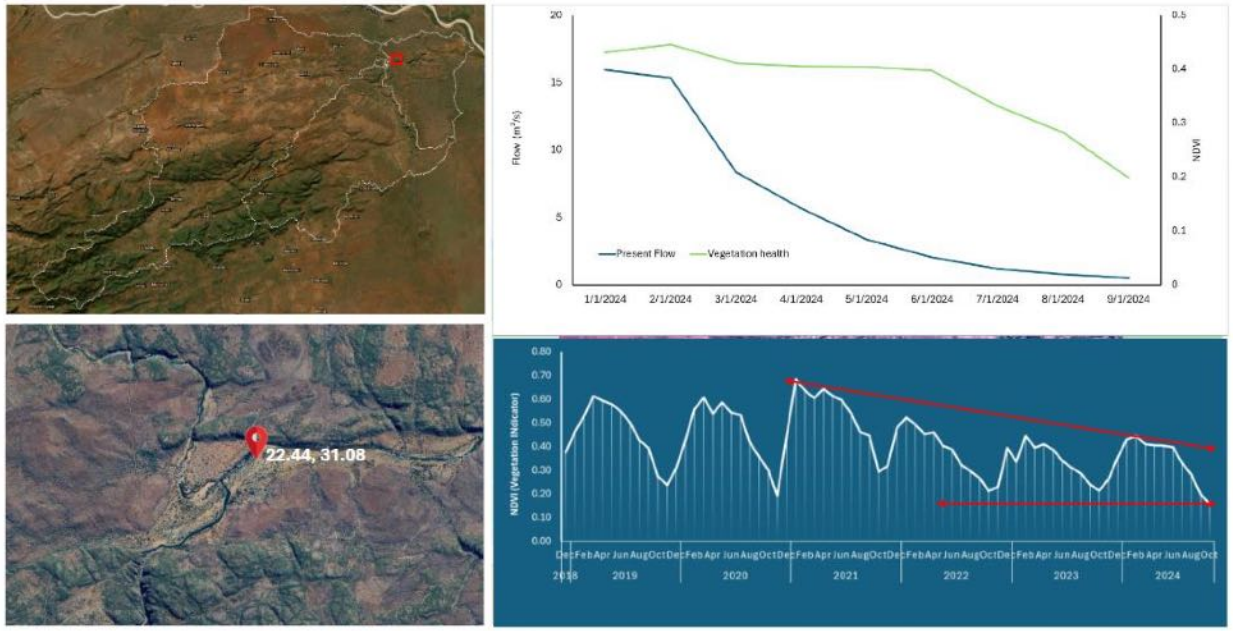



Assistant: ### Rainfall Data for Luvuvhu River (Station: s22605s30573e, Channel ID: cha0578)

Historical and Forecast Data from January 2024 to March 2025:




This chart includes both the historical rainfall data for the year 2024 and the forecast data up to March 2025 for the Luvuvhu River.




Data source: Limpopo Digital Twin, Sentinel-2 and ArcGIS Basemap



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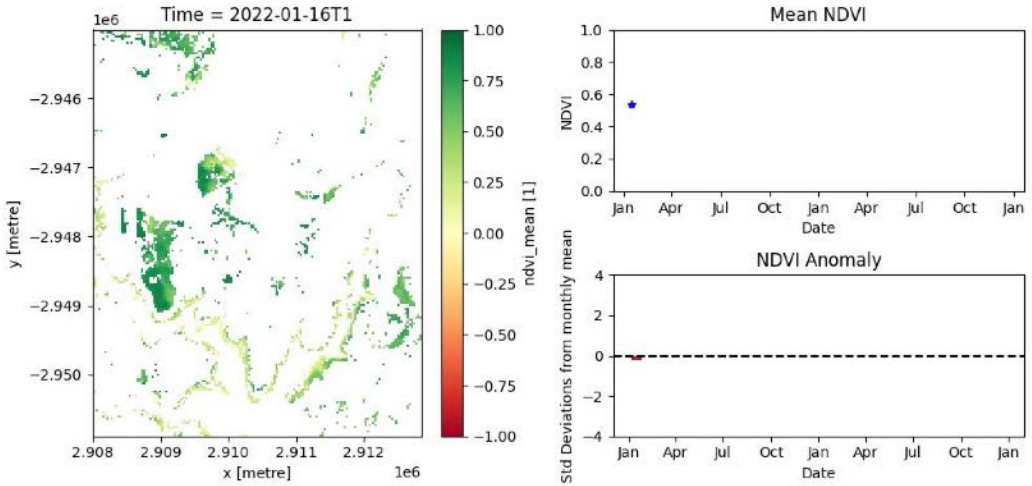
# DEA – Use Cases Hands on!



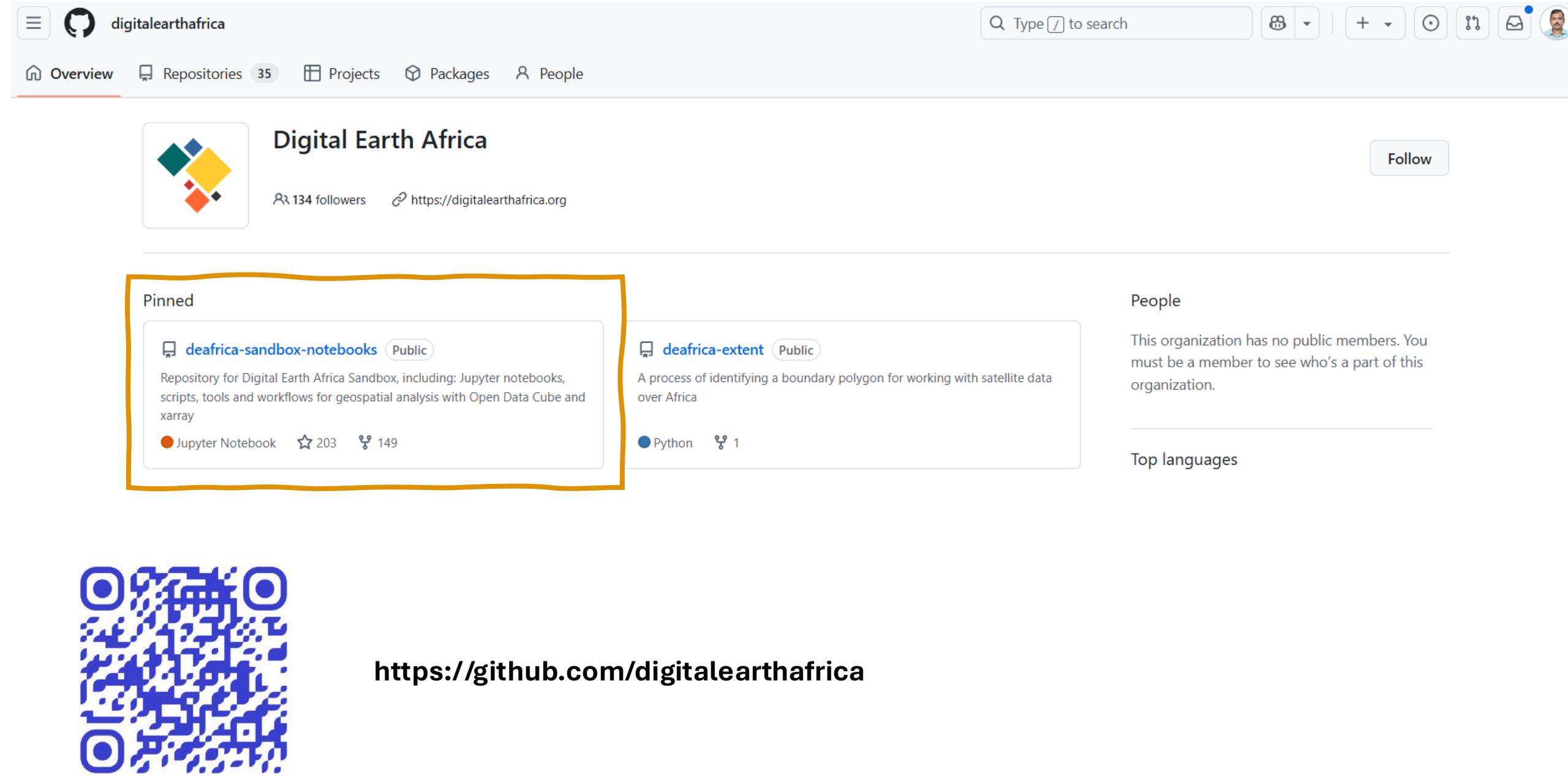

Identification of use cases

Notebook development

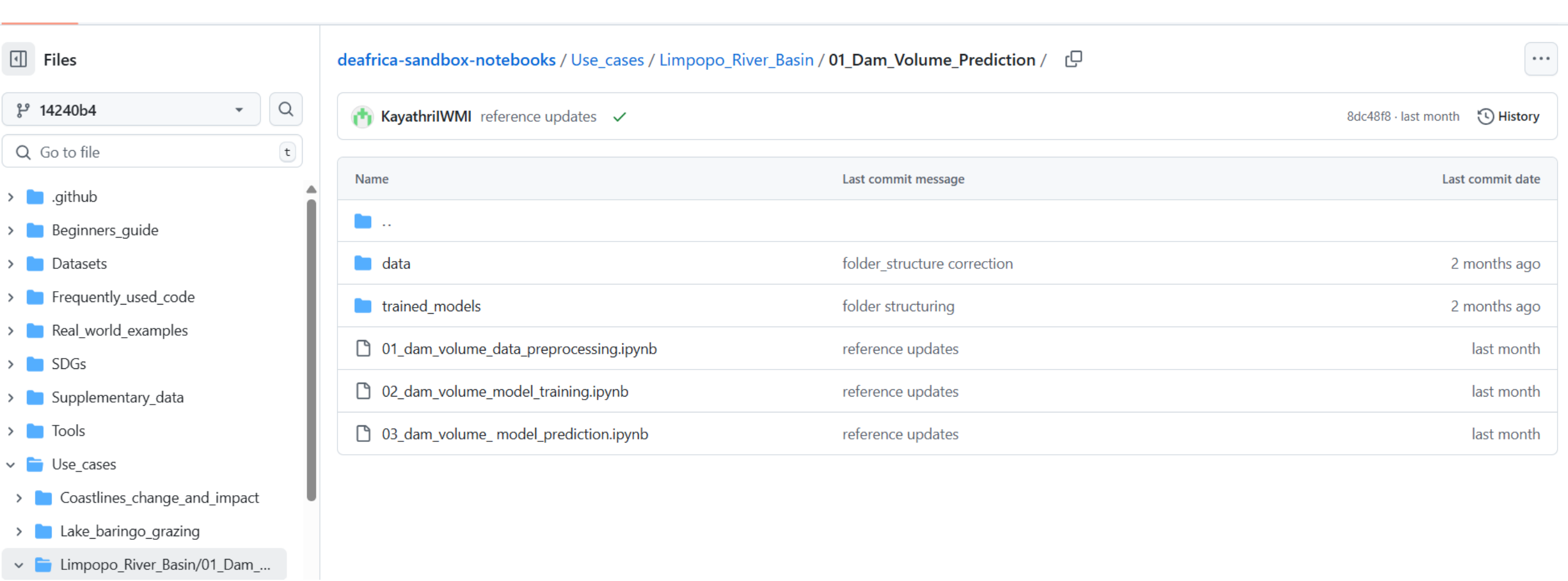
Collaboration and consultation

Validation and verification of the results

Sandbox deployment




**https://github.com/digitalearthafrica**




https://bit.ly/43Aowif

Link

# Overview

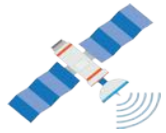
| Module | Objective | Data Used | Method | Key Output | Application |
|---|---|---|---|---|---|
| **1. Dam Volume Estimation** | Prediction of dam Volume using EO data & ML | DE Africa Waterbodies (surface area) | Gradient Boosting ML model | Predicted dam volume($m^3$), Wet Surface Area Time Series | Reservoir management, drought early warning, storage monitoring |
| **2. Irrigation Water Use Tracking** | Assess water use in irrigated farmlands | Irrigated area mask (binary raster), WaPOR AETI-M data (evapotranspiration) | Spatial overlay in Jupyter Notebook | Irrigation water use ($m^3$) by region/date, irrigation footprint (ha) | Agricultural water accounting, Seasonal monitoring |
| **3. Water Availability Estimation** | Water stress in river channels using SWAT & EO data | SWAT flow output + NDVI + rainfall | Time-series & map overlays | Flow forecasts, rainfall/NDVI insights | Basin-wide planning, Digital Twins, Climate risk analysis |

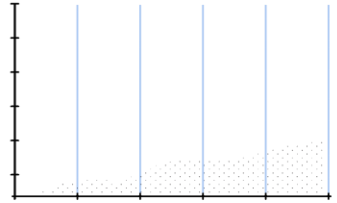
# Use Case I – Predicting Dam Volume

**IMPORTANCE**

- **Water Management Efficiency:** Accurate dam volume estimation supports the **efficient allocation of water** for agricultural, industrial, and domestic needs It ensures water is used sustainably and **reduces conflicts between sectors** during periods of scarcity (Fuentes et al., 2021).
- **Disaster Risk Mitigation: Helps mitigate disasters such as floods** and **droughts**. During heavy rainfall, it enables **timely reservoir release** to prevent overflow and downstream flooding. During dry periods, it aids **in drought preparedness by forecasting declining water availability and enabling early interventions (**Enayati et al., 2024).
- **Ecosystem and Environmental Flow Management: Predicting water volumes helps ensure that** environmental flow requirements are **maintained to support aquatic ecosystems**. This helps in **conserving biodiversity, maintaining river health, and avoiding the negative impacts** of abrupt flow alterations(Kumar &Jayakumar,2021 ).

# Workflow Overview





Dam Volume Prediction

Secondary Data

EO-based information

DoWAS, South Africa

Digital Earth Africa

Dam volume

Water area

Observed water levels

Data Cleaning and Preprocessing

Gradient Boosting

Model Evaluation & Diagnostics

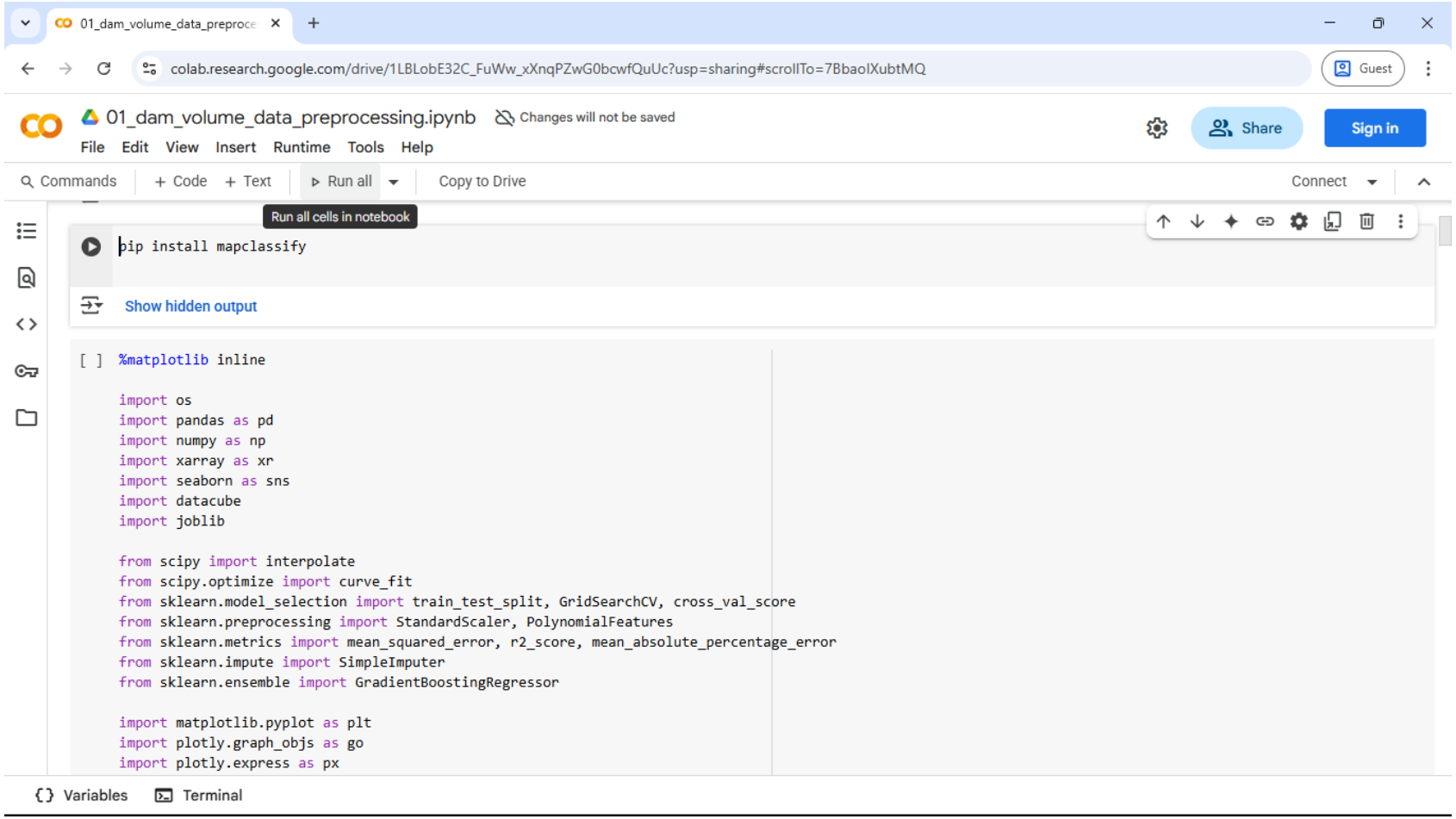
Predicted Dam Volume Time Series ($m^3$)

# Steps to Use Google Collab

1. Go to by this link https://colab.research.google.com/
2. **Sign in** with your Google account
3. Click "**New Notebook**"
4. Change runtime type (optional)
5. Write and run Python code in cells
6. Install required packages using **!pip** install
7. Upload files using **files.upload()** or mount Google Drive
8. Import the necessary Python libraries
9. **Save** the notebook to Google Drive or download it


# Google Colab

Open the **Google Colab notebook** and run all cells



# Data Flow

**Colab Notebook**
*01_dam_volume_data_preprocessing*

- **Downloaded CSV**
  - preprocess_data.csv

**Colab Notebook**
*02_dam_volume_data_training*

- **Uploaded CSV**
  - preprocess_data.csv
- **Downloaded CSVs**
  - prediction_data.csv
  - test_data.csv

**Colab Notebook**
*03_dam_volume_data_prediction*

- **Uploaded CSVs**
  - preprocess_data.csv
  - prediction_data.csv
  - test_data.csv

# Use Case II – Monitoring Irrigation Water

**IMPORTANCE**

- **Water Resource Planning and Management**: Mapping irrigated areas helps **estimate agricultural water demand**, which is essential for **efficient allocation of irrigation water** from sources like dams, canals, and groundwater(Abd-Elaty et al., 2024).
- **Agricultural Productivity Monitoring:** By mapping irrigated lands, **monitoring crop performance, assessing yield potential, and identifying areas of low productivity** can be done. This supports the design of targeted interventions to **improve food security and agricultural resilience** (Abiri et al.,2024).
- **Drought Impact Assessment:** Accurate maps of irrigated areas allow for assessing the **vulnerability of agricultural zones to climate extremes**, such as droughts and heatwaves. This enables **better adaptation strategies and climate-resilient planning in agriculture**(Ambika et al.,2016).

# Overview

**Inputs**

- Irrigated farmland maps
- Water use data (WaPOR AETI-M)

**Method Steps**

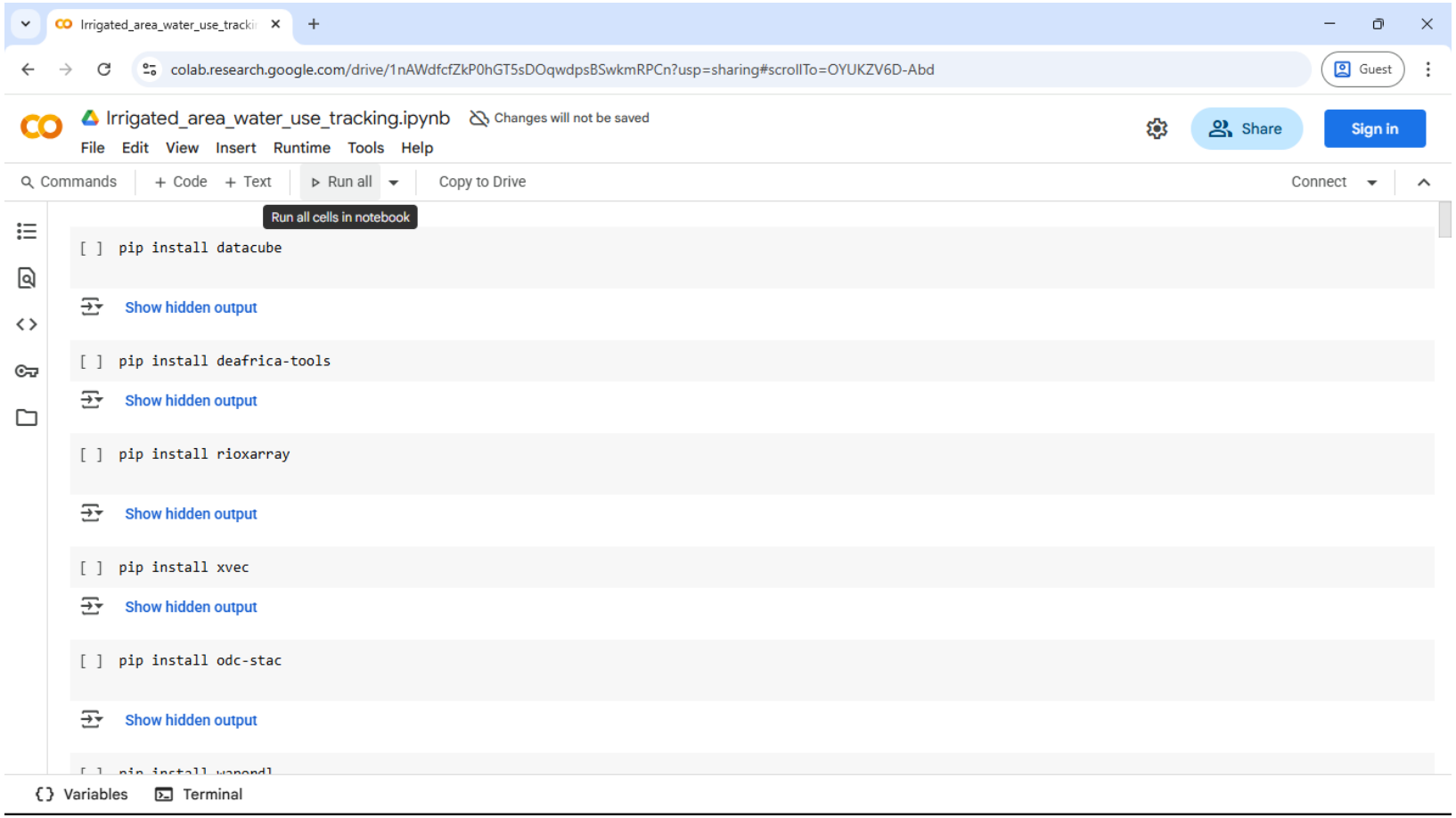
- Select **study area**
- **Align spatial resolution**
- Convert **rasters to polygons**
- **Overlay & aggregate water use**

**Outputs**

- Total water used ($m^3$)
- Irrigated land area (ha)
- Time-specific irrigation estimates

# Google Colab

Open the **Google Colab notebook** and run all cells

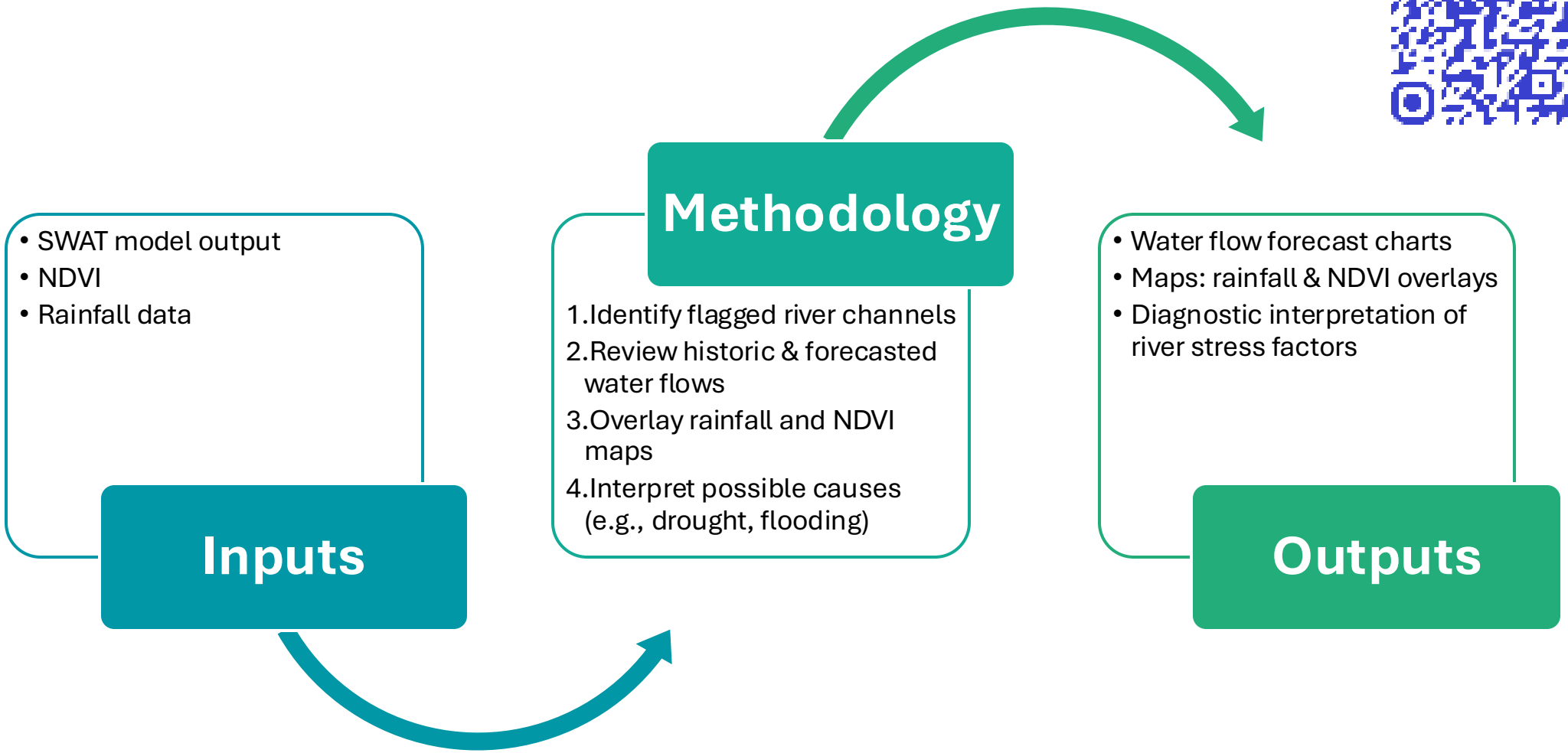


# Use Case III – Water Availability

**IMPORTANCE**

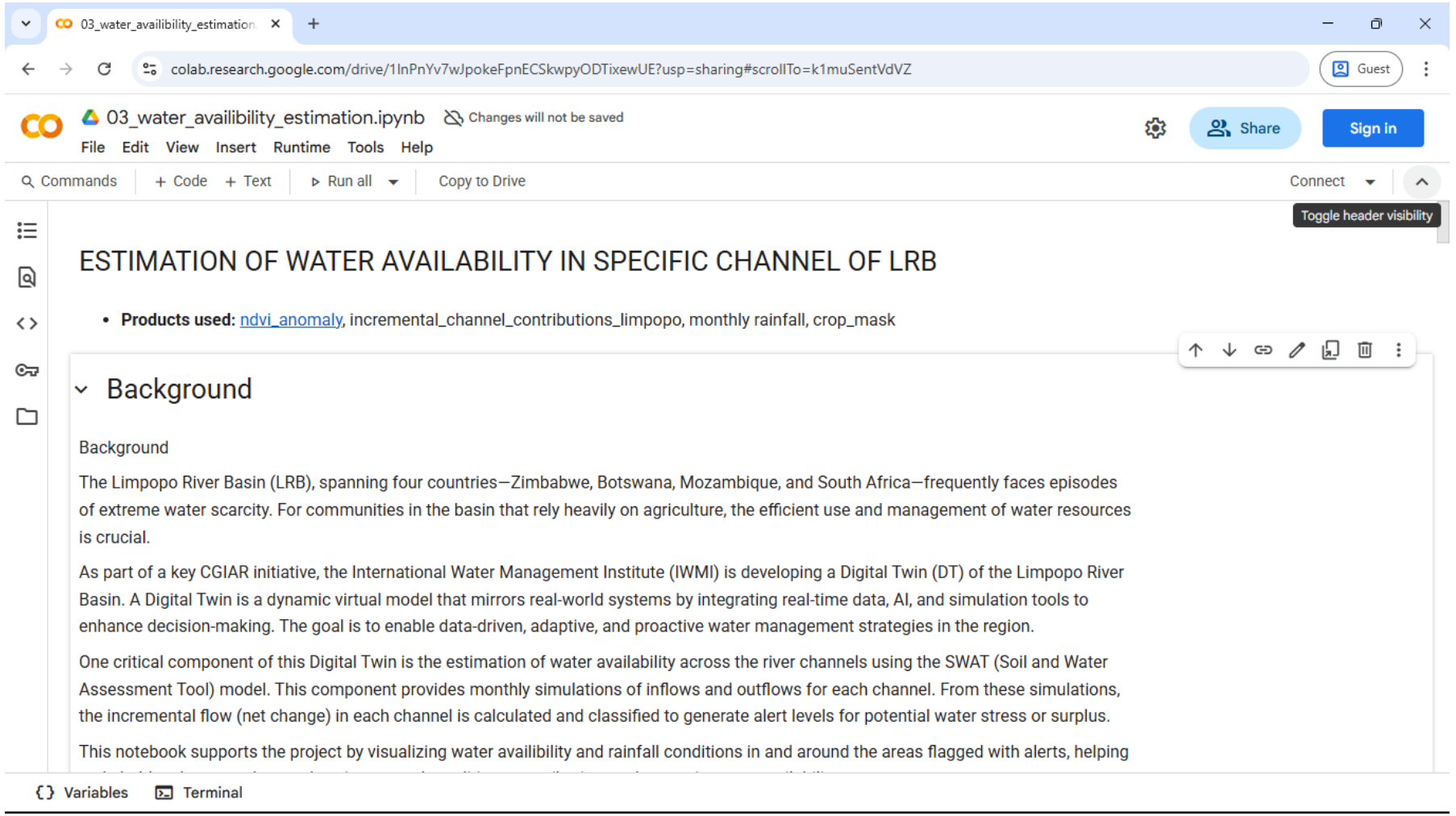
- **Water Resource Planning:** Long-term simulation of water flows across large river basins helps in **planning and estimating** available water for **agriculture, drinking, and industrial uses**. This supports **strategic allocation** and sustainable development.
- **Disaster Risk Mitigation: Forecasting and simulating flood and drought scenarios**, issuing early warnings based on real-time and forecasted data, can help in **preparedness and support climate-resilient water management**. This can also support Digital Twin-based alert systems.

# Overview


Inputs
• SWAT model output
• NDVI
• Rainfall data
Methodology
1.Identify flagged river channels
2.Review historic & forecasted water flows
3.Overlay rainfall and NDVI maps
4.Interpret possible causes (e.g., drought, flooding)
Outputs
• Water flow forecast charts
• Maps: rainfall & NDVI overlays
• Diagnostic interpretation of river stress factors

# Google Colab

Open the **Google Colab notebook** and run all cells



# Notebook Links

1. Dam Volume Data Pre Processing 01
2. Dam Volume Model Training 02
3. Dam Volume Prediction 03
4. Irrigation Water Use Tracking
5. Water Availability Estimation

# Published Documents & Further Reading

Digital Twin for management of water resources in the Limpopo River Basin: a concept. Colombo, Sri Lanka: International Water Management Institute (IWMI) Documentation & Articles: [Topic A] –

Garcia Andarcia, M., Dickens, C., Silva, P., Matheswaran, K., & Koo, J. (2024). Digital Twin for management of water resources in the Limpopo River Basin: a concept. Colombo, Sri Lanka: International Water Management Institute (IWMI). CGIAR Initiative on Digital Innovation. 4p.

Limpopo River Basin Digital Twin Open Data Cube Catalog

Afham, Abdul; Silva, Paulo; Ghosh, Surajit; Kiala, Zolo; Retief, H.; Dickens, Chris; Garcia Andarcia, Mariangel. 2024. Limpopo River Basin Digital Twin Open Data Cube Catalog. Colombo, Sri Lanka: International Water Management Institute (IWMI). CGIAR Initiative on Digital Innovation. 22p.

Status of irrigated area in the Limpopo River Basin: July 2024

Kiala, Zolo; Matheswaran, Karthikeyan. 2024. Status of irrigated area in the Limpopo River Basin: July 2024. Colombo, Sri Lanka: International Water Management Institute (IWMI). CGIAR Initiative on Digital Innovation. 5p.

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SCAN FOR MORE INFORMATION

# THANK YOU!

Research and Innovation for Water Security

Driving Action • Propelling Change

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