Small Water Cycles

Welcome to the 2nd Roundtable!

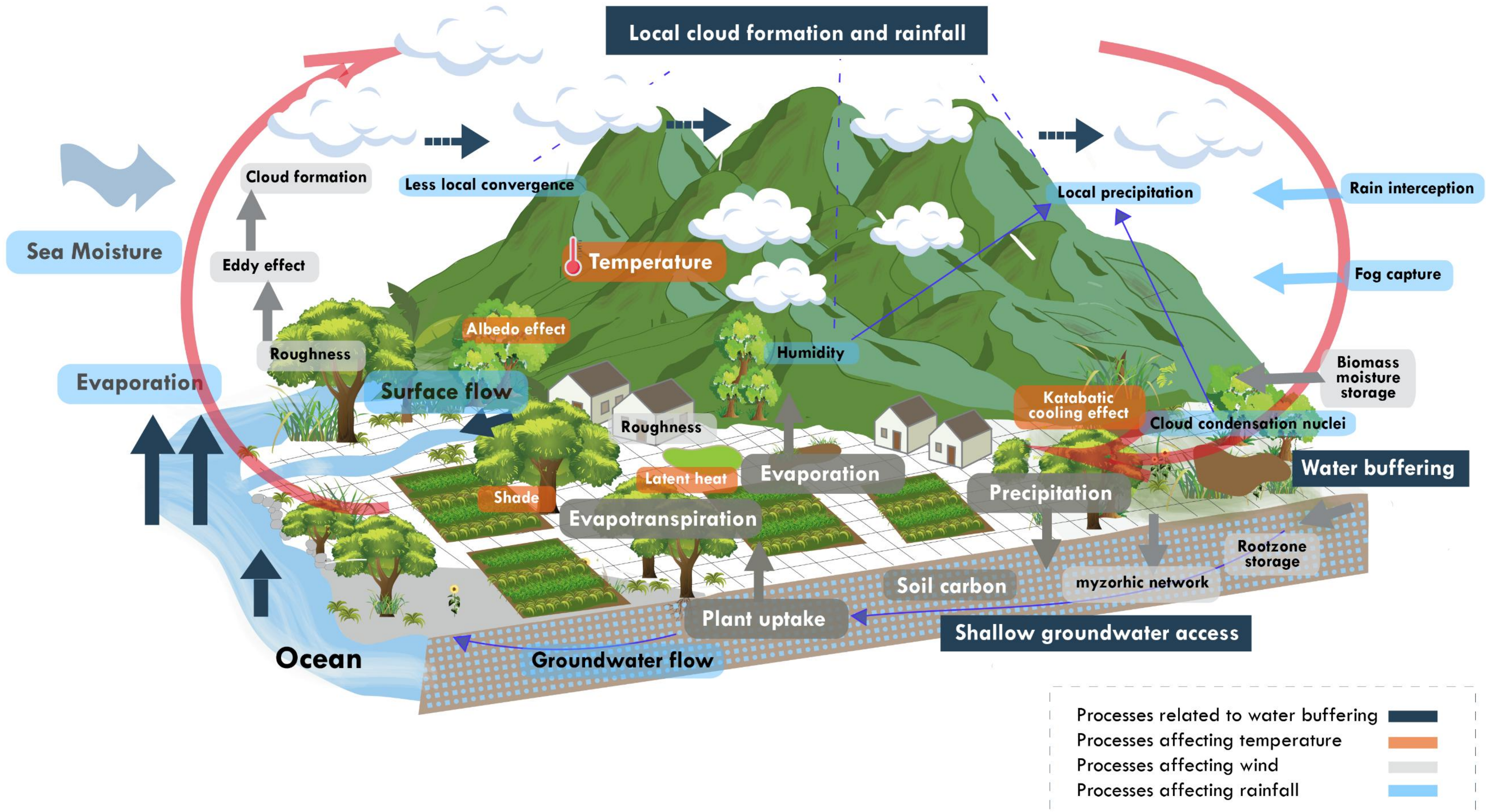
Recap from 1st roundtable

- 28 scientists, practioners, policy makers @ NIOO-KNAW, Wageningen
- Inspiring presentations:
    - Ecology driving hydrology
    - Forest-water connection
    - Land-atmosphere interactions
    - Influencing evaporation
    - Effect of nature-based solutions
    - Inspiring field cases from Tanzania and Zeeland
- New connections made
- Unknowns identified
- Start of a community of practice

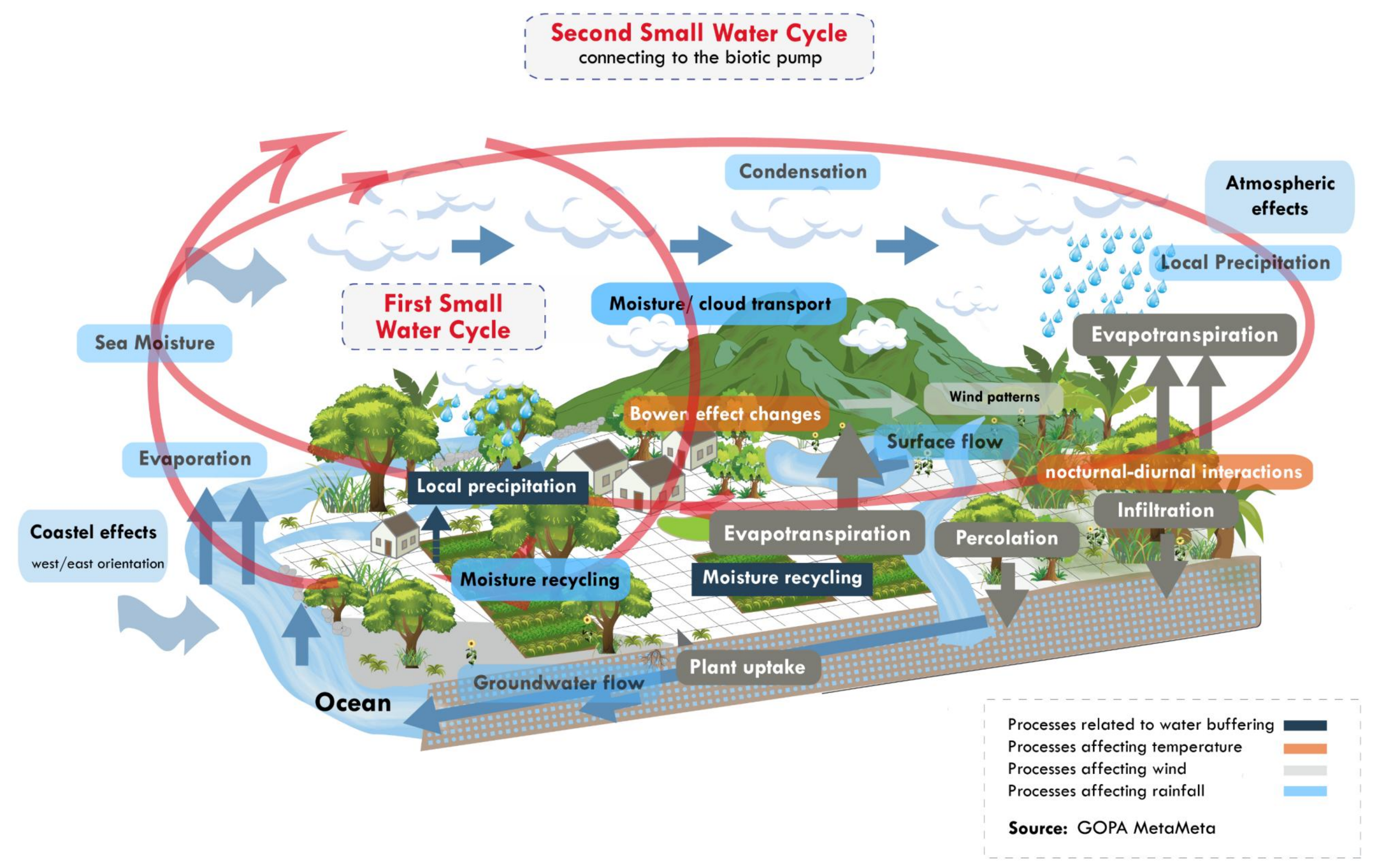
Recap from 1st roundtable

- Conclusion: climate action is not only about carbon
- Fix the water and carbon and biodiversity fill follow
- Making restoring small water cycles one of the highest-leverage interventions available to us

First Small Water Cycle



Source: GOPA MetaMeta


Second Small Water Cycle
connecting to the biotic pump
Condensation
Atmospheric effects
Local Precipitation
First Small Water Cycle
Moisture/ cloud transport
Sea Moisture
Evapotranspiration
Wind patterns
Bowen effect changes
Surface flow
Evaporation
nocturnal-diurnal interactions
Local precipitation
Infiltration
Coastel effects
west/east orientation
Evapotranspiration
Percolation
Moisture recycling
Moisture recycling
Plant uptake
Groundwater flow
Ocean
Processes related to water buffering
Processes affecting temperature
Processes affecting wind
Processes affecting rainfall
Source: GOPA MetaMeta

Many factors and feedback loops

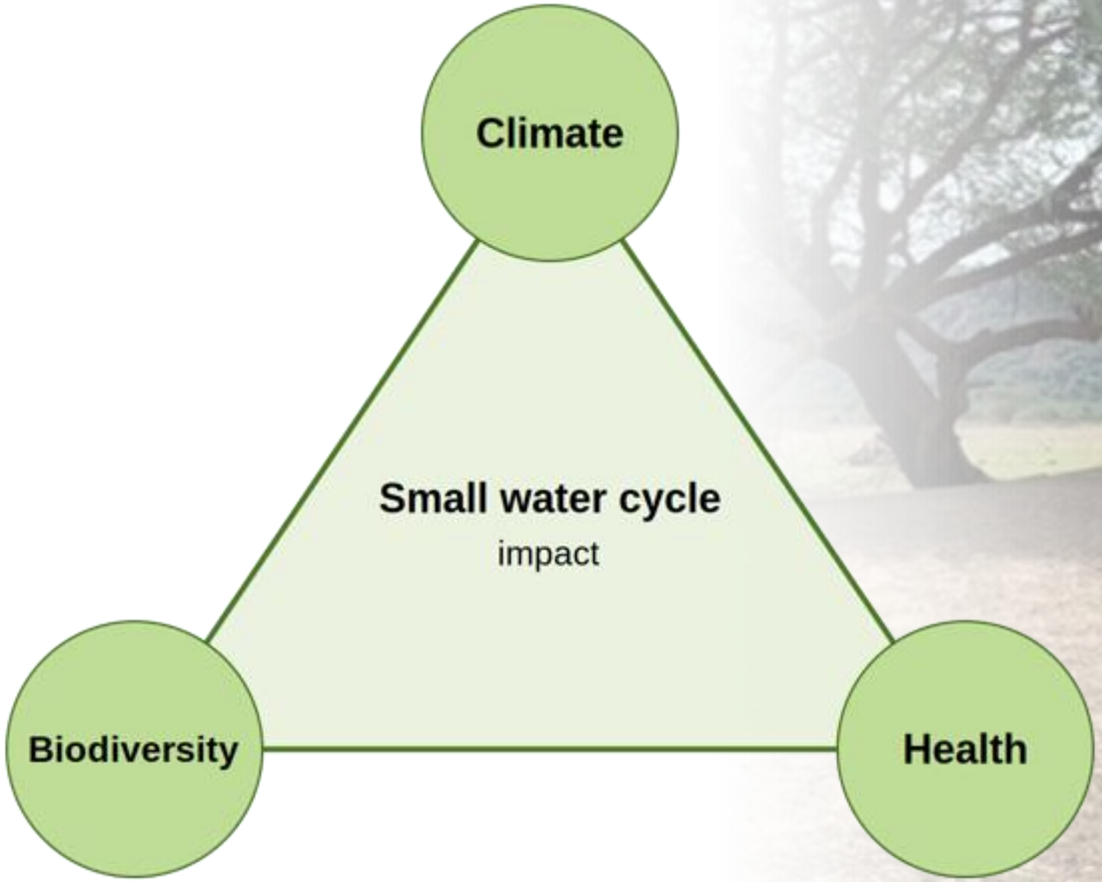
First water cycle

- Processes related to water buffering
  - Rain interception
  - Moisture/ fog capture
  - Biomass moisture storage
  - Rootzone storage, myzorhic network, access to shallow groundwater
  - Development of soil carbon: high water retention
- Processes affecting temperature
  - Latent heat
  - Karabatic effect
  - Shade
- Processing affecting wind
  - Roughness
  - Eddy effects
  - Uplift, thermic effects
- Processes affecting rainfall
  - Adding humidity,
  - Greening up
  - Effect of wind dispersion
  - Less local convergence
  - Release of cloud condensation nuclei (different types and effectiveness)
  - Change of magnetic field
- Interplay of water buffering, temperature, wind, and precipitation/ cloud formation

Second water cycle / biotic pump

- Moisture availability and recycling at different scales
- Preservation/ disruption of first small water cycle (incl release of CCN, Bowen effect changes)
- Wind patterns - moisture/ cloud transport
- Nocturnal-diurnal interactions
- Interceptions and accelerators – orographic effects (or thermal only), coastal effects (west/east orientation)
- Primers (heavy rainfall, coastal effects)
- Atmospheric effects

The Small Water Cycles – Their impact



The Small Water Cycles – Their impact

- Climate regulation (rainfall, temperature)
- Economic effect
- Ecosystem services

The Small Water Cycle – The action

- Actionable climate response
  - It can be managed
  - It is local
  - It is fast
  - It can reverse, it is positive

A roadmap - for discussion

The topic gets too little attention. How do we change that?

1. Build a community of practice
2. Build influence: shape agendas in policy, practice and science
3. In particular bring small water cycles into the climate debate and enrich/ enliven it
4. Connect to what is already happening on the ground. Identify gaps in research and practice. Strengthen the content agenda.
5. Showcase existing pilots as climate action. Make the evidence sharper and more visible.

Aim of this community – for discussion

- Have joint message/ statements on Small Water Cycles
- Contribute to major policy debates
- Connector role: link existing initiatives, work on the ground, and scientific work
- Become an expertise network

JUSTDIGGIT

COOLING DOWN THE PLANET


BUNDS COLLECT RAINWATER
So water infiltrates into the earth


WE HAVE DUG
>660.000 BUNDS

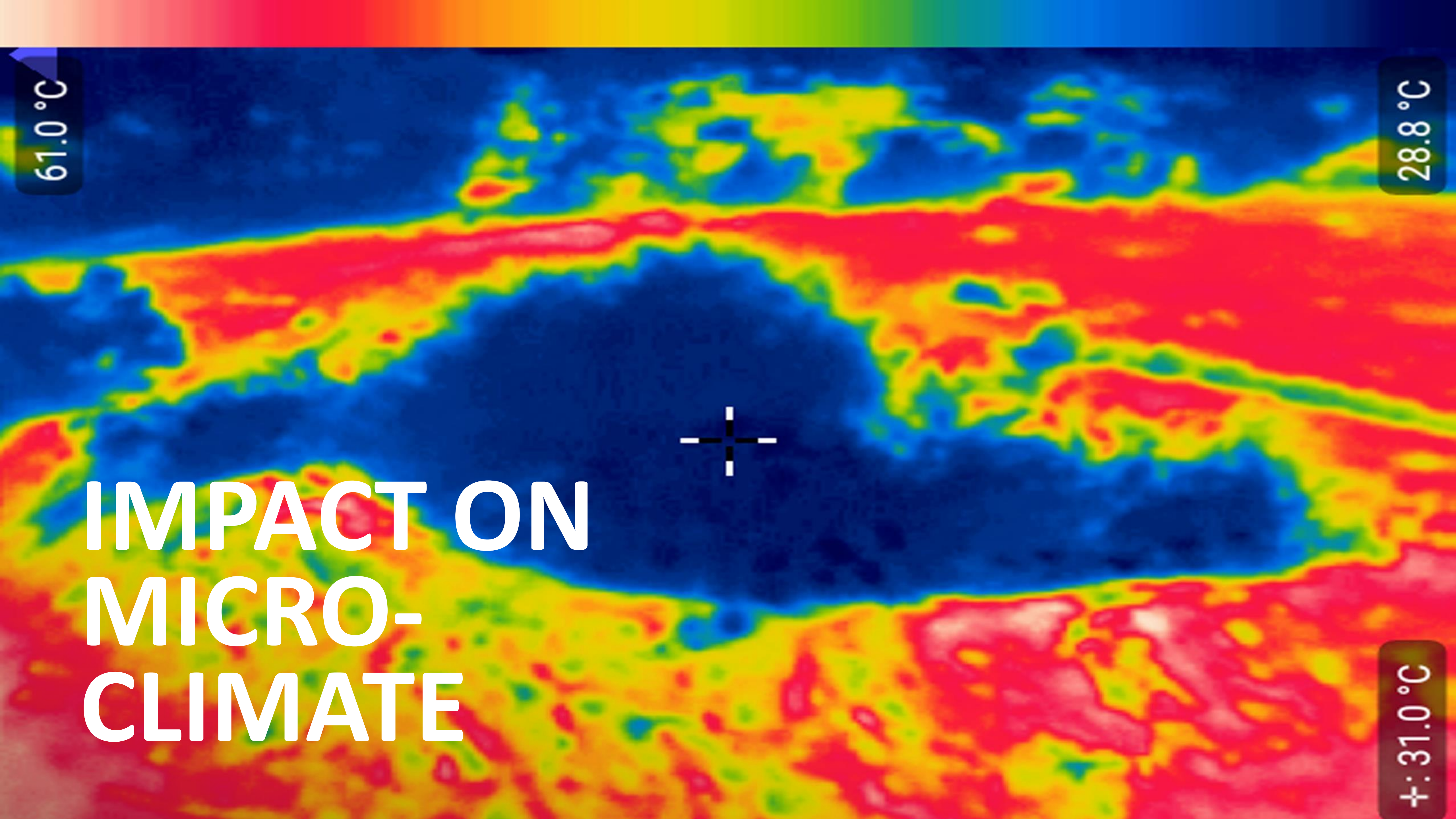

BUNDS
COLLECT
WATER


SEEDS IN
THE
EARTH
SPROUT


JUNE
2018
JUNE
2019
JUNE
2020
JUNE
2022

29.9°C
40.8°C
COOLI
NG
EFFECT

IMPACT ON MICRO-CLIMATE



CHANGE VISIBLE IN SATELLITE DATA

IMPACT ON SOIL WATER CONTENT, NDVI & TEMPERATURE

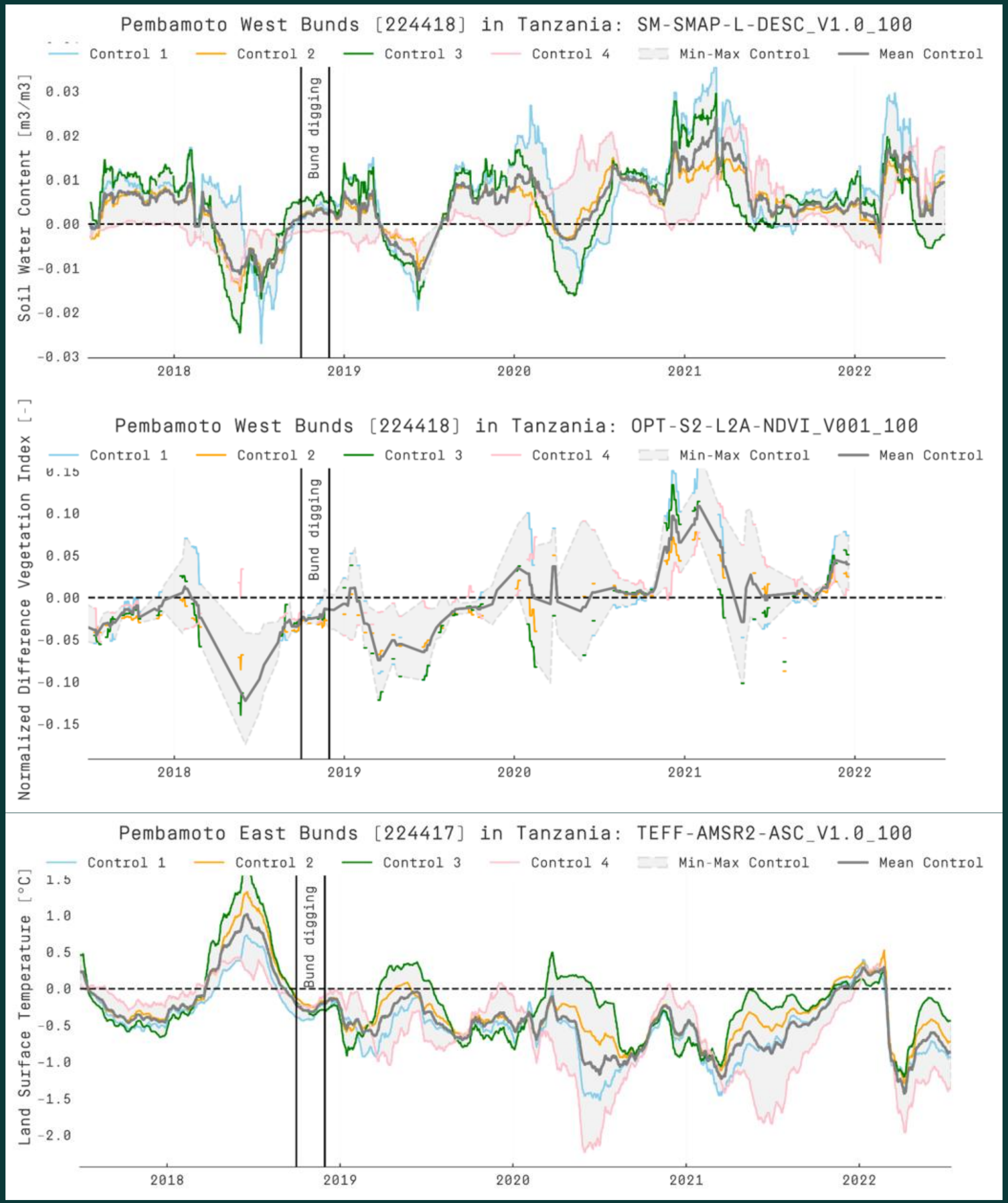
Used satellite data to quantify impact of restoration on:

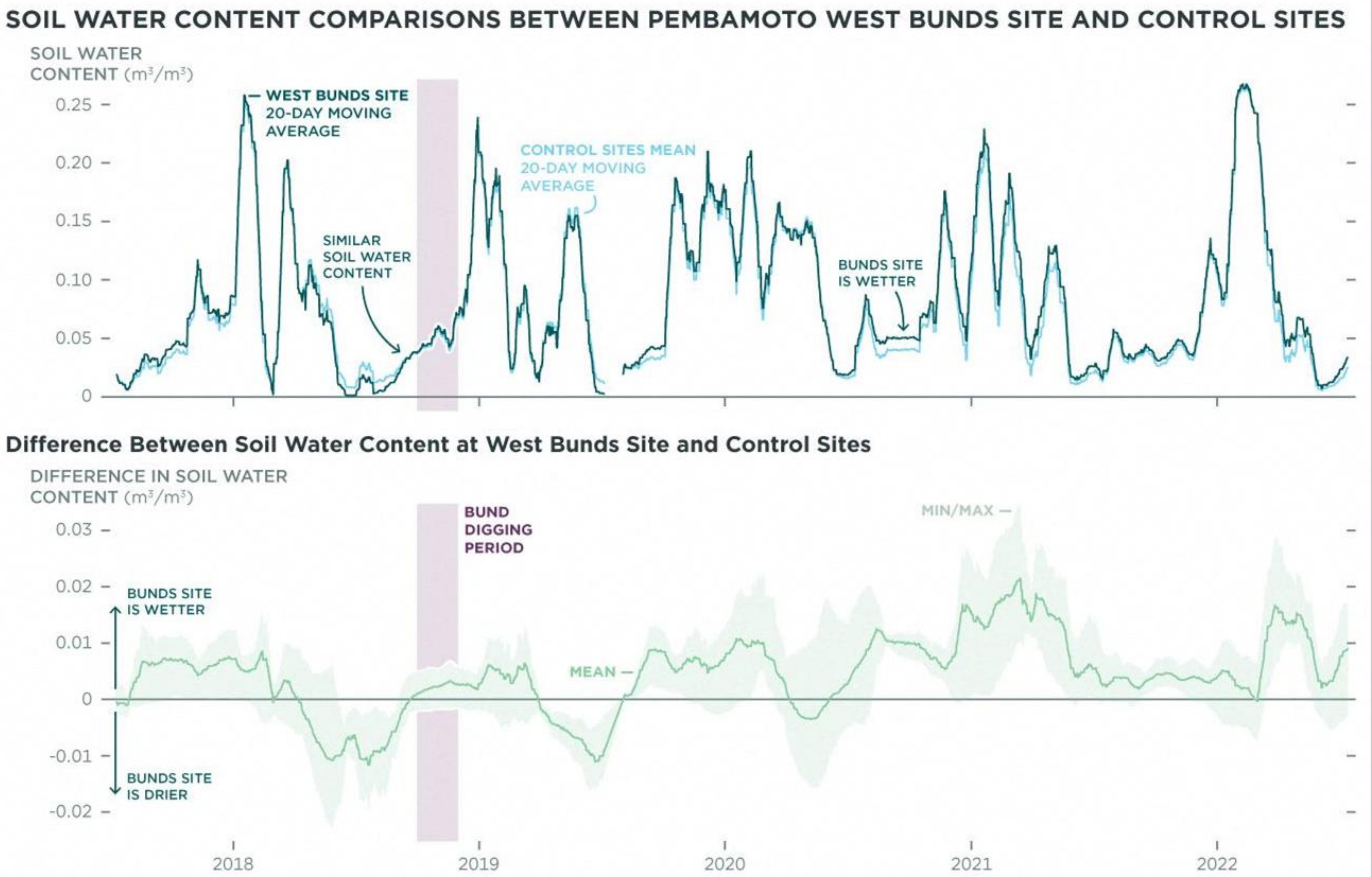
- Soil Water Content: on average 7-13% wetter
- Greenness (NDVI): on average 23-41% greener
- Temperature: on average 0.4-0.5 °C cooler

Partnership with Planet

Peer-reviewed paper: Van der Vliet M., Malbeteau Y., Ghent D., Haas S. de, Veal K.L., Van der Zaan T., Sinha R., Dash S.K., Houborg R. and De Jeu RAM (2024) **Quantifiable impact: monitoring landscape restoration from space. A regreening case study in Tanzania.** Frontiers in Environmental Science

Blog post: https://www.planet.com/pulse/african-restoration-from-space/

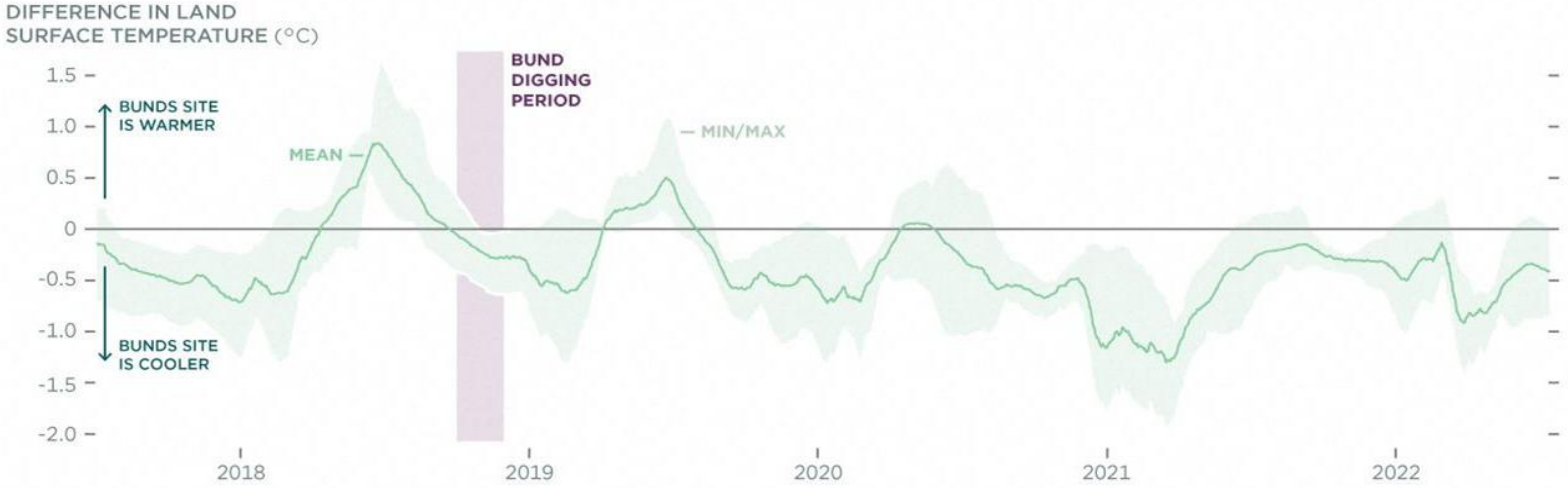




SOIL WATER CONTENT COMPARISONS BETWEEN PEMBAMOTO WEST BUNDS SITE AND CONTROL SITES
SOIL WATER CONTENT (m³/m³)
0.25
0.20
0.15
0.10
0.05
0
WEST BUNDS SITE 20-DAY MOVING AVERAGE
CONTROL SITES MEAN 20-DAY MOVING AVERAGE
SIMILAR SOIL WATER CONTENT
BUNDS SITE IS WETTER
Difference Between Soil Water Content at West Bunds Site and Control Sites
DIFFERENCE IN SOIL WATER CONTENT (m³/m³)
0.03
0.02
0.01
0
-0.01
-0.02
BUND DIGGING PERIOD
MIN/MAX
MEAN
BUNDS SITE IS WETTER
BUNDS SITE IS DRIER
2018
2019
2020
2021
2022

DAYTIME LAND SURFACE TEMPERATURE COMPARISONS BETWEEN PEMBAMOTO WEST BUNDS SITE AND CONTROL SITES

Difference Between Daytime Land Surface Temperature at West Bunds Site and Control Sites



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We'd love to team up with others and offer our sites, impact, data and partnerships to bring this topic forward.

LET'S REGREEN TOGETHER

CBF Erkend Goed Doel

ANBI Algemeen Nut Beogende Instelling

Sander de Haas
sander@justdiggit.org

Local climate & small water cycles

Integrating Land–Water–Atmosphere Processes into Environmental Assessment

Alex Puisais, Dennis van Peppen

April 29th, 2026

Environmental Assessment Instruments

In Principle: How Environmental Assessment Frameworks address SWC and Local Climate

Relevant Performance Standards

PS1: Defines how impacts are identified, assessed and managed, and set the ESIA structure.

PS3: Covers resource usage, efficiency and emissions.

PS 6: Covers biotic and abiotic elements, as well as ecosystem functions.

SWC and local climate are not explicitly mentioned nor defined

Core components are spread across standards

No integrated land–water–atmosphere system framing.

Impact and mitigation assessed by topic

In Practice: How SWC and local climate are addressed in ESIA

Standards translated into measurable, project-level parameters

- Measurable parameters: Rainfall, erosion, groundwater level, seasons, number of species…
- Can be codified in regulation
- They are directly linked to risks to the project

Climate framed through GHGs and climate risks to projects

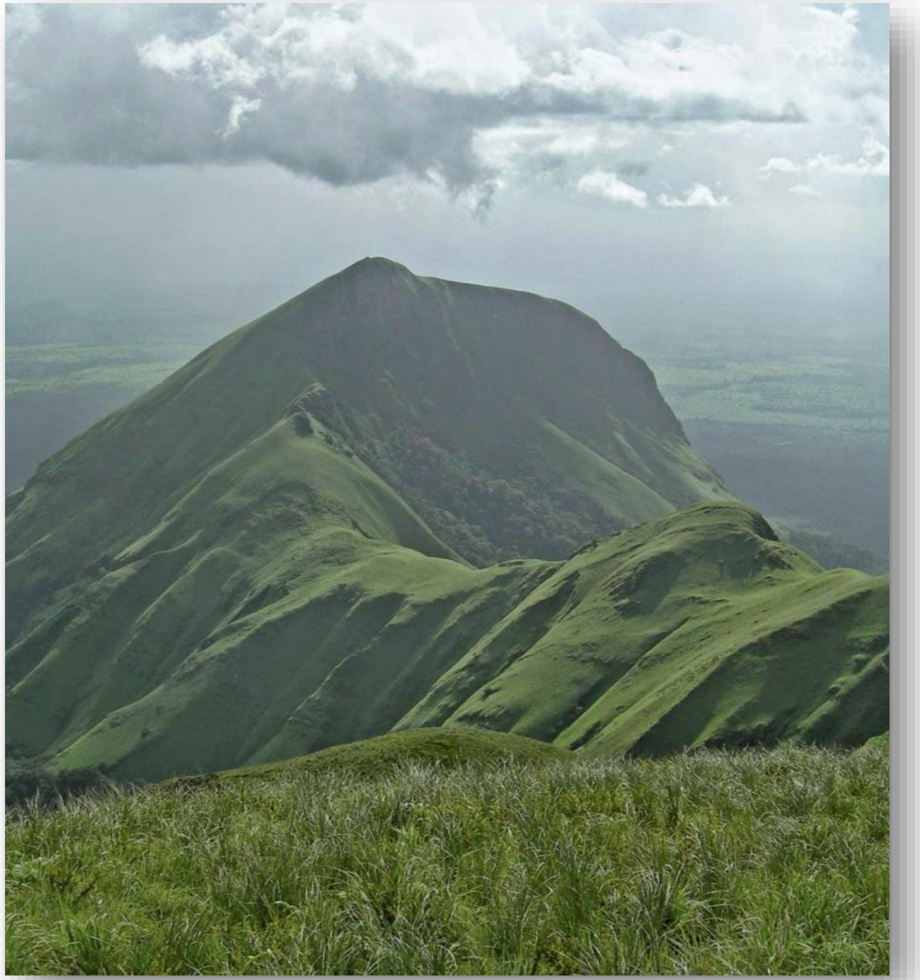
- CCRA: How future climate may affect operation.
- At global level: Participation of the project to global emissions
- Not how the project may modify local climate

Impacts analyzed at project footprint level and timeline

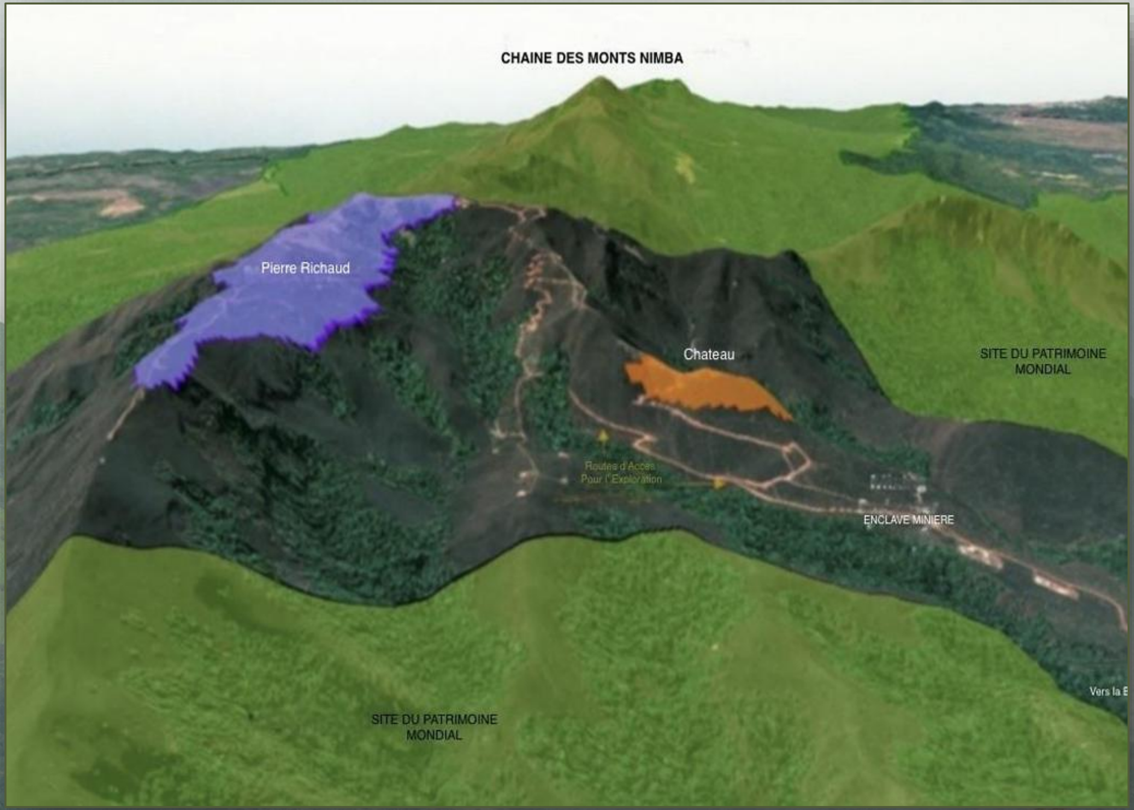
- Impact at project scale (time and spatial)
- Landscape and atmosphere are background conditions, not a system that can be affected
- Cumulative impacts are rarely addressed properly

Systemic land–water–atmosphere processes remain implicit

- Impact and mitigation measures are addressed at individual environmental parameter, not holistically.
- Regulation processes (i.e. evapotranspiration) are implicit and do not drive mitigation choices
- Ecosystem services are rarely analyzed



In Practice: Case of ESIA for Mont Nimba open pit iron ore mine project



Mont Nimba (Guinée Forestière)

- UNESCO World Heritage (in danger), Biosphere/Strict Nature Reserve...
- High relief (1750m), strong orographic effects (uplift rainfall, cloud and fog formation on slopes...) , marked local climate (cloud-forest, high humidity, evapotranspiration, katabatic winds)
- Dense forest ecosystems sheltering endemic and endangered species

Iron ore mining project

- Open-pit, rock dumps, processing facilities and access roads.
- Located on upper slopes and headwater area of the Mount
- Abstraction of surface water and rain run-off. Energy via diesel generators.

In Practice: Case of ESIA for Mont Nimba open pit iron ore mine project

Mentioned / described

- Climate and local climate characteristics
- Orographic rainfall and headwater context
- Dense forest cover and hydrological sensitivity

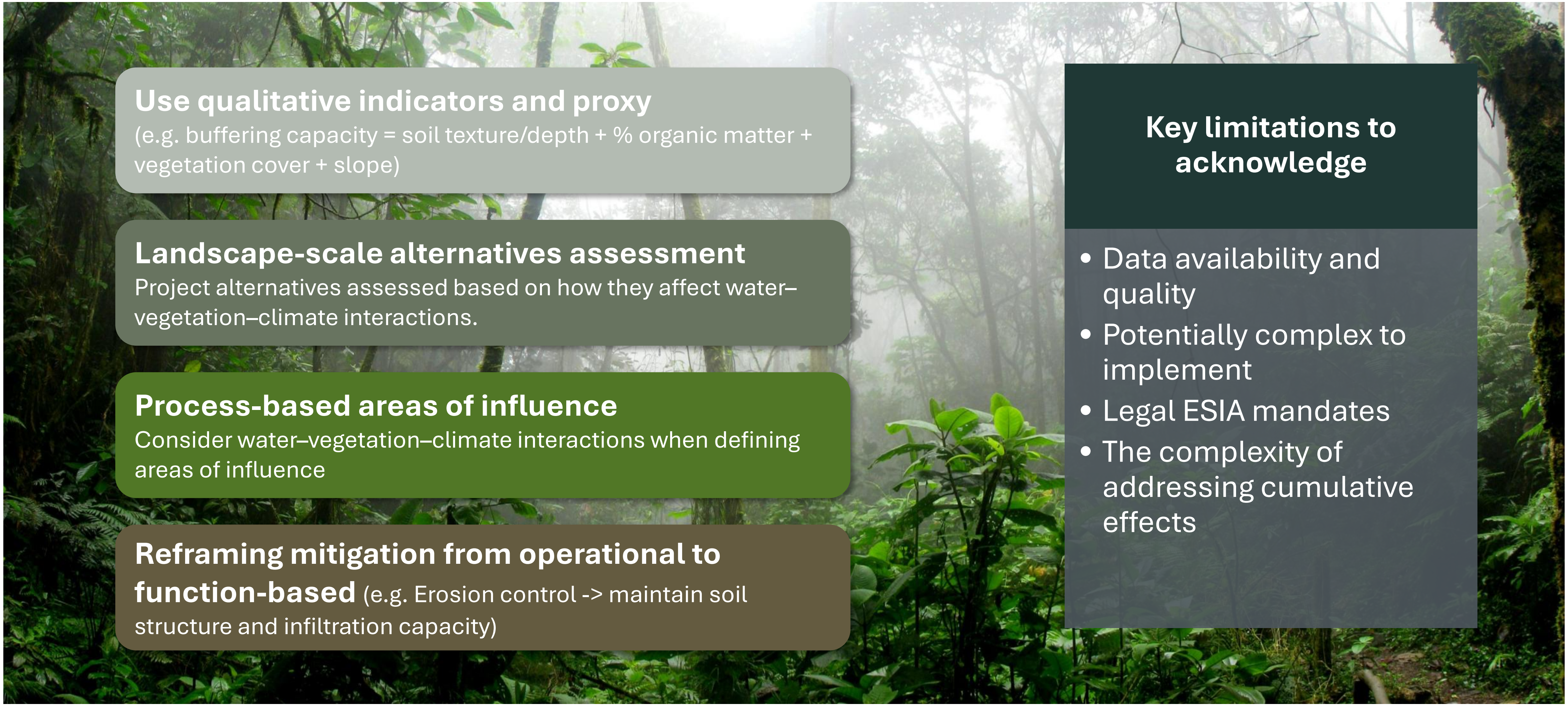
Factually analyzed

- Hydrology and hydrogeology (runoff, infiltration, baseflow)
- Water–ecosystem interactions
- Erosion and sediment dynamics

Not explicitly addressed

- Small water cycles not analyzed as a system.
- Local climate regulation analyzed as a baseline, and not as being impacted by the project
- Interactions between vegetation, water and atmosphere not made explicit
- No indicators describing how the landscape can buffer disturbances (how resilient).
- Impacts assessed by environmental topic rather than as a system.

Opportunities and Limitations Within Existing ESIA Frameworks



Use qualitative indicators and proxy
(e.g. buffering capacity = soil texture/depth + % organic matter + vegetation cover + slope)

Landscape-scale alternatives assessment
Project alternatives assessed based on how they affect water–vegetation–climate interactions.

Process-based areas of influence
Consider water–vegetation–climate interactions when defining areas of influence

Reframing mitigation from operational to function-based (e.g. Erosion control -> maintain soil structure and infiltration capacity)

Key limitations to acknowledge

- Data availability and quality
- Potentially complex to implement
- Legal ESIA mandates
- The complexity of addressing cumulative effects

Conclusion and perspectives

SWC and local climate regulation are rarely addressed explicitly

SWC and local climate are analyzed implicitly and in a fragmented way

Not explicitly considered by international standards or national ESIA regulations

ESIA offers a practical entry point to improve systemic understanding of project impacts

Conclusion and perspectives

How to clarify framing of existing standards and regulation?

What is the key message for ESIA/SEA practitioners?

Pilot project? (Simandou/Nimba)

Potential role for the NCEA?

Commissie voor de milieueffectrapportage

29 APRIL 2026, FOR SMALL WATER CYCLE

Water balance at the Veluwe

Stefan Dekker – NIOO-KNAW and UU

Bernard Voortman en Consortiumpartners Project RECHARGE

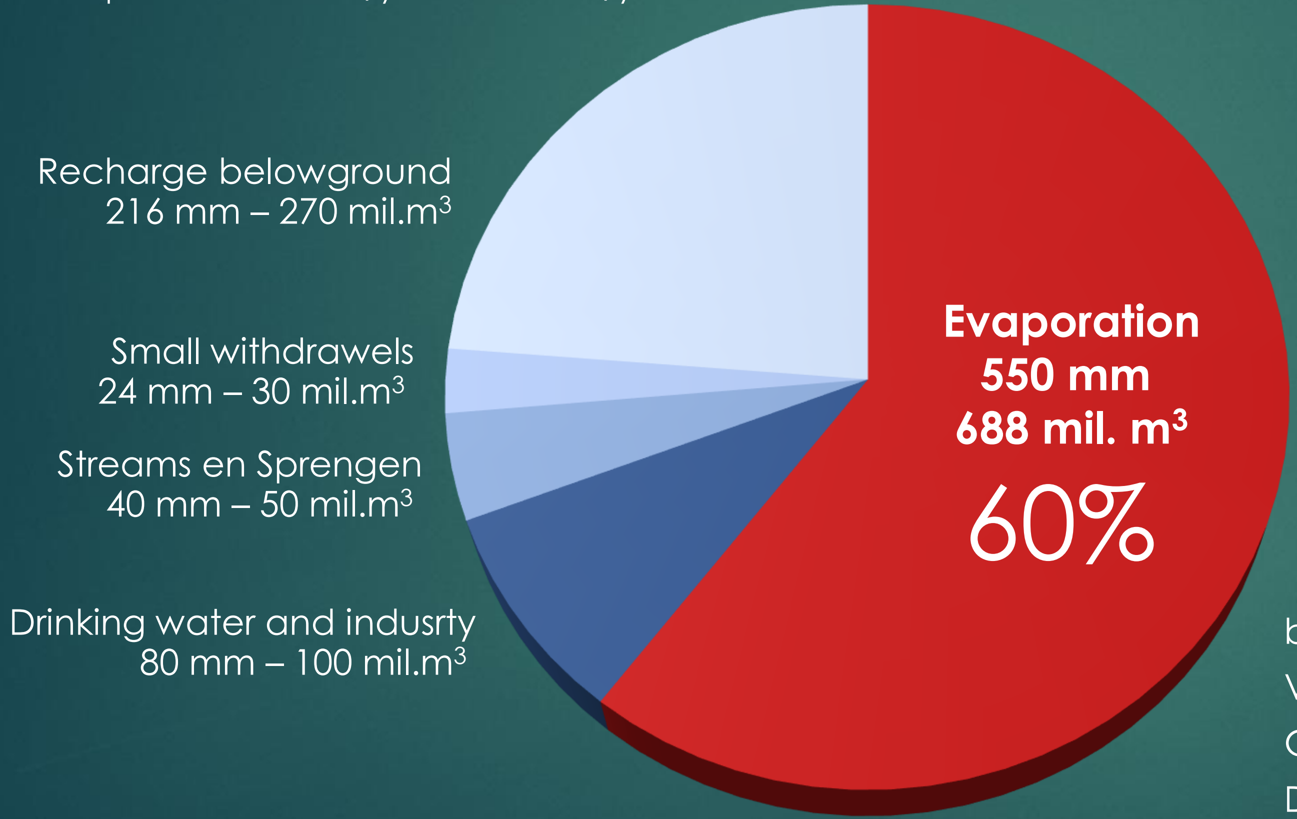
MOISTURE MATTERS

Water balans Veluwe

EVAPORATION MORE THEN HALF OF PRECIPITATION

Region 125.000 ha

Precipitation: 910 mm/y – 1138 mil.m^3/y



Model error of 20 % in evaporation is reasonable

bron:

Voortman 2024

Gehrels 1999

Driesen 2006

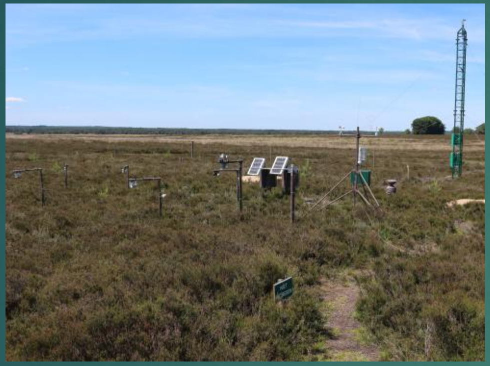
Withdrawels

MOISTURE MATTERS

Evapotranspiration and land use

Precip: 910 mm/year

OLD NUMBERS



Bare sand	Heathland	Deciduous Forest	Coniferous Forest	Dark Coniferours Forest
ET = 250 mm (27%)	ET = 430 mm (47%)	ET = 550 mm (60%)	ET = 660 mm (73%)	ET = 730 mm (80%)
R = 660 mm (73%)	R = 480 mm (53%)	R = 360 mm (40%)	R = 250 mm (27%)	R = 180 mm (20%)

In hydrological models those classes are to limited.

MOISTURE MATTERS

Coniferous forest more ET as Broadleaf

- To simple

MOISTURE
MATTERS

Project RECHARGE

https://tki-recharge.nl/

1. Groundwater recharge per vegetation type?
2. How can we support the organizations related to the water, land-owners and forest managers sectors?

Four years to:

- Measure forest ET.
- Digitial twin waterbalans and scenario-analyses.
- Knowledge development

Klankbordgroep:
Stefan Dekker (UU, NIOO)
Flip Witte (FWE)
Eddy Moors (IHE)

WATER & MARITIME
RISING CHALLENGES, SMART SOLUTIONS

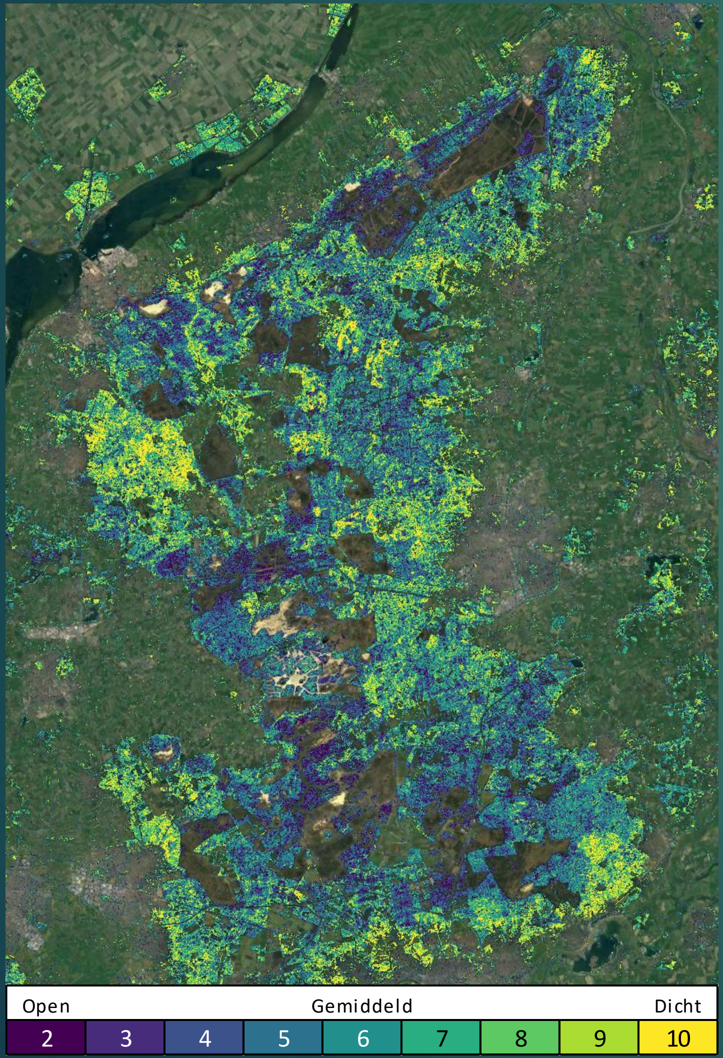
Vitens
provincie Gelderland
MOISTURE MATTERS
HOOGHEEMRAADSCHAP DE STICHTSE RIJNLANDEN
STELLASPARK
Waterschap Brabantse Delta
waterschap vallei en veluwe
KWR
van hall larenstein university of applied sciences
brabant Water
Provincie Noord-Brabant

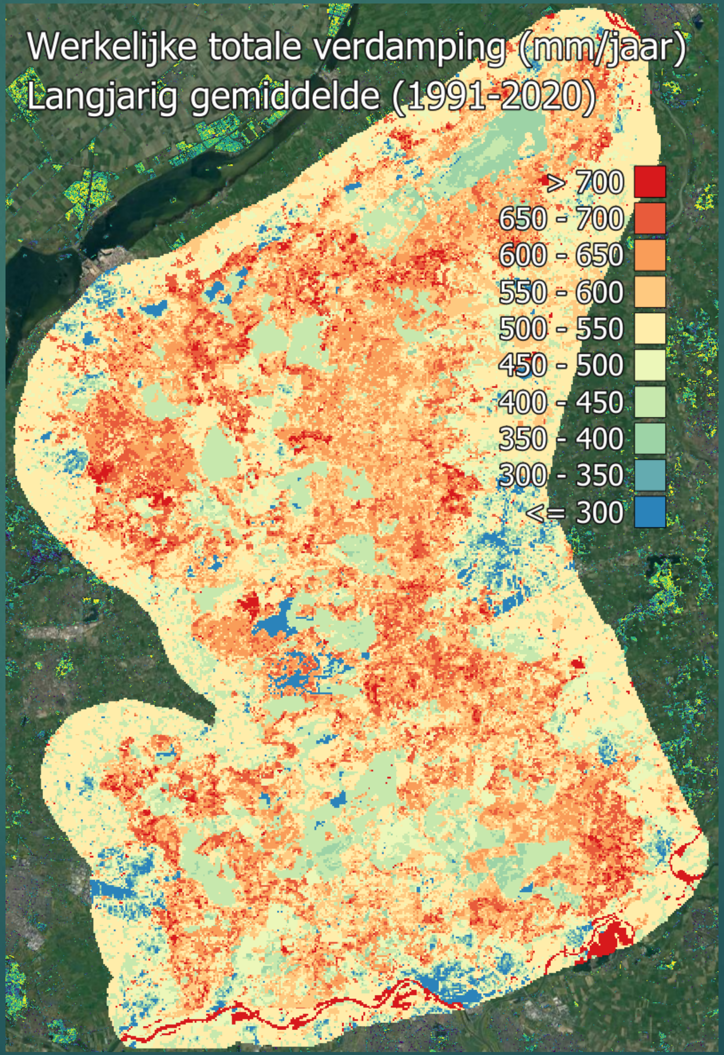
Partners:

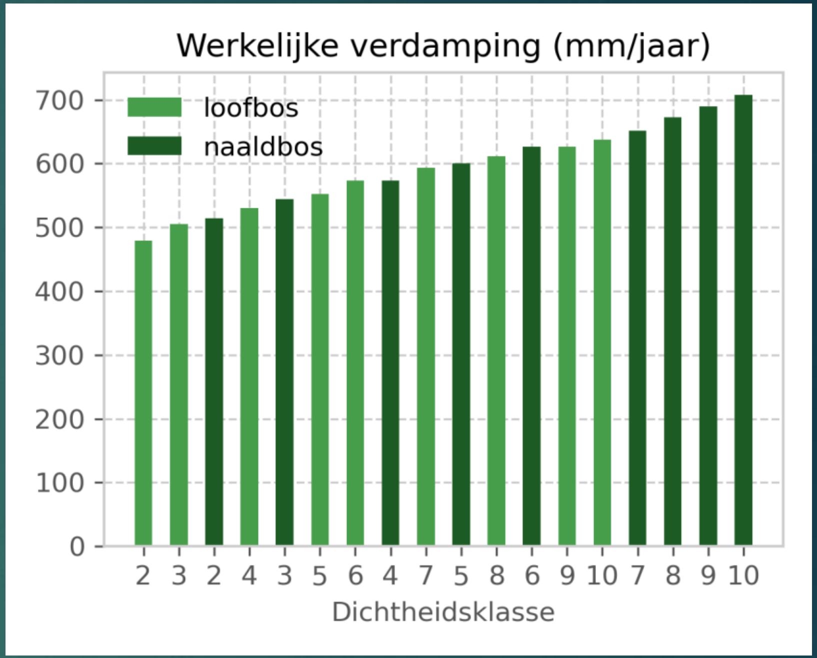
Natuurmonumenten
WAGENINGEN UNIVERSITY & RESEARCH
UNIVERSITY OF TWENTE.
staatsbosbeheer
ede
THÜNEN

Modelling ET per forest type

From 3 to 18 types of forests in FluxPark dependent on density classes

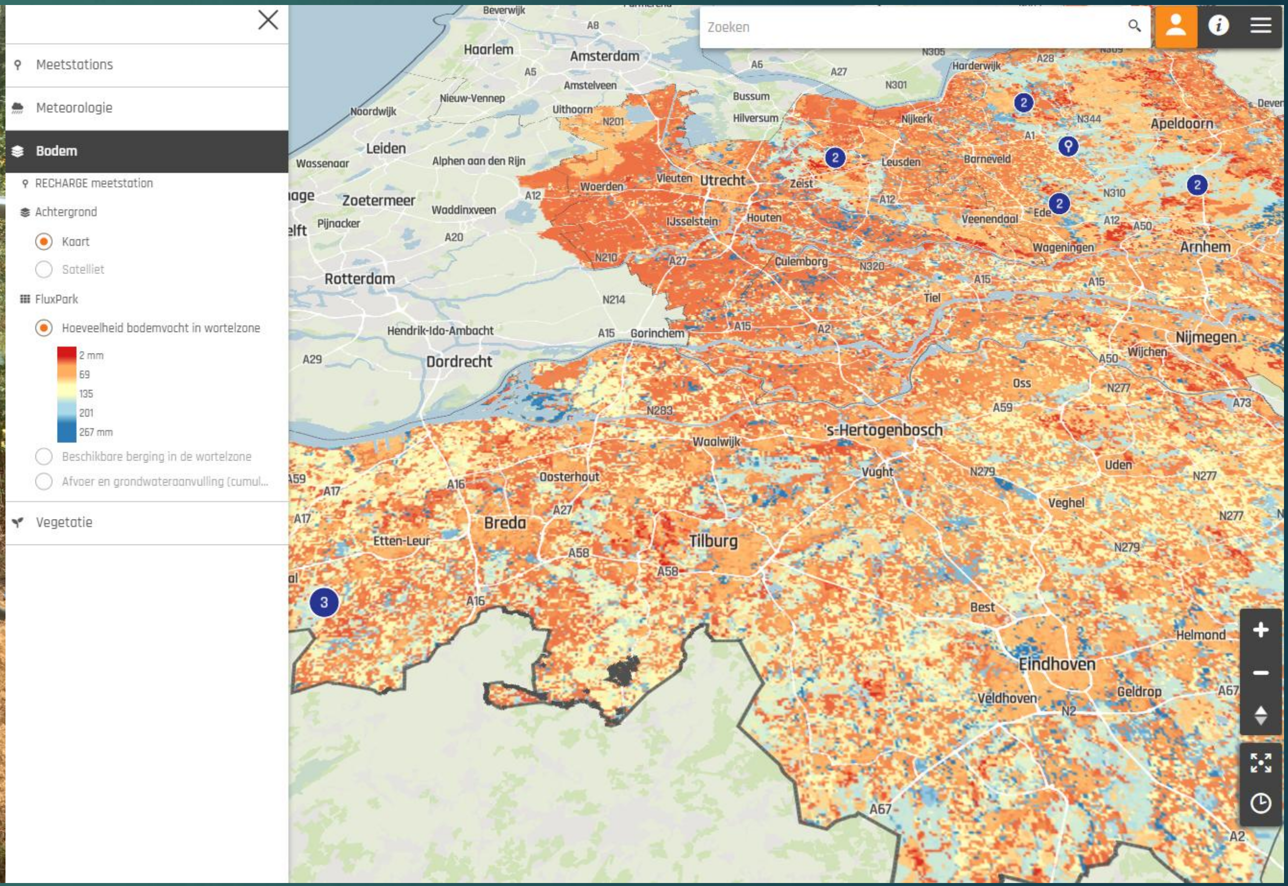






PPS-project RECHARGE (public, private cooperation)

MONITORING, MODELLING AND SHARING



Veldmetingen
11 locaties in forests op de Heuvelrug,
Veluwe en Brabantse sandy soils

Digital Twin
Field measurements, models, modellen, scenario
analysis: Climate, land-use, forest managment

MOISTURE MATTERS

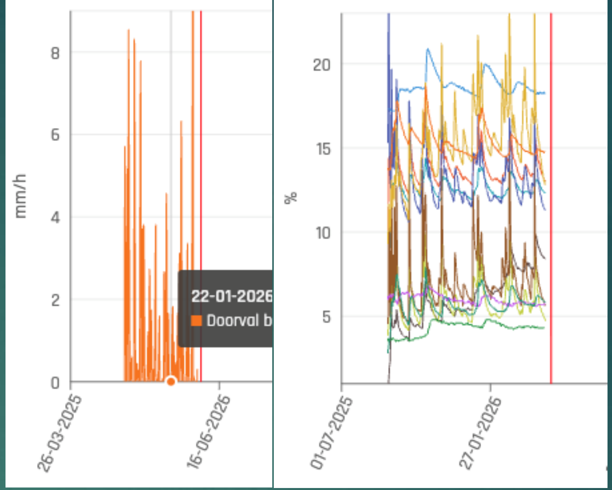
Effects of droughts?

- A large areal has no effect on a drought – some estimates that only 10 mm recharge left over.
- Trees (for instance oak) continue to grow

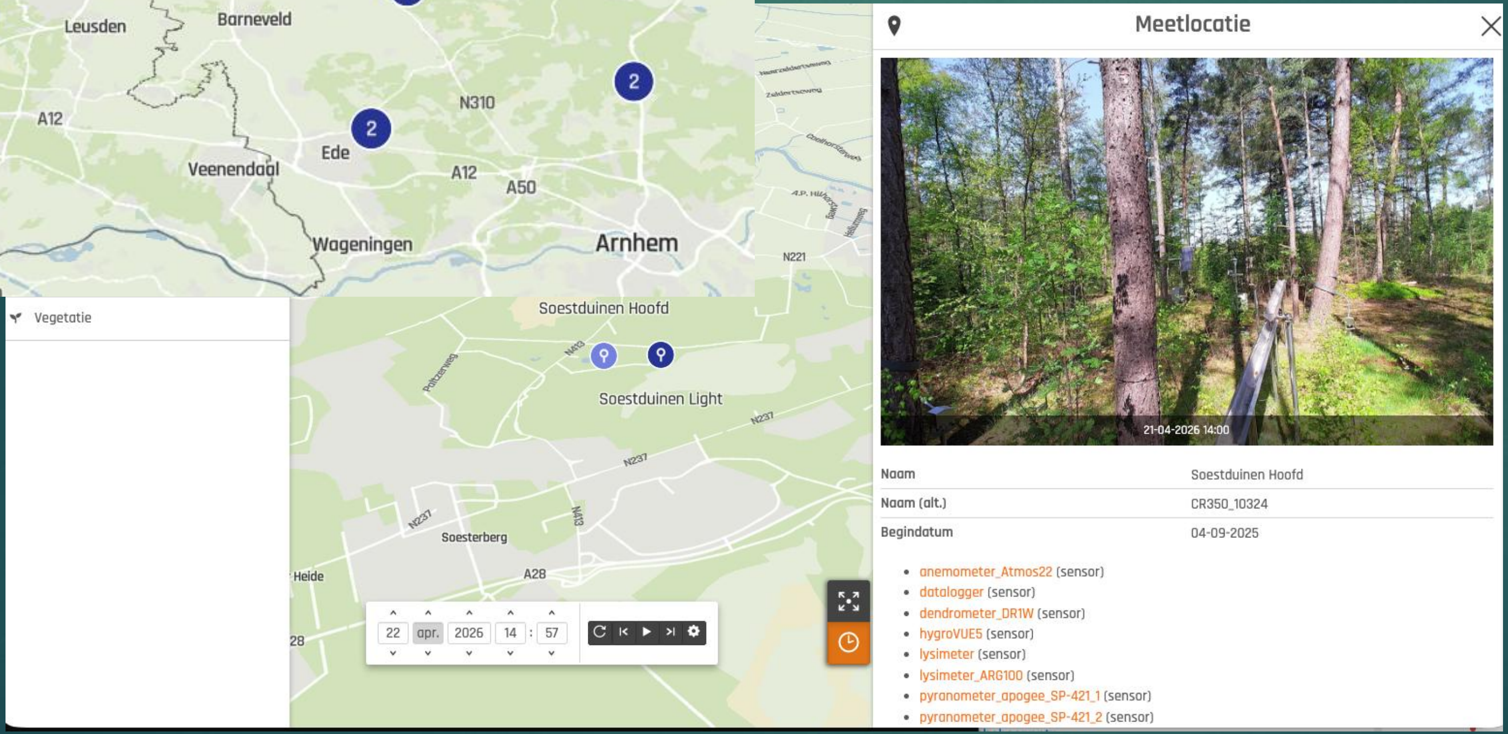
MOISTURE MATTERS

Digital twin

- https://nexus.stellaspark.com/#/viewer/230



Throughfall and Soil moisture



MOISTURE MATTERS

Royal Netherlands
Meteorological Institute
*Ministry of Infrastructure and
Water Management*

OogVoorDroog

towards a national monitoring network for actual evaporation and soil moisture

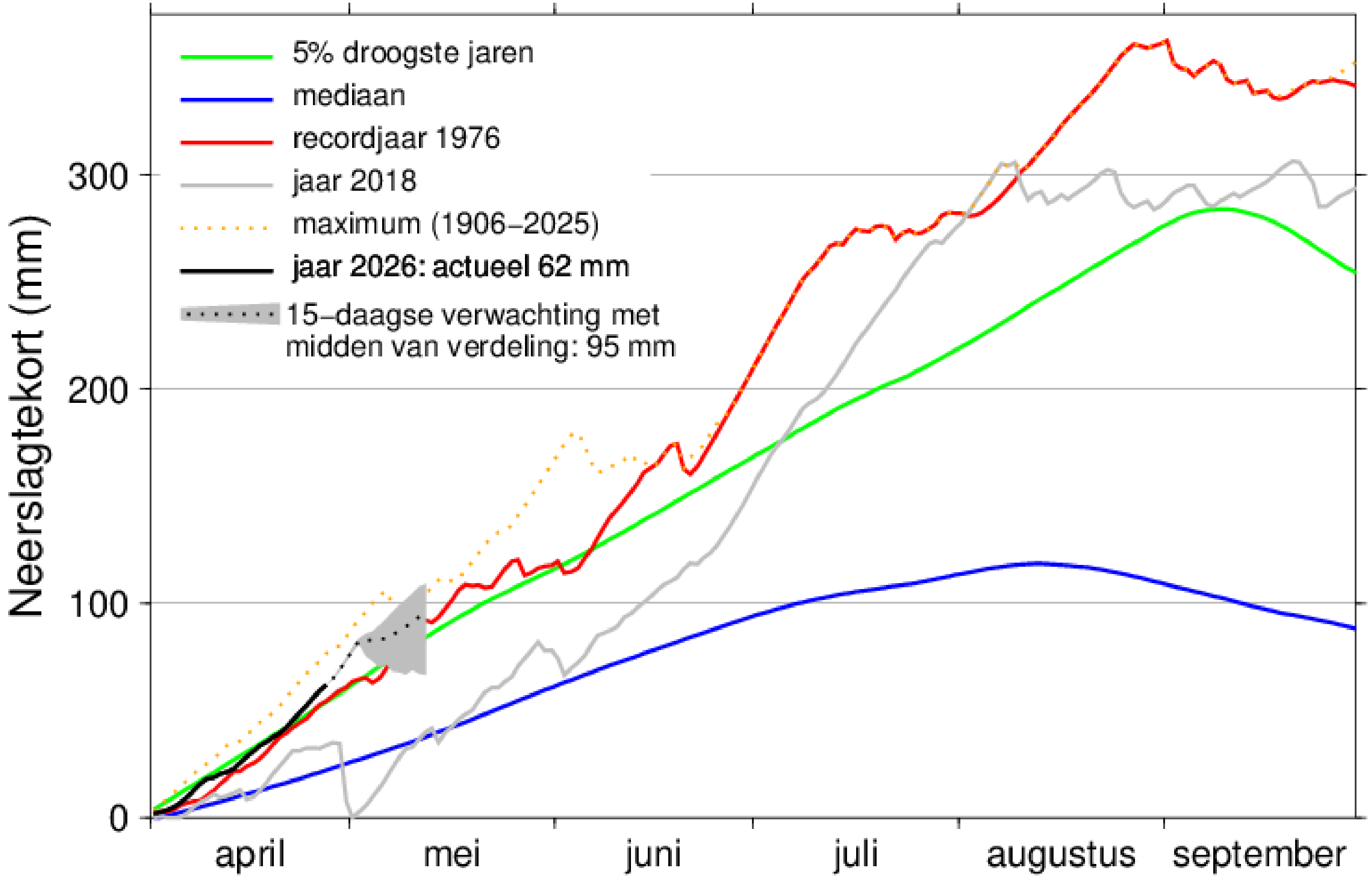
Theo Brandsma and Gerard van der Schrier

theo.brandsma@knmi.nl; gerard.van.der.schrier@knmi.nl

Small Water Cycles, 29 April 2026

Neerslagtekort in Nederland in 2026

Landelijk gemiddelde over 13 stations



$$P = ET + Q + \Delta S$$

$$Q_N = LE + H + G$$

$$P = ET + Q + \Delta S$$

$$Q_N = LE + H + G$$

Objective

Setting up and maintaining an operational network in the Netherlands that measures actual evaporation and soil moisture

- ✓ of high and known quality,
- ✓ for a representative set of combinations of land use, soil types, and groundwater levels.

Approach

Existing measurements

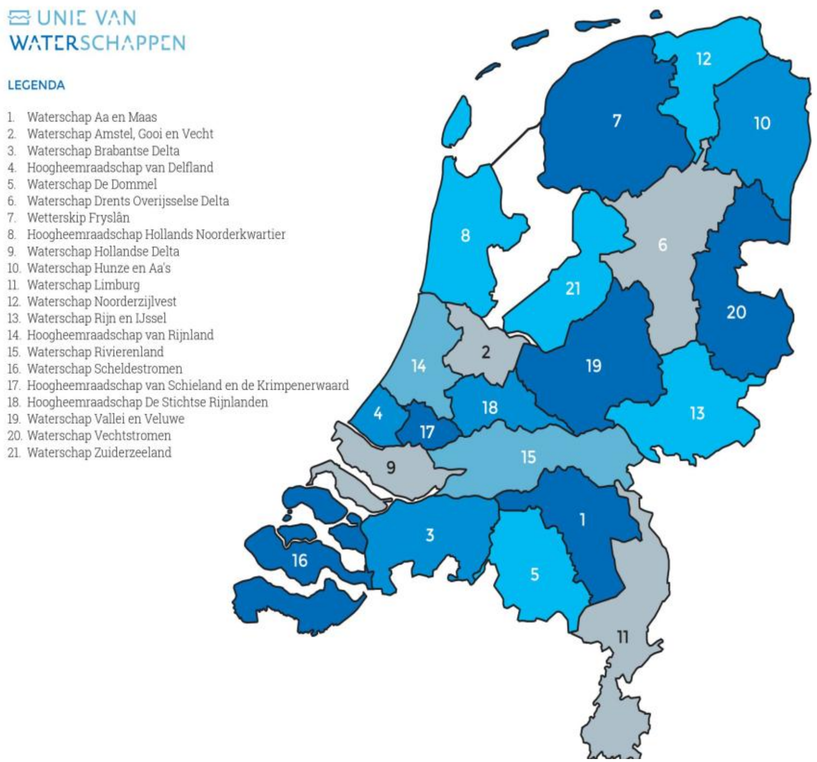
Nationaal Onderzoeksprogramma Broeikasgassen Veenweiden (NOBV)

Jansen et al. (2023) doi:10.1029/2022WR034361

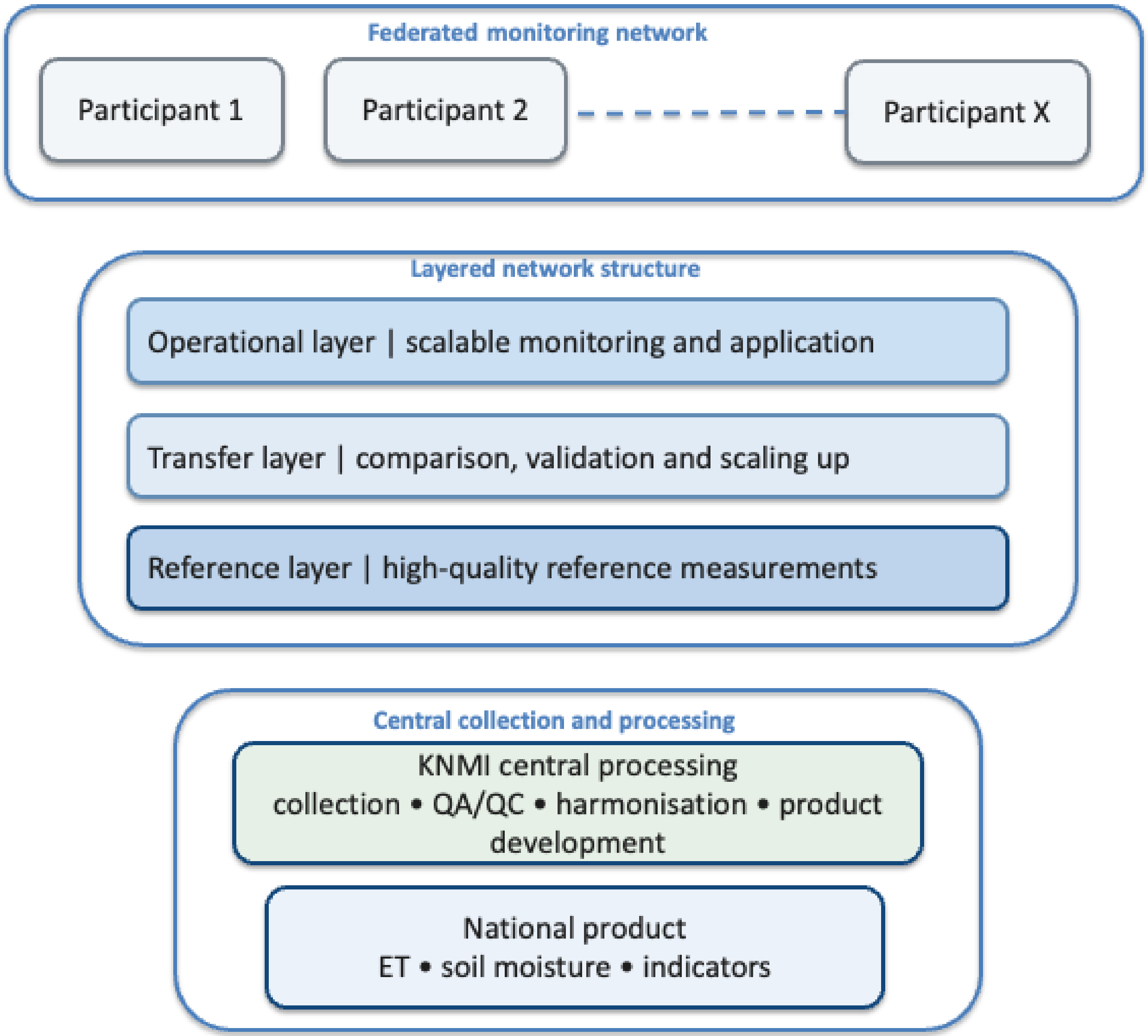
https://www.nobveenweiden.nl/

New measurements

Water boards



Drinking water companies


Federated monitoring network
Participant 1
Participant 2
Participant X
Layered network structure
Operational layer | scalable monitoring and application
Transfer layer | comparison, validation and scaling up
Reference layer | high-quality reference measurements
Central collection and processing
KNMI central processing
collection • QA/QC • harmonisation • product development
National product
ET • soil moisture • indicators

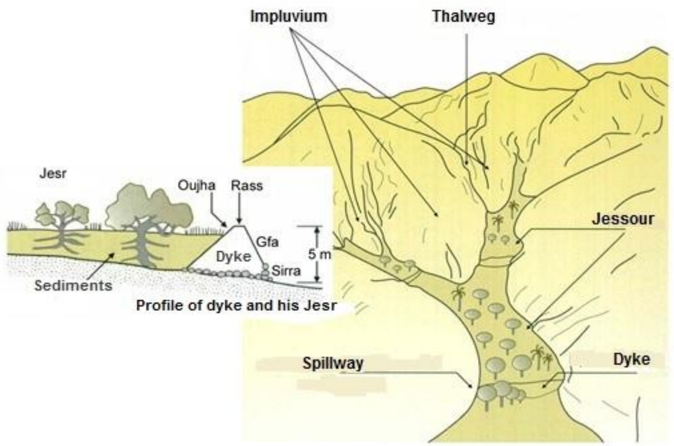
UNIVERSITÀ DEGLI STUDI FIRENZE

Water Harvesting Lab - University of Florence

Giulio Castelli, Lorenzo Villani, Elena Bresci

Case 1: **Remote sensing for monitoring of water harvesting / soil conservation systems in arid and data-scarce areas**

Jessour water harevsting systems in Tunisia



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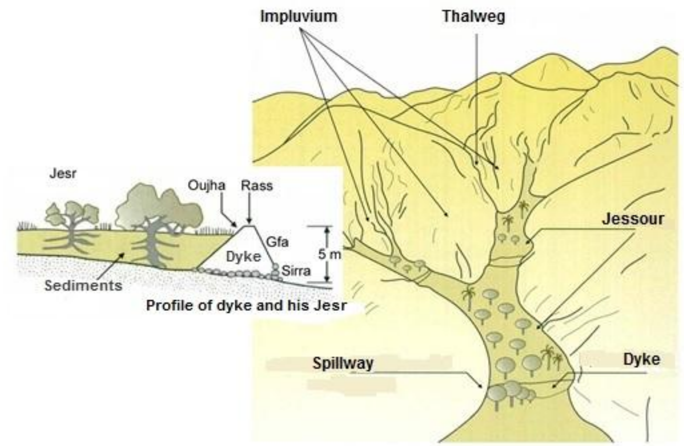

Soil moisture analysis at **site scale** (remote small-holder farm areas)

UNIVERSITÀ DEGLI STUDI FIRENZE

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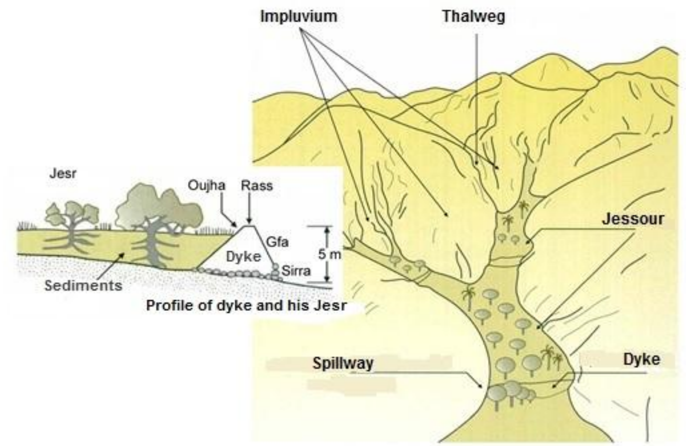

Soil moisture analysis at **site scale** (remote small-holder farm areas)

$$NDII = \frac{\rho_{0.85} - \rho_{1.65}}{\rho_{0.85} + \rho_{1.65}}$$

Analysis of **NDII index** (correlated to root-zone soil moisture in arid conditions) on **Google Earth Engine**

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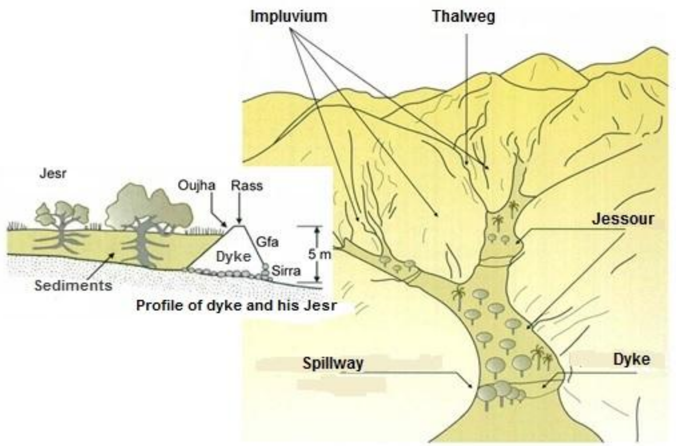

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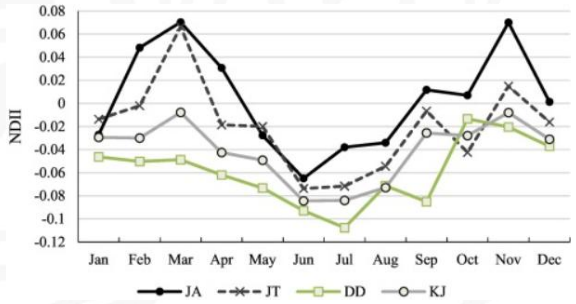
Jessour can **better hold soil moisture** in dry season



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Case 2: **Microclimate analysis (Mesoclimate)**
Mesoclimate regulation induced by water harvesting

$$WCI_i(y) = 1000\frac{NDII_i(y)}{R_{rs}(y)}$$

$$t_i(y) = {LST_i(y)}/{T_{850,i}(y)}$$

Calculation of a indeces of water conservation (WCI) and temperature (t), based on remote sensing databases

NDII – Normalised Difference Infrared Index from Landsat 7
Rrs – rainfall of rainy season from CHIRPS
LST – Lans Surface Temperature From MODIS
T850 – T @ 850hPa from ERA-INTERIM

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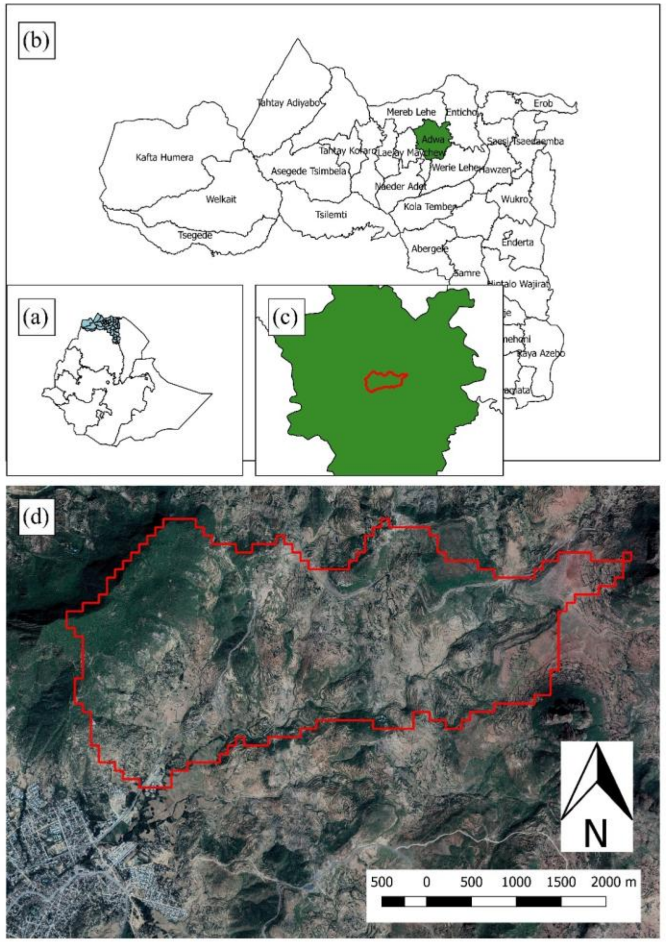

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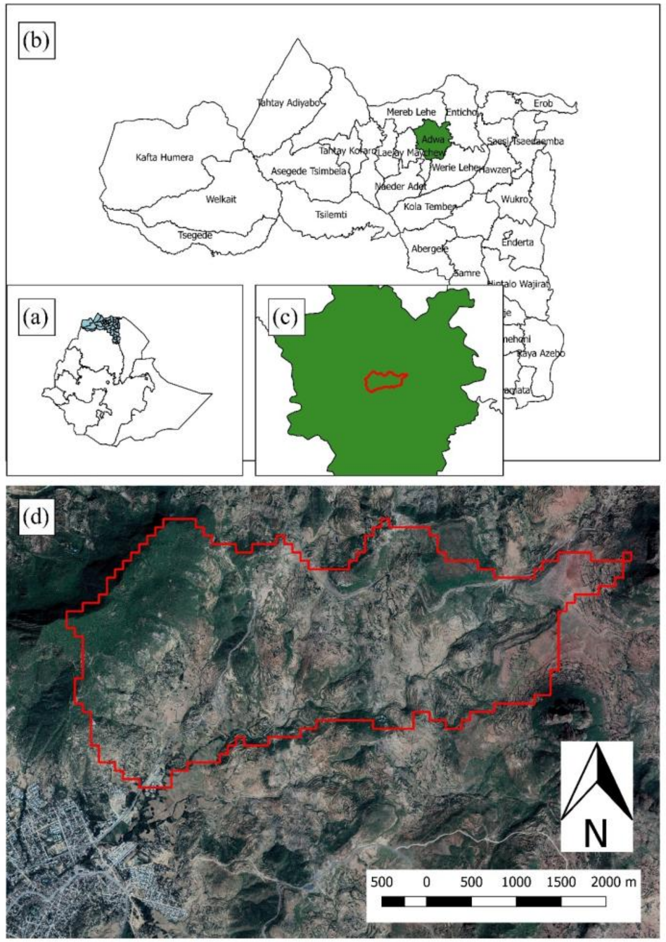
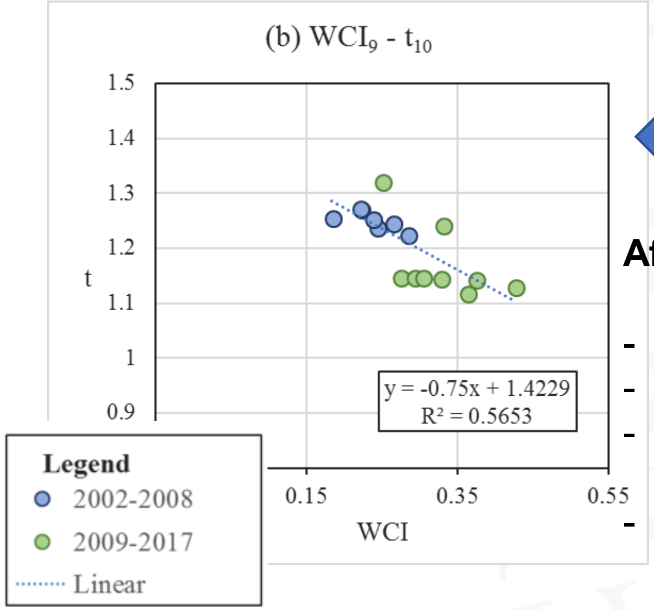
Analysis of a **catchment in semi-arid area (Ethiopia)** where **water harvesting** was **recently implemented** at **catcment scale**



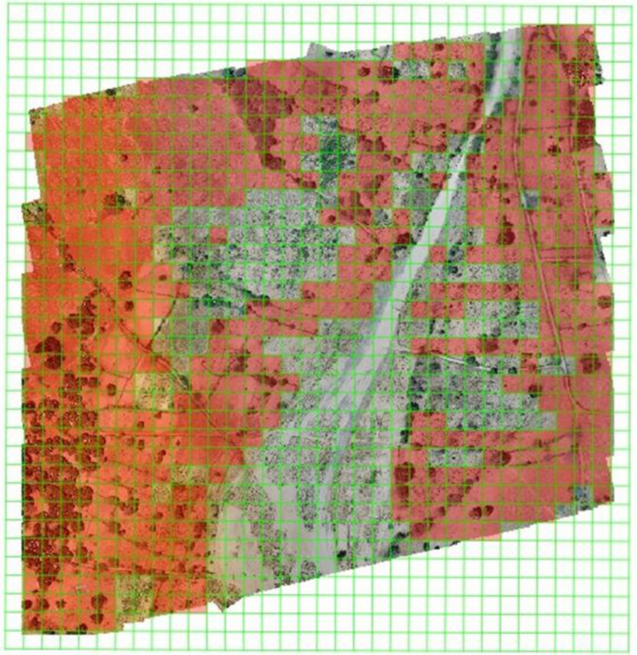


After WH implementation:

- WCI increases
- t decreases
- LST decreases

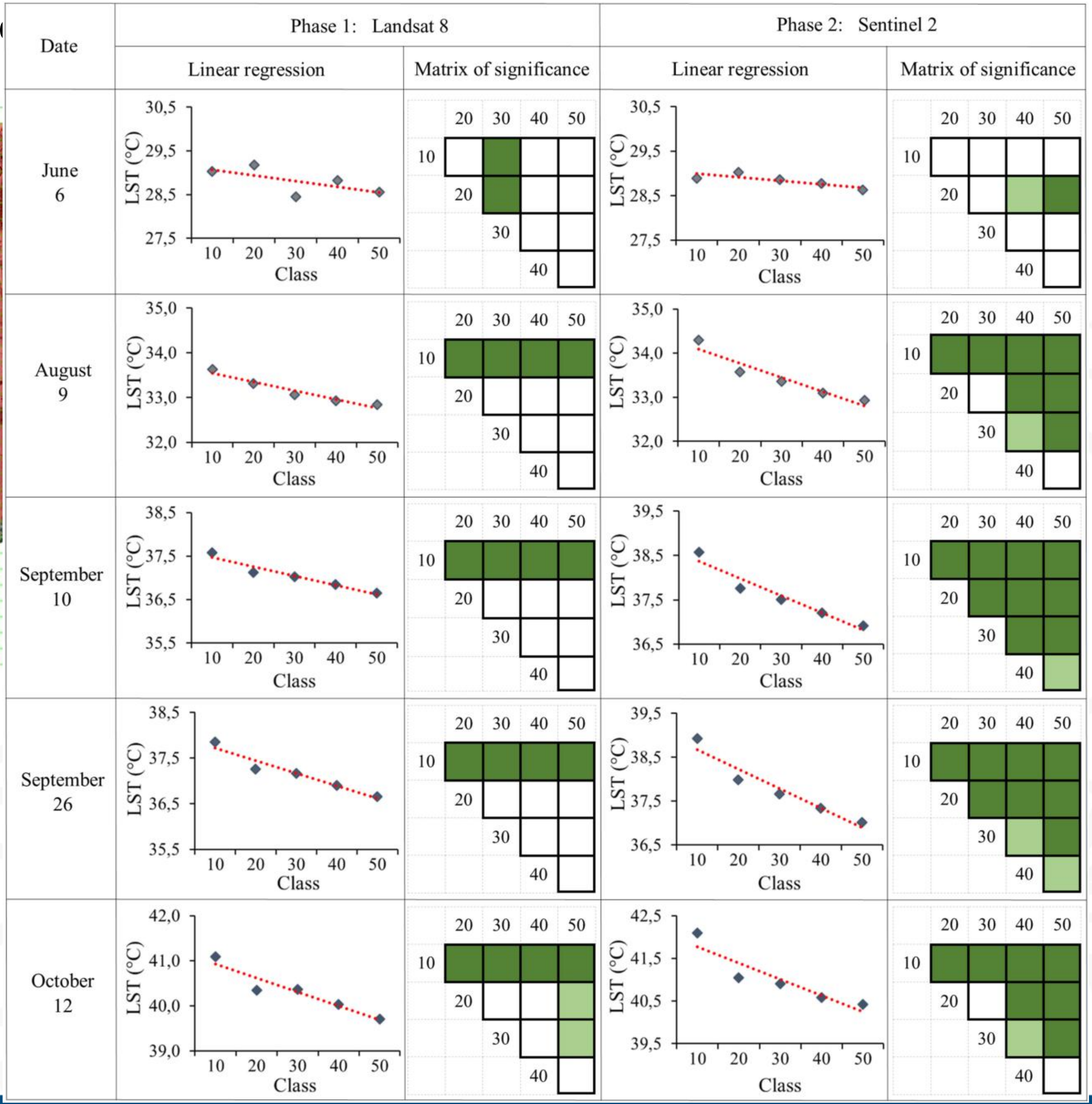
- **Soil Moisture – T** coupling deteted

Case 3: **Influence of trees on landscape temperature in semi-arid agro-ecosystems of East Africa**

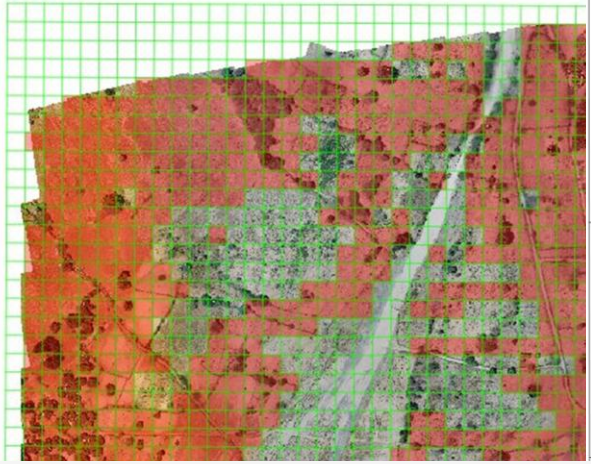


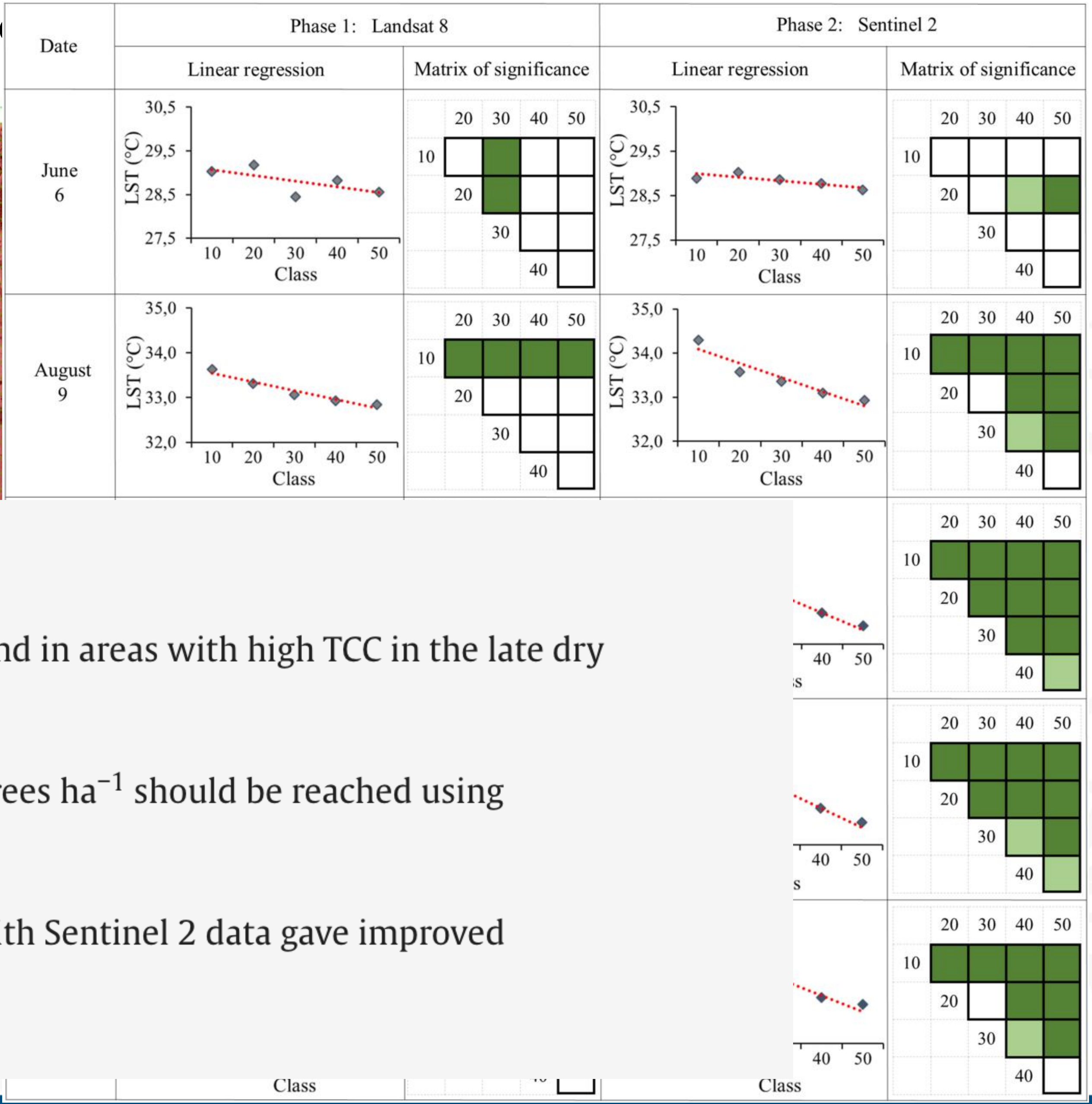
Drone analysis of Tree Canopy Cover (TCC) and use of **Landsat 8 and Sentinel 2** data for NDVI and Land Surface Temperature (LST)

Case 3: **Influence of trees on landscape temperature in semi-arid agro-ec**



Case 3: Influence of trees on landscape temperature in semi-arid agro-ec





Highlights

- LST decrease of 1.32 °C found in areas with high TCC in the late dry season.
- 10% TCC threshold, or 50 trees ha^{-1} should be reached using restoration.
- Integration of Landsat 8 with Sentinel 2 data gave improved analysis.

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Discussion

- Defining scope and scale
  - What falls within scope and what doesn't?
- Looking ahead: toward a roadmap
  - What could this group do together, and how?