Water Monitoring v2.0

Innovations through Local Involvement & Remote Sensing

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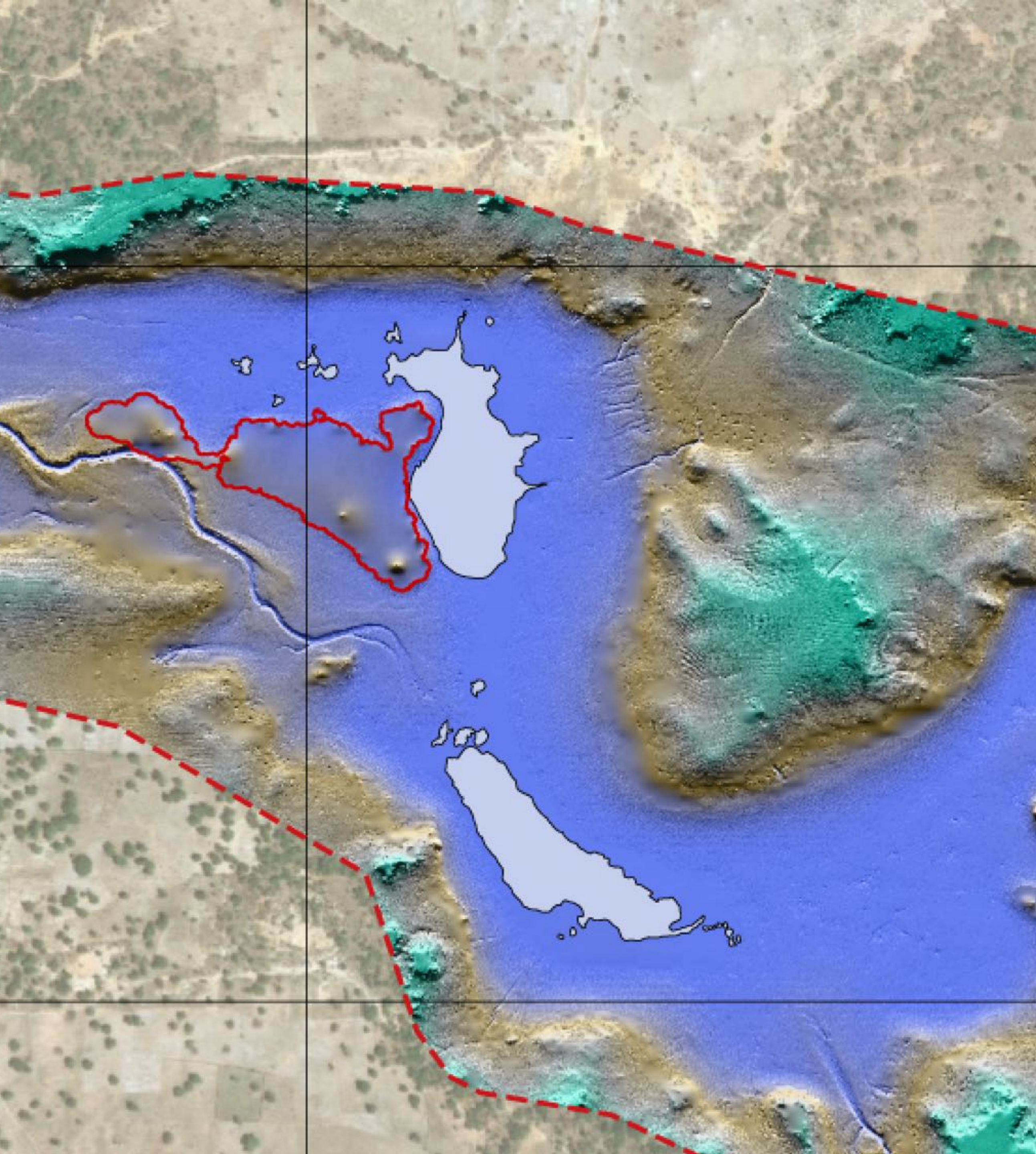
Overview

- Innovative Complementary Monitoring
    - Monitoring through local involvement
    - Remote Sensing
- Water Balance Applications
    - Changes in Water Storage
    - Water Accounting
- Operationalization & Private Sector Dev.
- Challenges & Risks
- Conclusions



Integral Monitoring

IN-SITU STATIONS

PEOPLE'S INVOLVEMENT

REMOTE SENSING

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In-Situ Stations

- Normally, expensive acquisition.
- Operation & maintenance challenges
- Vandalism

iMoMo

- Global initiative
- Incubated by the Swiss Agency for Development and Cooperation (SDC).
- Supported by the World Meteorological Organization (WMO).
- Successful applications in Ethiopia, Kenya, Tanzania, Uganda, Mali, Mozambique, Kyrgyzstan, Uzbekistan, China. etc.

Schweizerische Eidgenossenschaft
Confédération suisse
Confederazione Svizzera
Confederaziun svizra

Swiss Agency for Development and Cooperation SDC

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People's Involvement

- Monitoring conducted, in whole or in part, by amateurs and/or non-professionals.
- Data is acquired through local involvement, rather than through automatic sensors.

- Example: iMoMo Mozambique

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- **Example: iMoMo Mozambique**

People's Involvement

- **Example: iMoMo Mozambique**

  Emilio measuring water depth with a simple ruler.

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People's Involvement

- **Example: iMoMo Mozambique**

  José writing the measurements in a notebook. The notebook was regularly photographed by an extension officer who typed it into Excel, carried out quality control and then shared it with responsible persons.

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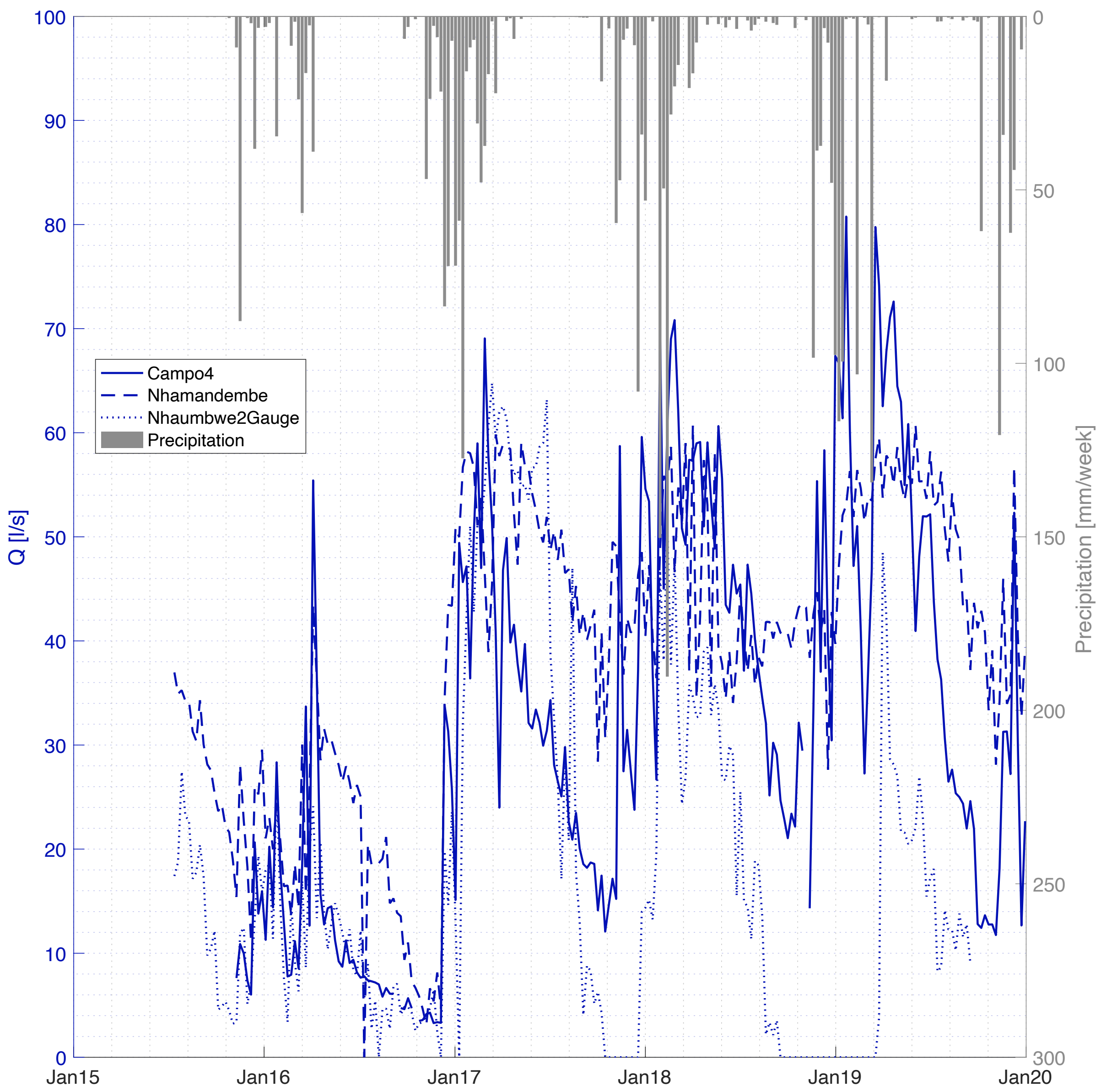
People’s Involvement

- **Example: iMoMo Mozambique**

  Resulting 5-year timeseries enabled to measure water productivity at field scales and to help local farmers to improve water use efficiency.



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People's Involvement

- The same workflow applies to other low-cost sensors.

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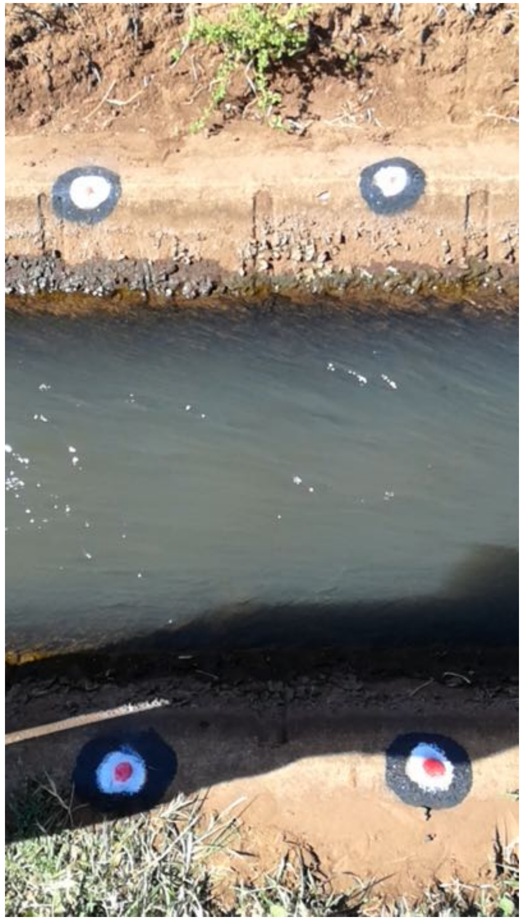
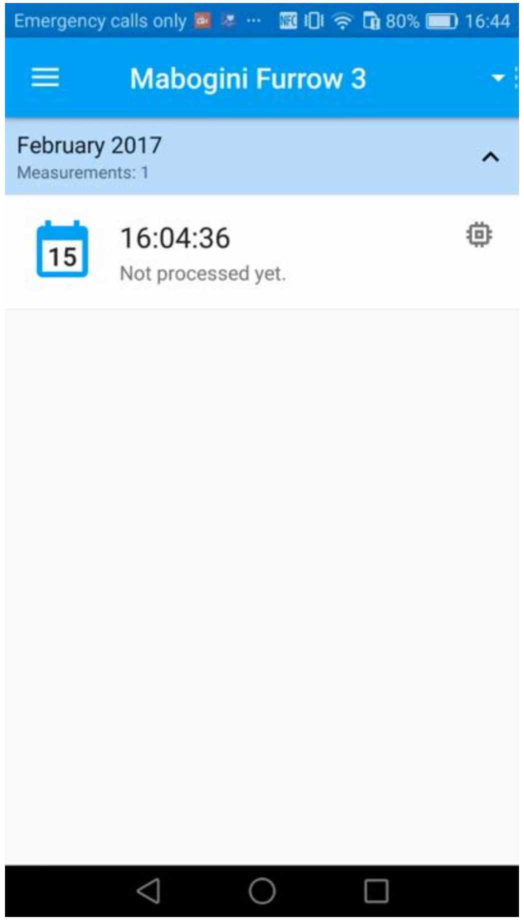
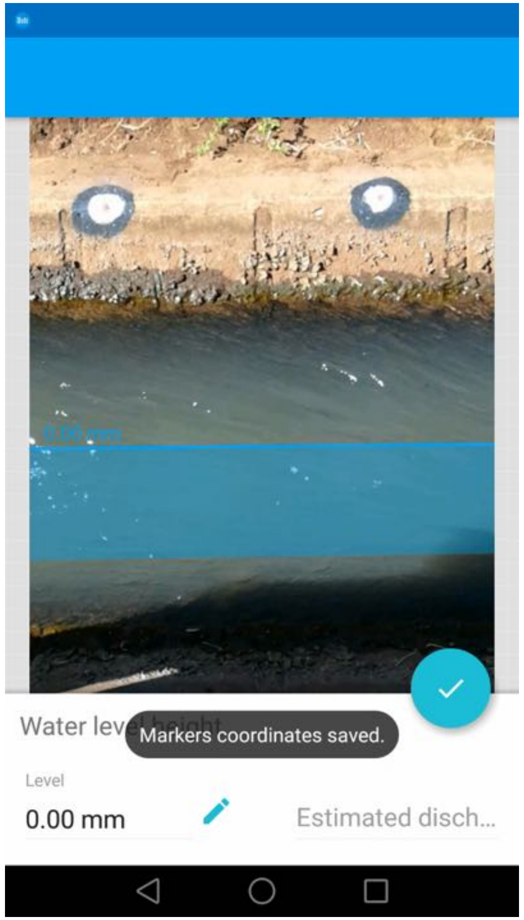
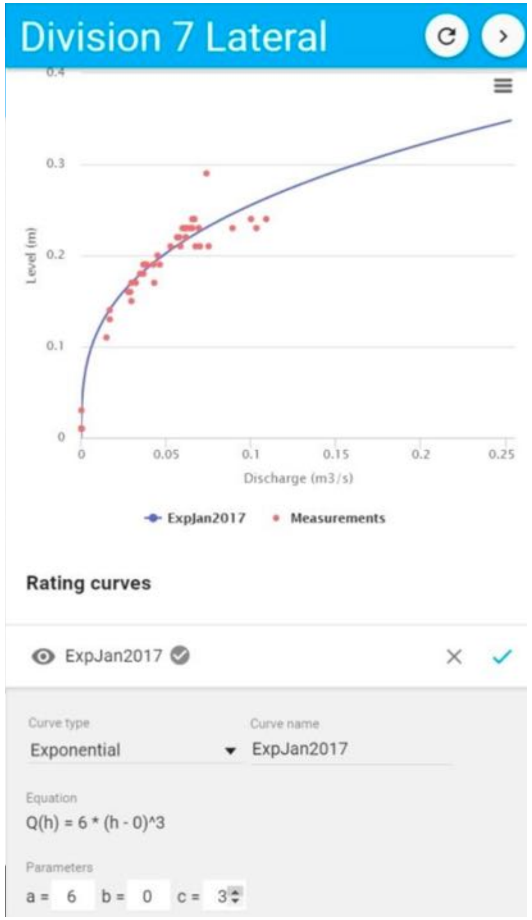
discharge.ch

Measuring water level and discharge in a canal with your smartphone.



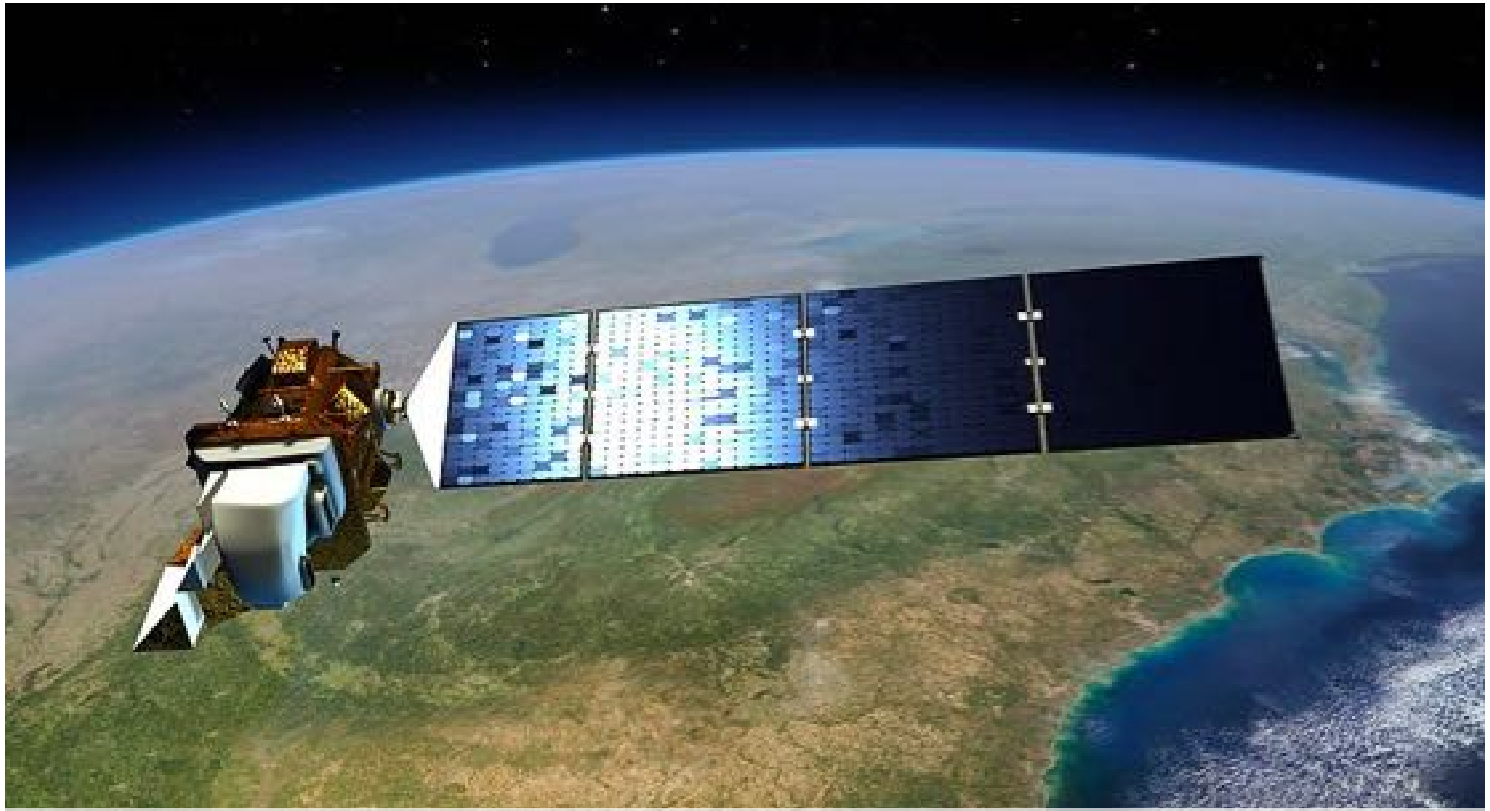






Challenges & Risks

- Monitoring through local involvement
  - No free lunch
  - Careful co-design of monitoring protocols with locals required
  - Data quality control and assurance of utmost importance
  - Establishment of a clear communication chain
  - Cross-agency collaboration can create synergies
  - Requirements for certification?



Source: ESA

Remote Sensing

- Objective Observations
- Systematic data in space & time
- Multiple spatial scales, economies of scale
- Accessibility (open-source) & cloud-based delivery
- Integration into models, GIS und WIS

Remotely Sensed Variables of Interest for the Water Manager

Directly Observable
Land cover and changes
Irrigated areas and crop types
Soil moisture
Soil Salinity
Precipitation
Lake/reservoir levels and volume changes
Snow cover extent & dynamics

Derived Variables
Water use (evapotranspiration)
Crop health, incl. plant water stress / need
Irrigation performance indicators
Crop production / yield
Local high-quality meteorological forecasts
Compound climatic events & agricultural risks

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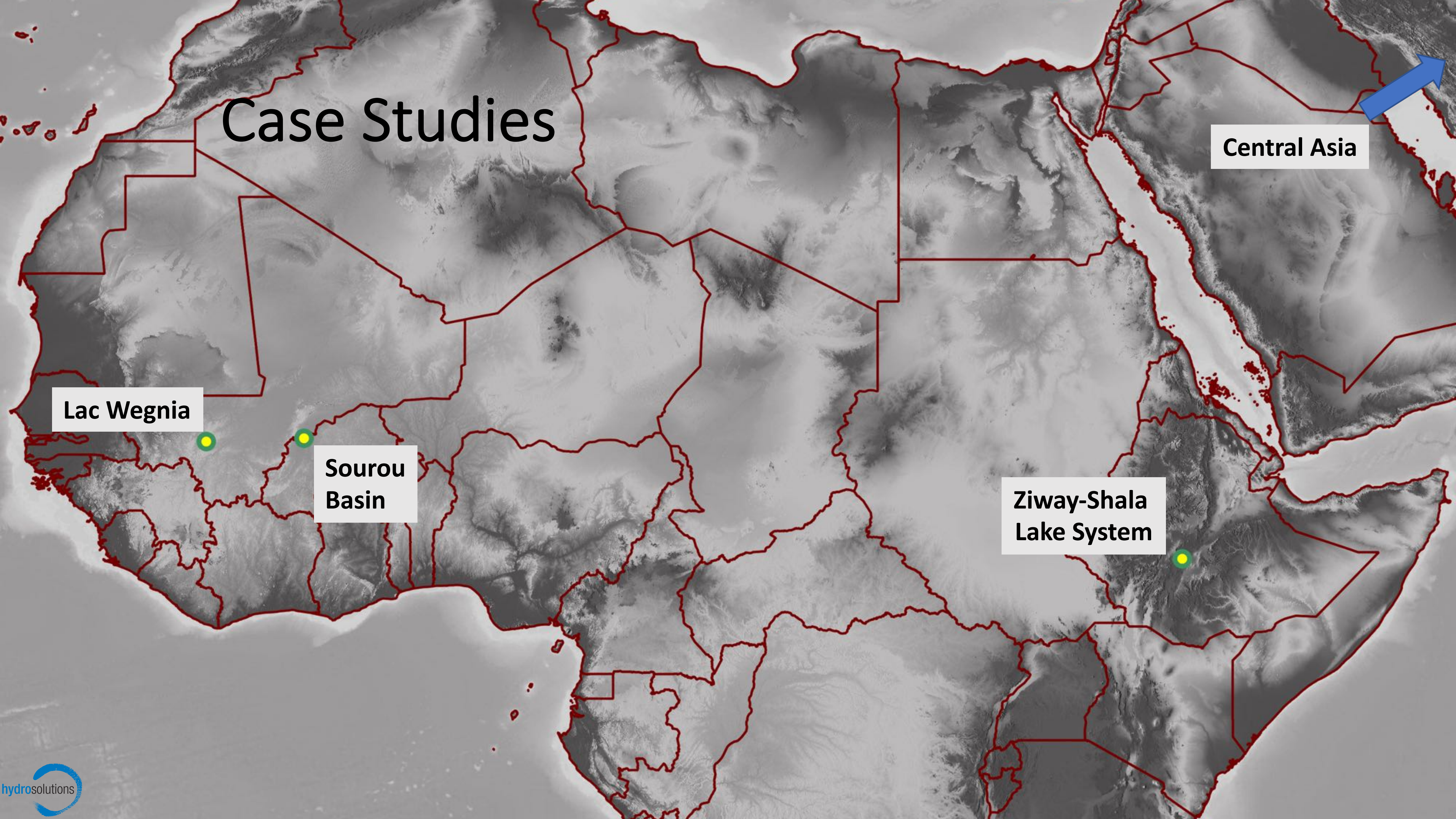
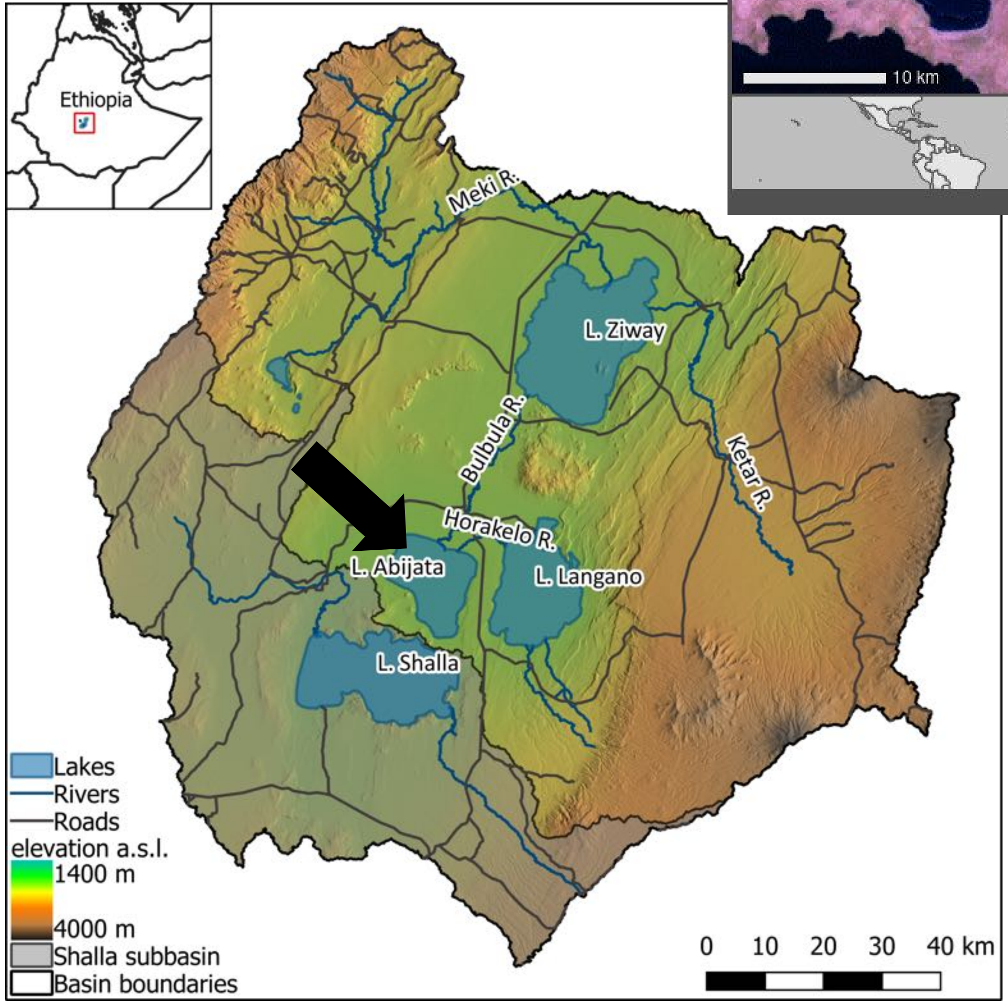
Case Studies

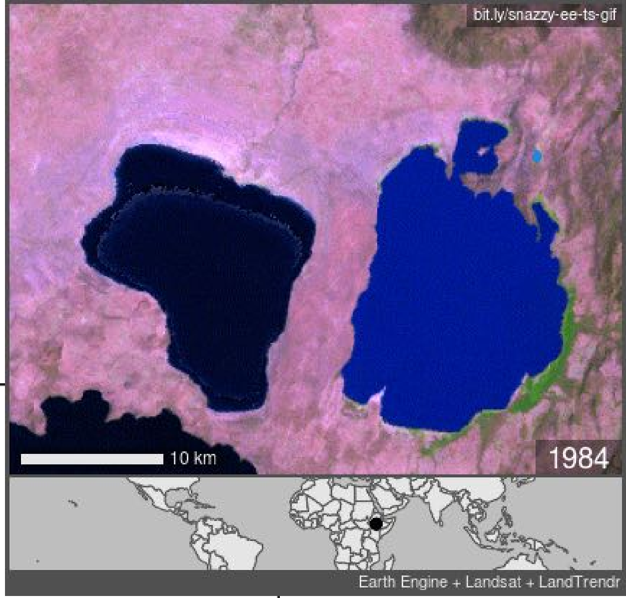


Lake Abijata, Ziway-Shala Lake System, Ethiopia

Measuring Storage Changes

- **Place**: Lake Abijata in the Ethiopian Rift Valley
- **Problem**: Vanishing endhorreic lake, lack of in-situ measurements
- **Challenge**: Spotty, erroneous data record





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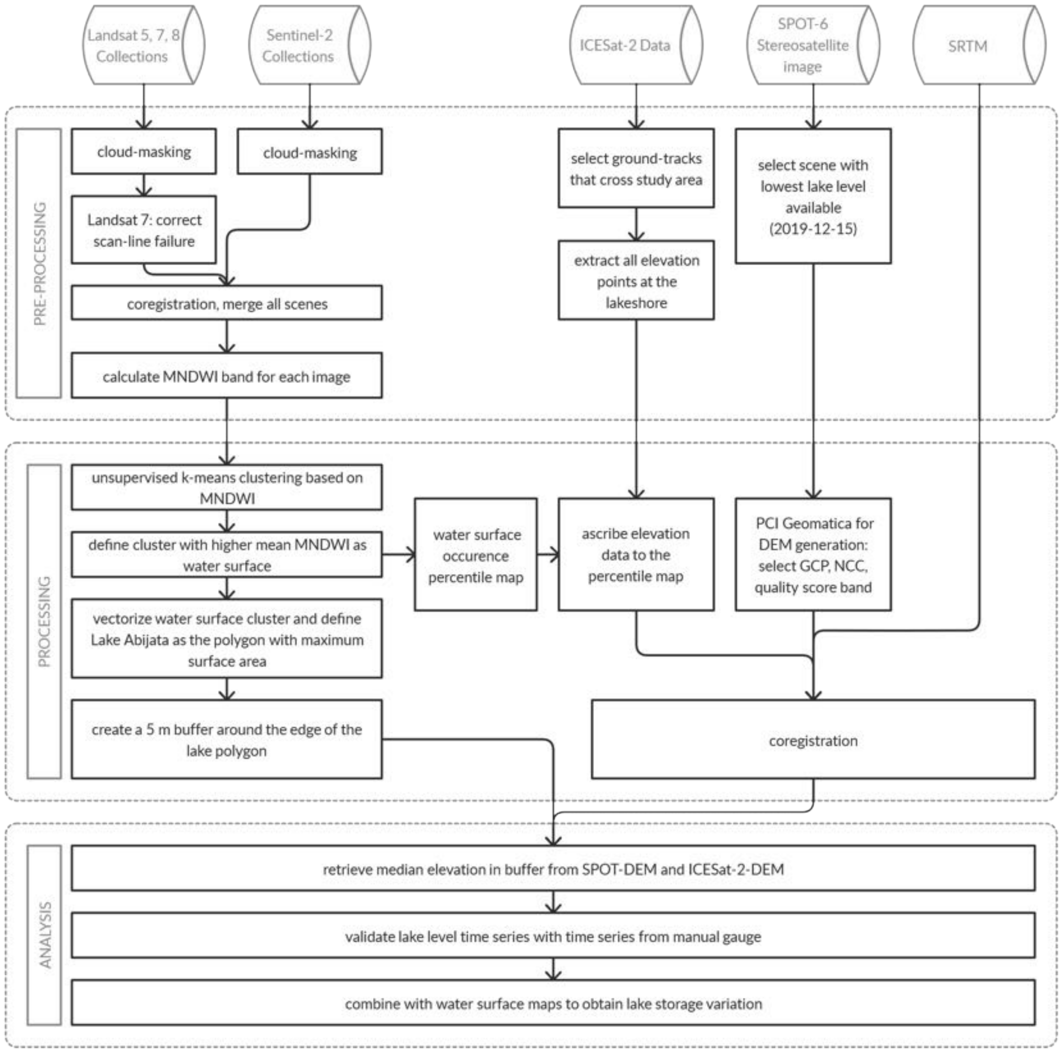
Lake Abijata, Ziway-Shala Lake System

- Sensors: Landsat 5/7/8, Sentinel 2, ICEsat 2
- **A-E-V Approach**: Multi-sensor data for the computation of lake area, elevation and storage volume over time



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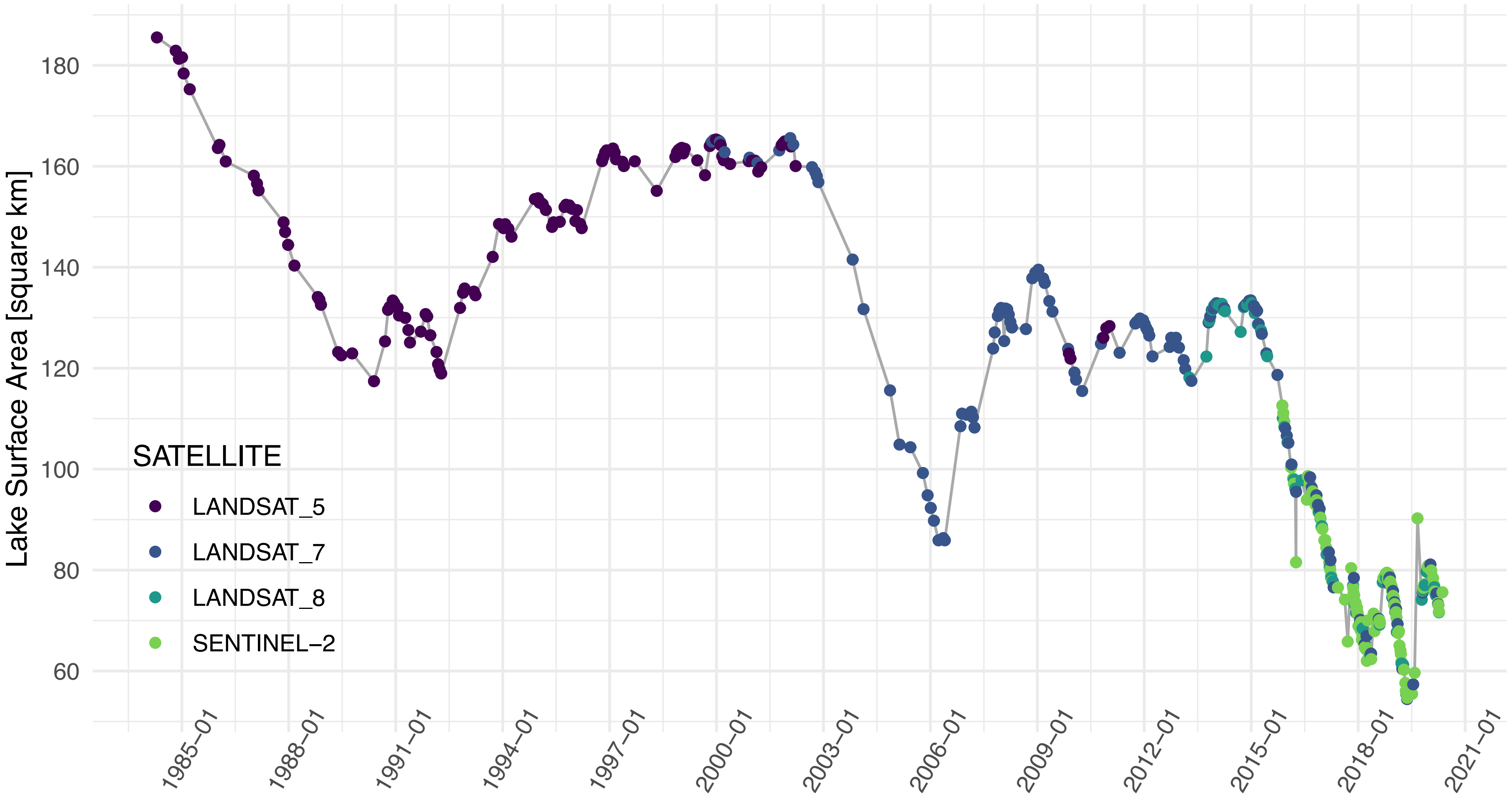
Lake Abijata, Ziway-Shala Lake System

- Surface area decline from 186 km^2 in 1984 to 54 km^2 in 2019



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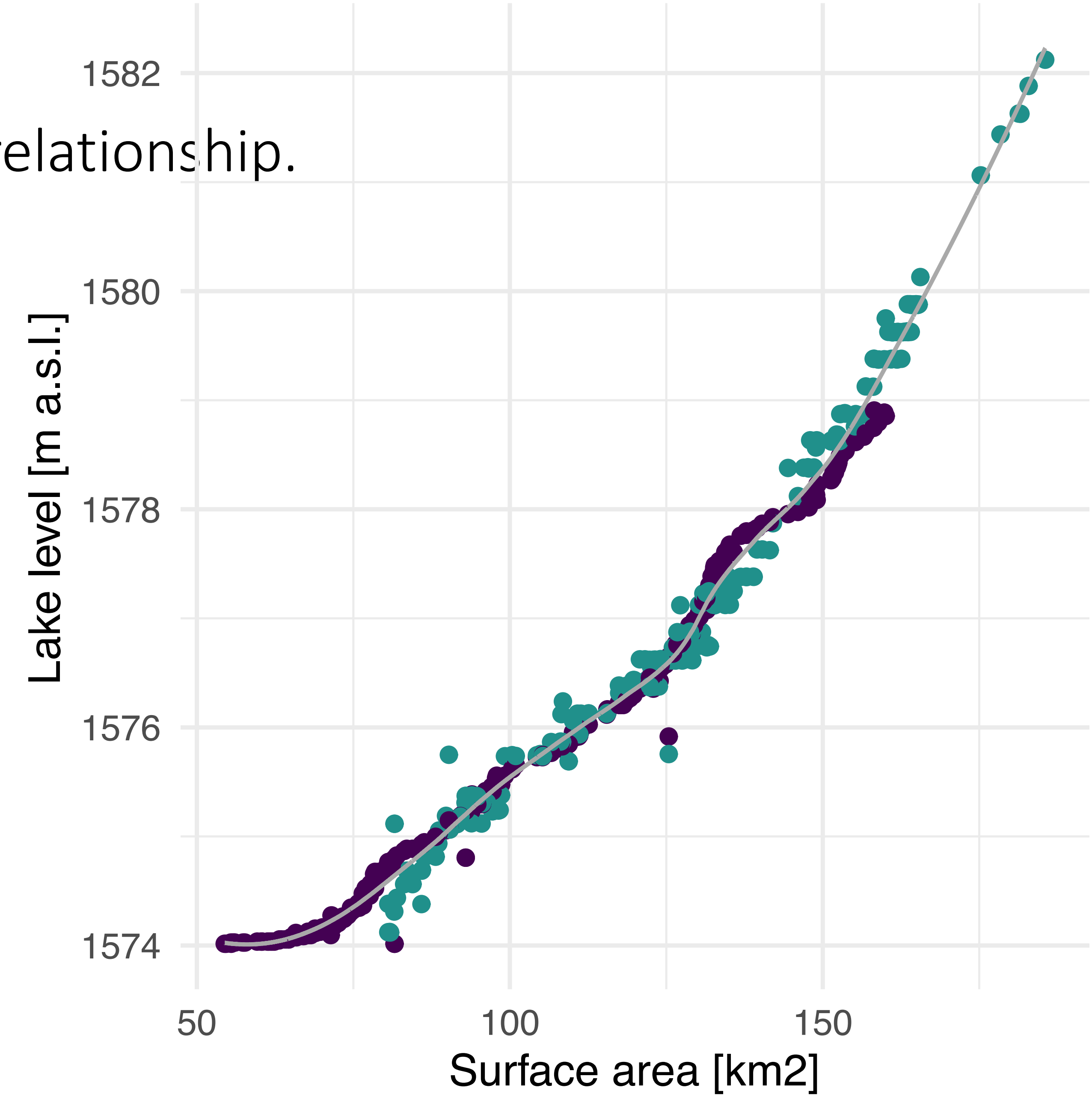
- Derivation of water level – area relationship.



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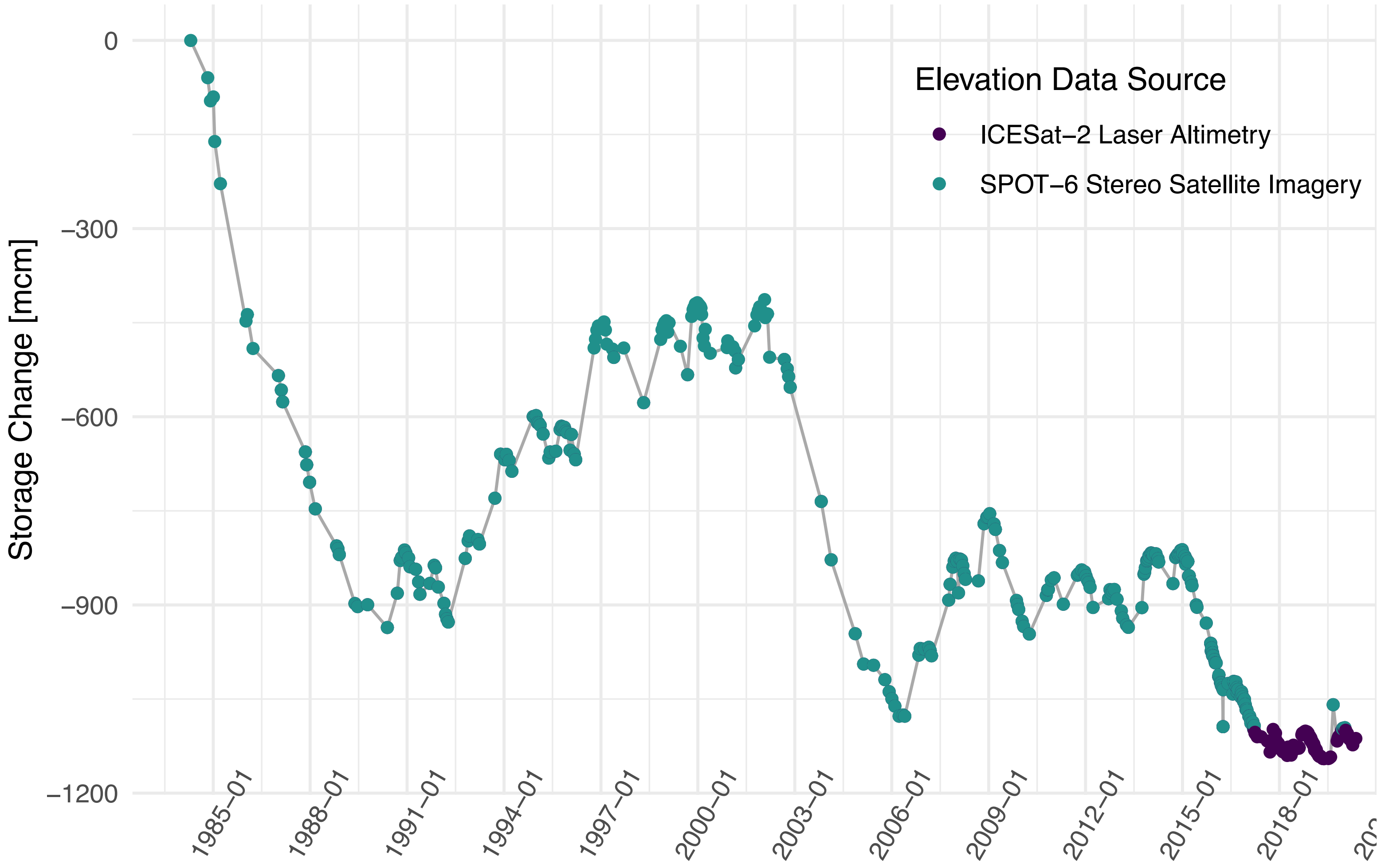
Lake Abijata, Ziway-Shala Lake System

- Signficant lake storage loss over observation period of **-1’100 mcm**



→ Implications IWRM

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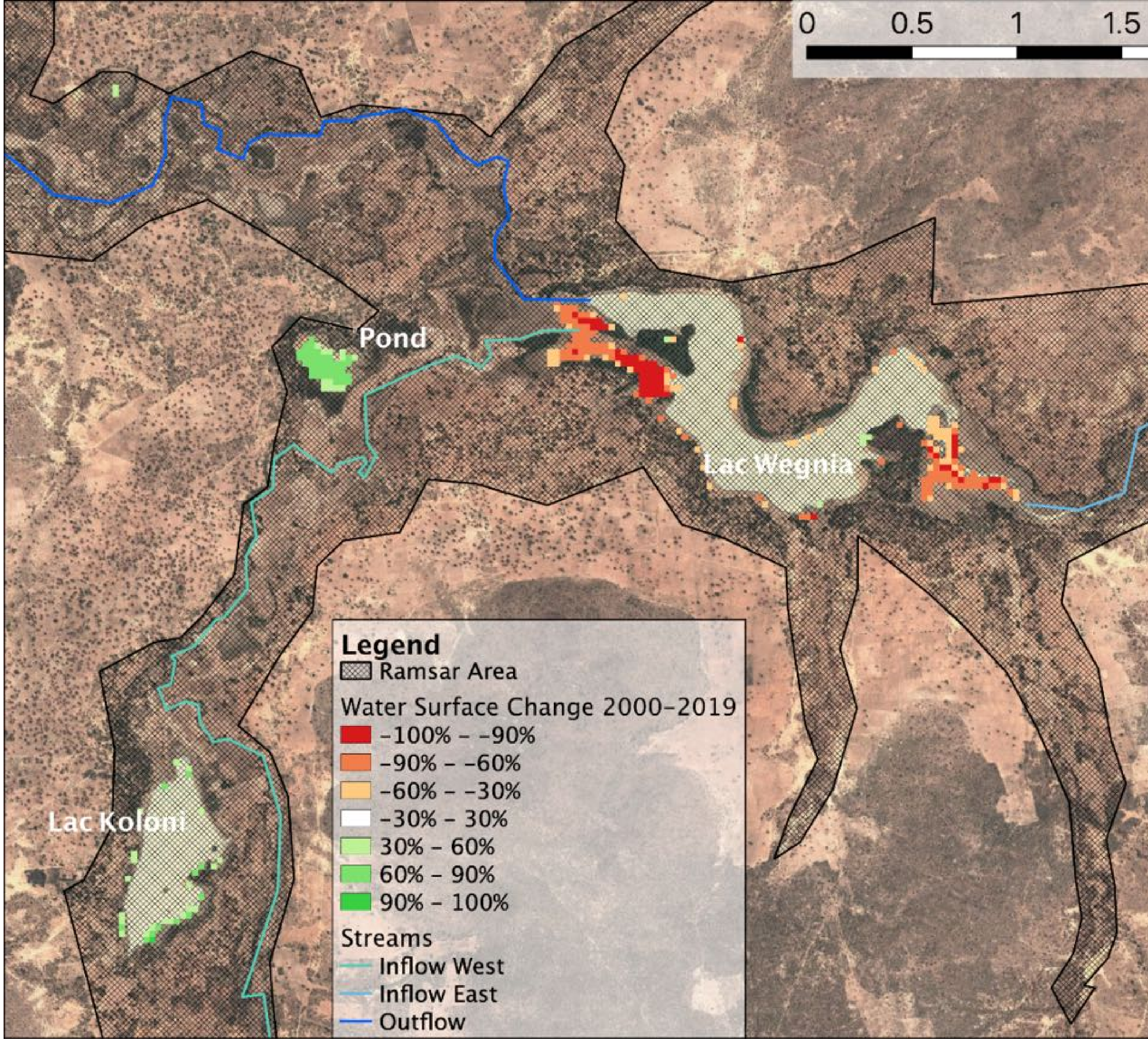
Lac Wegnia, Ramsar Site in Mali

Water Accounting

- **Place**: Lac Wegnia, Mali
- **Problem**: Vanishing shallow lake aquatic ecosystem posing a threat to local livelihoods.
- **Task**: Attribution analysis to ensure ecologically sustainable water resources management and the protection of the Ramsar site.
- **Challenge**: No observational record.



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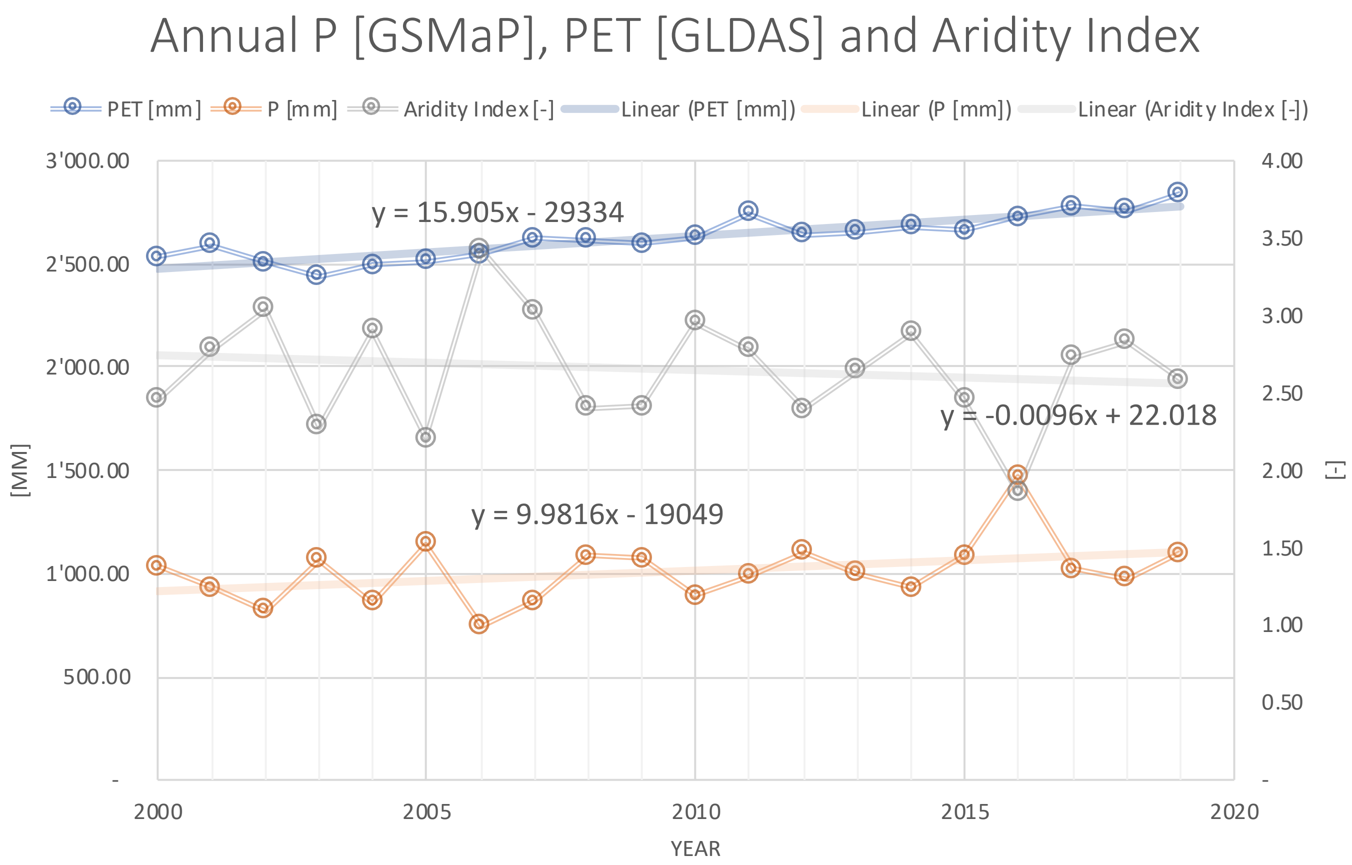
Basin Climate Characteristics

- Data from Reanalysis for years 2000 - 2020
- Mean annual P: 1’009 mm
- Mean annual PET: 2’627 mm
- Aridity Index: 2.6
- PET and P show an important increasing trend over the last 20 years!



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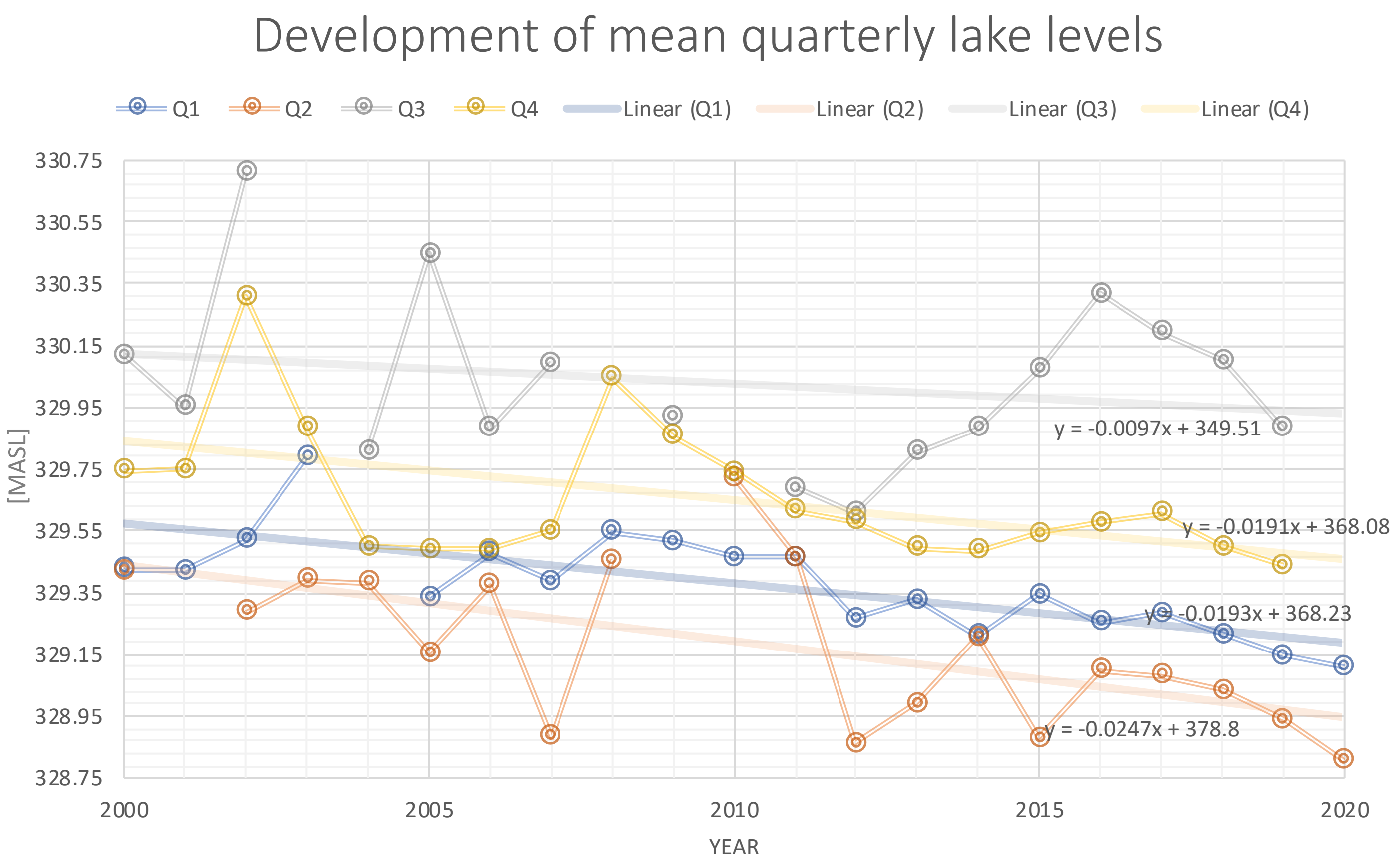
Development of Lake Levels

- Quarterly lake levels and their trends are shown from 2000 – 2020.
- Despite the slightly increasing precipitation levels in the catchment, decreasing lake level trend detected in all quarters.
- Increasing likelihood of lake drying completely out towards the end of the dry season.



High-Resolution Digital Terrain Model

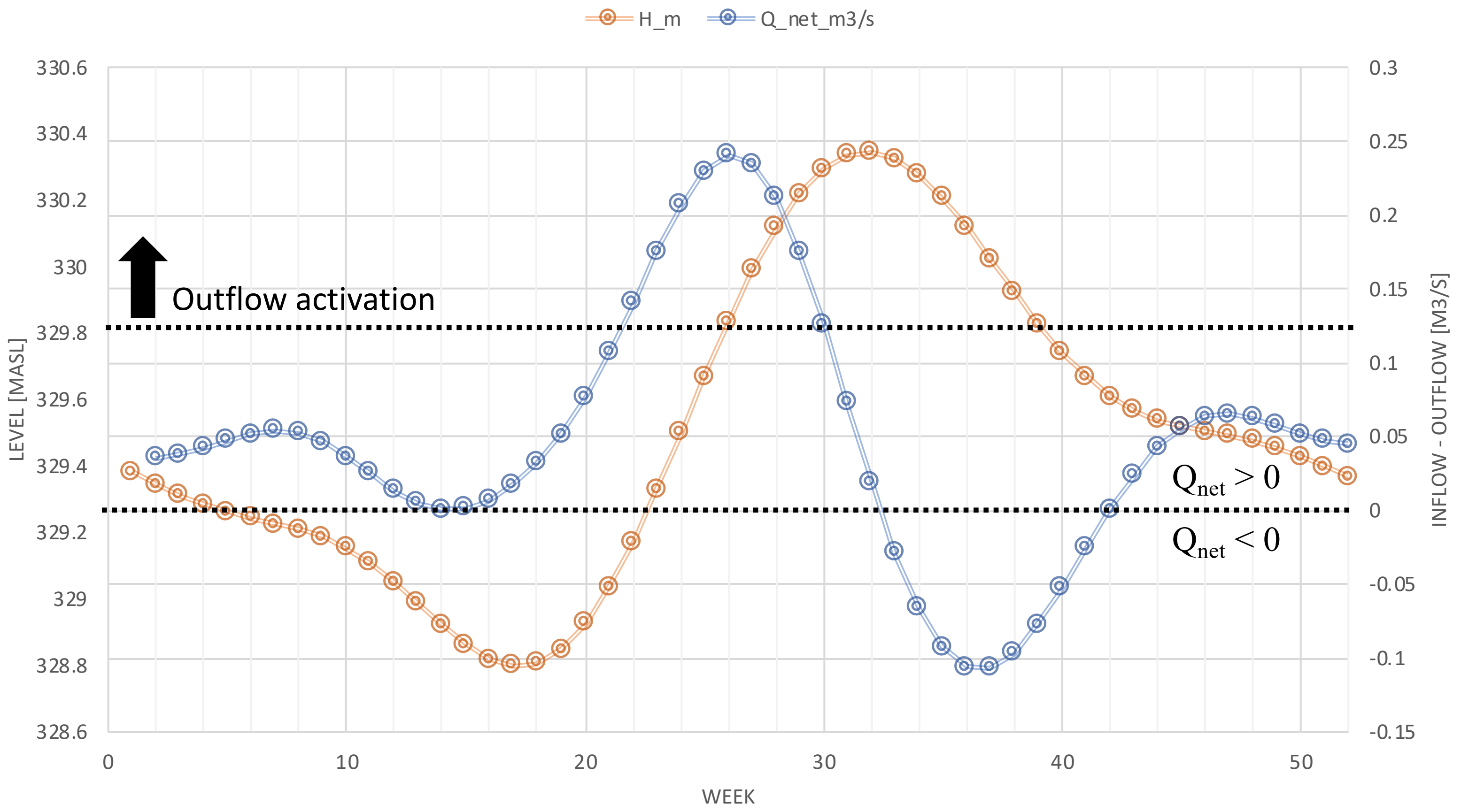
Airbased remote sensing with a drone. Centimeter scale spatial resolution.

Lake Level and Inflow-Outflow Variations

- $\Delta V = (P\text{-}ET) + (Q_{in}\text{-}Q_{out}) + \varepsilon$

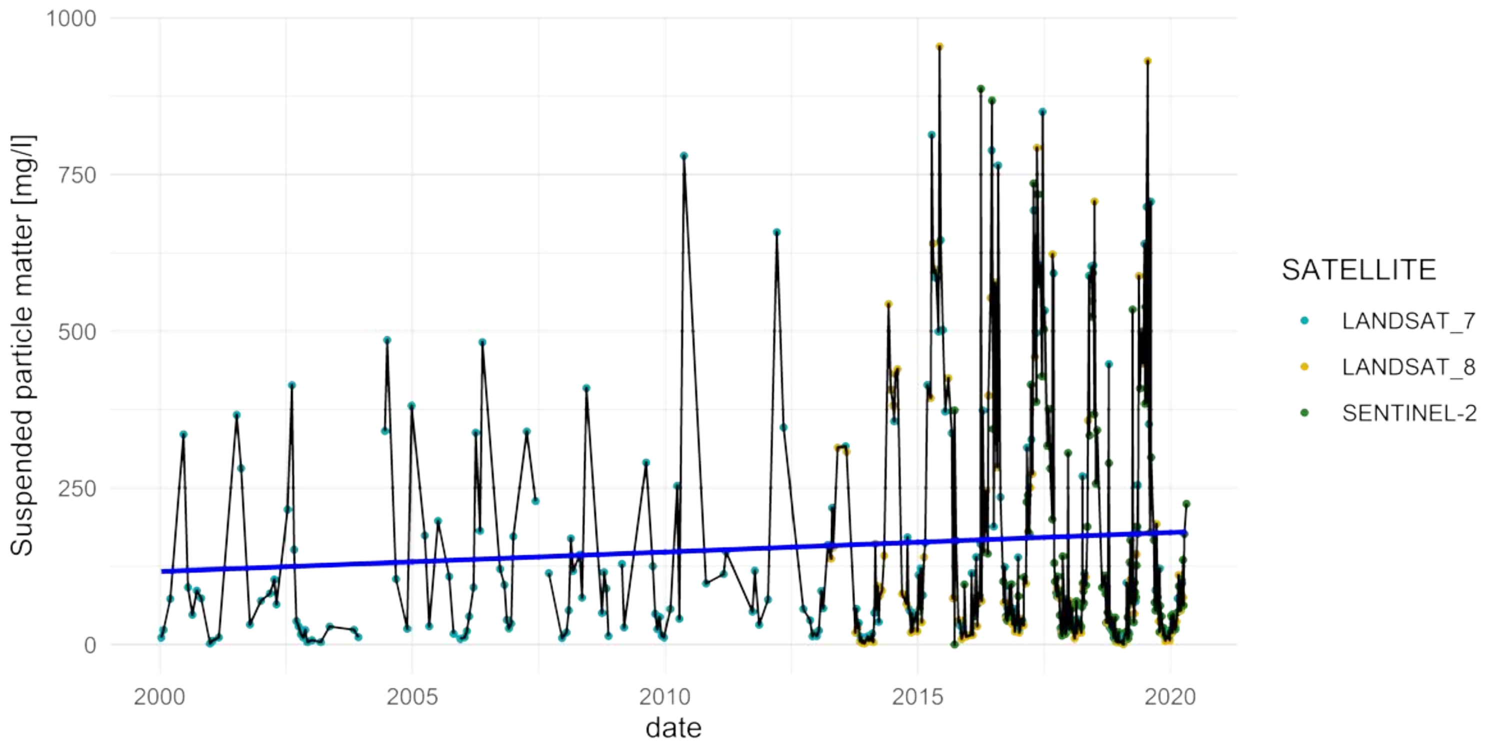
A-E-V   Re-analysis   ⇒ Result

- Water balance closure using A-E-V approach in combination with reanalysis data!
- **Conclusion:** Increase lake water depth at end of rainy season to store more water
in order to prevent the lake from entirely drying out.



Understanding Sedimentation from Remote Sensing

- Increasing trend of suspended particle matter in the lake
- Increasing erosion processes in the catchment?
- => Estimating sedimentation rates in Lac Wegnia is possible!



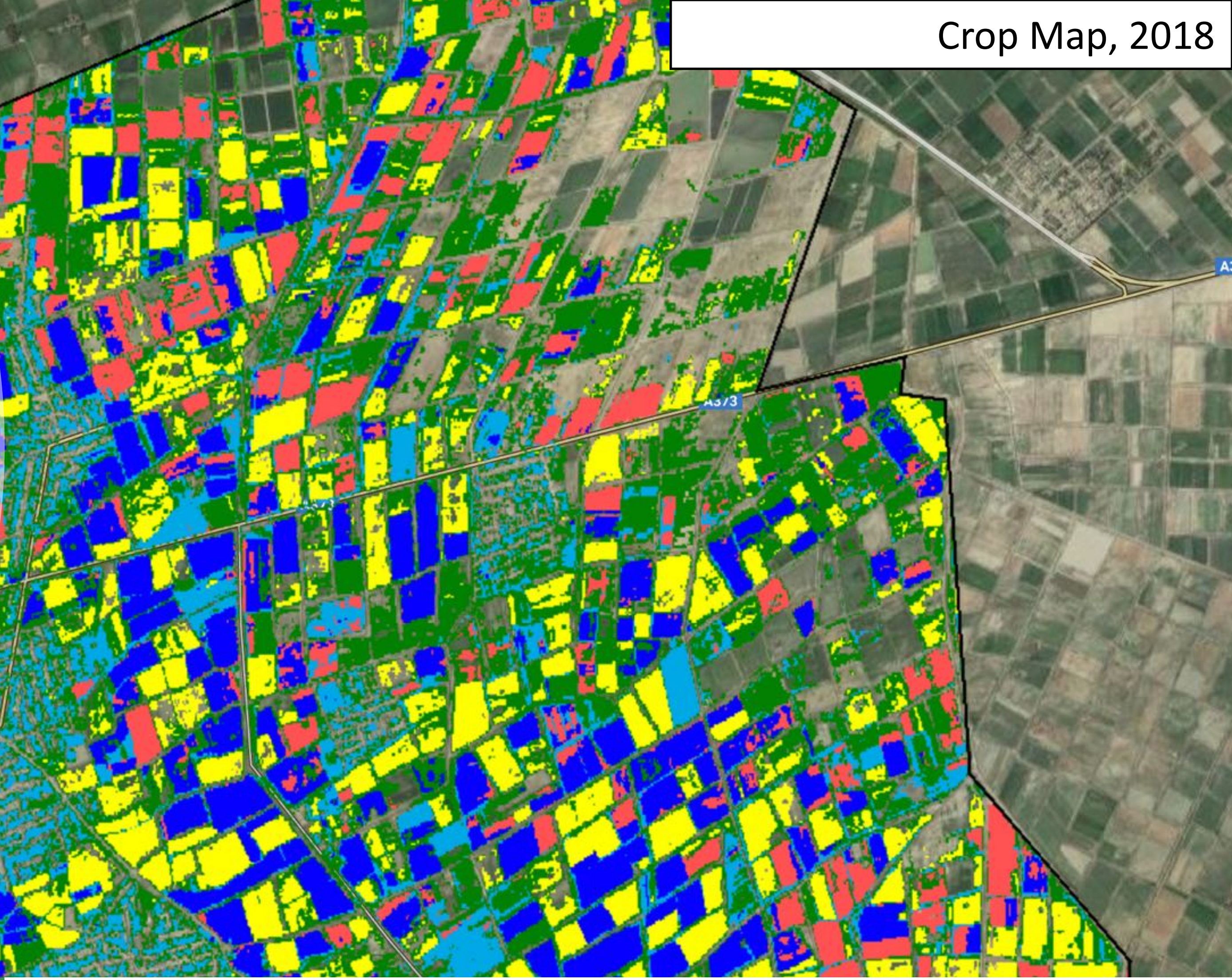
Increasing trend in sediment concentration observed in Lac Wegnia.
Source: hydrosolutions ltd., Google EarthEngine

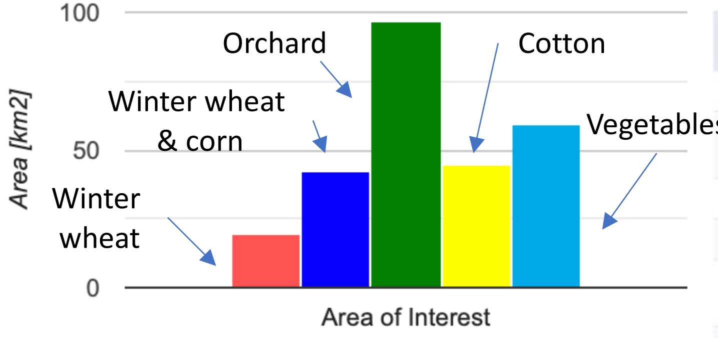
Fergana Valley, Central Asia

Mapping Field Level & Crop Specific Water Balances

- Unsupervised machine learning approach for classification of crops on irrigated land.
- Water balance assessments can be carried out at different levels of aggregation for areas of interest, i.e. agricultural fields, canal command areas, for specific crops and district-level aggregates, etc.

Crop Map, 2018





Cluster ID	Crop Type	Area (km2)	Area (%)	ET (mm)	P (mm)
1	Winter Wheat	19.249	7.342	978	204
2	Dbl Crop WinWht/Corn	42.566	16.236	1,157	204
3	Orchard	96.346	36.75	1,001	204
4	Cotton	44.591	17.008	959	204
5	Misc Vegs & Fruits	59.417	22.664	1,113	204

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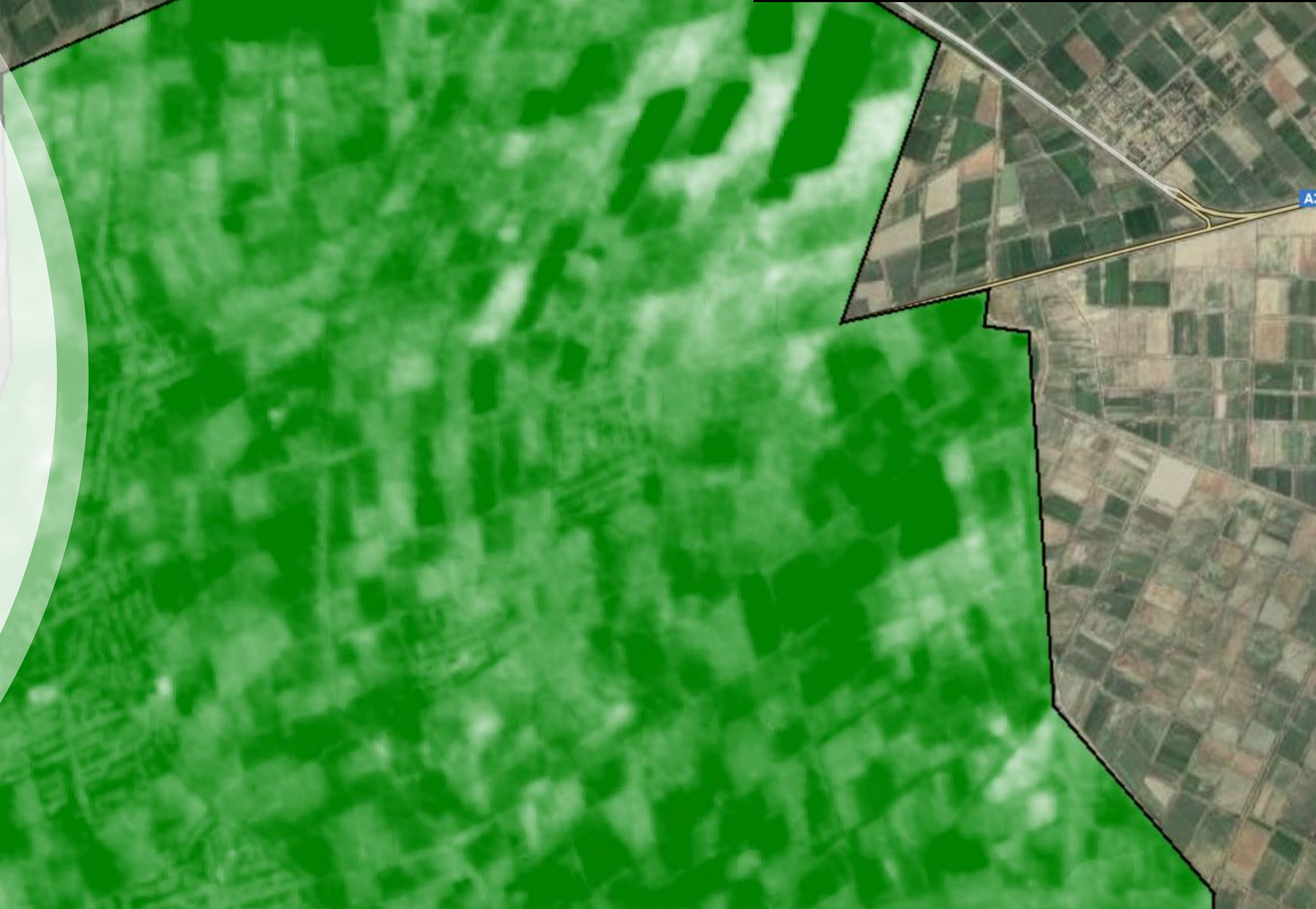
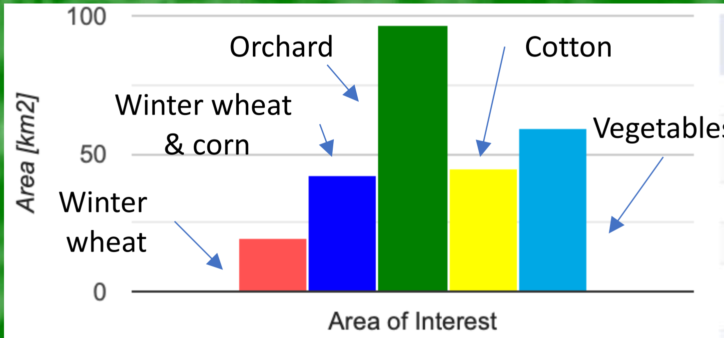
Evapotranspiration Map, 2018





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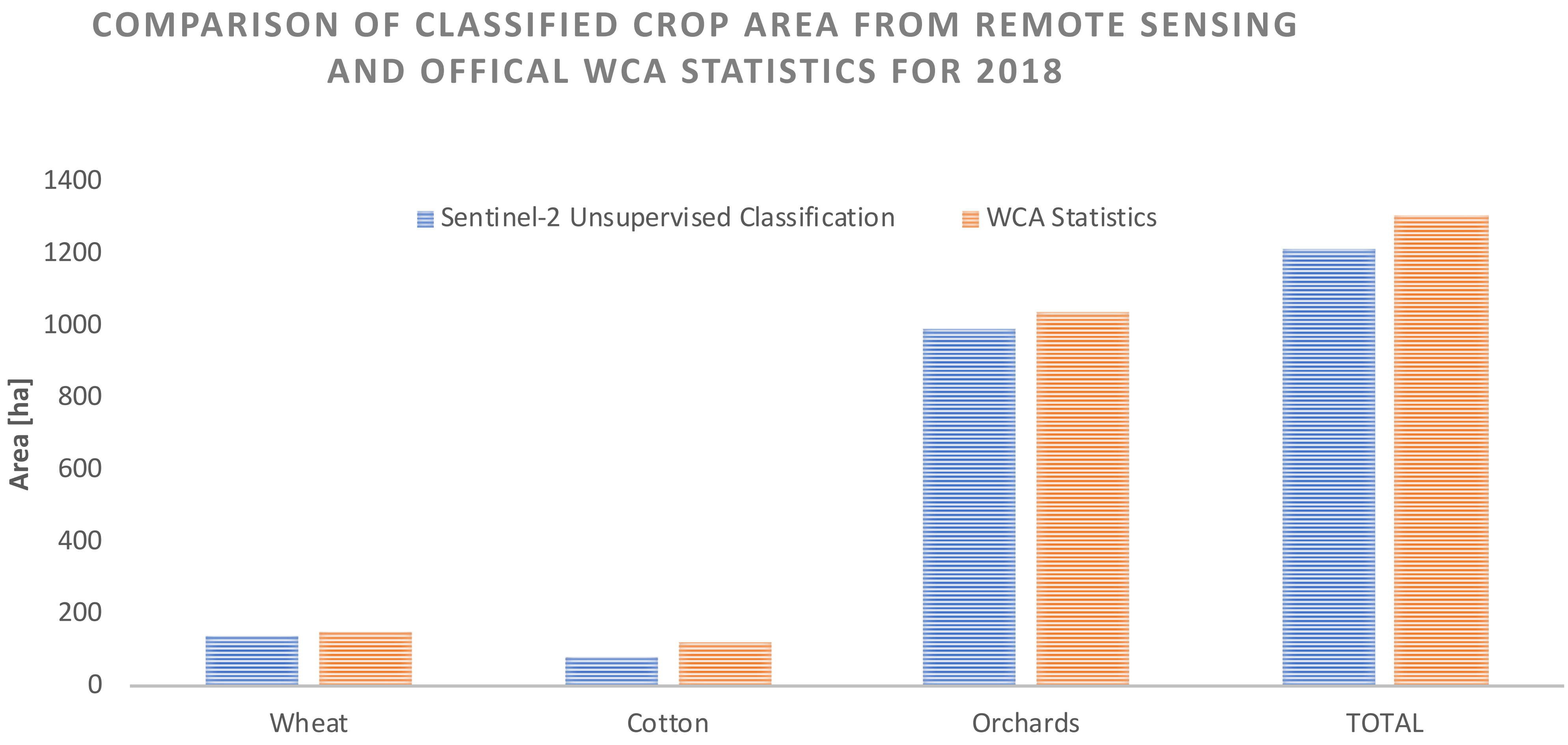
Favorable Comparison with Offical Statistics



Generalization

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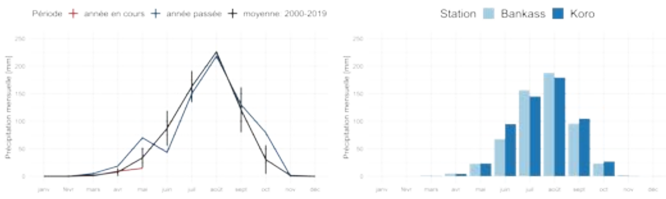
Sourou Basin, transboundary wetland shared between Mali & Burkina Faso

Sample Monthly Hydro-Agrometeorological Bulletin

Résumé de la pluviométrie: mai 2020

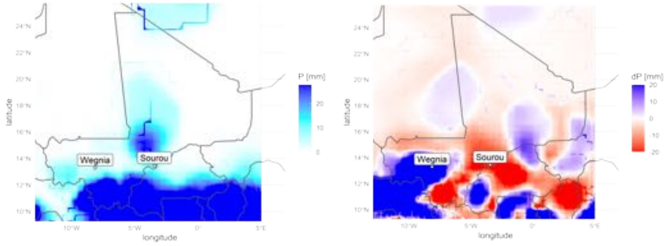
Les prochaines figures montrent la précipitation mensuelle de la région du Sourou. Le produit satellitaire opérationnel GSMaP (source: Jaxa Earth Observation Research Centre) permet des observations presque en temps réel et les données sont disponibles à partir de l'année 2000. La zone d'intérêt est le site Ramsar de la Plaine Inondable du Sourou. Comme source historique les données des stations pluviométriques à Bankass et Koro ont été utilisés qui sont disponibles à partir de 1940 jusqu'à 2019 (bien que beaucoup des données sont manquantes après 2000). Par conséquent, il existe une différence d'échelle spatiale et temporelle entre les données des stations et les données du produit satellitaire opérationnel.



(a) Précipitation du produit GSMaP: Pour la moyenne 2000-2019 l'écart type est indiqué sur la courbe.

(b) Données historiques des stations pluviométriques

Figure 1: Précipitation mensuelle de la région du Sourou. Le produit opérationnel montre la précipitation pour la Plaine Inondable du Sourou, les données historiques sont disponibles pour les stations de Bankass et Koro.



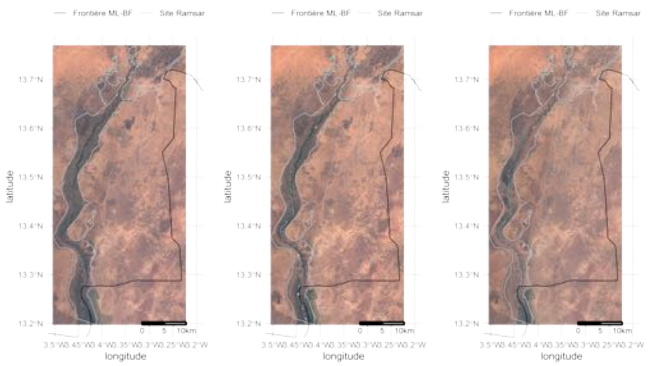
(a) Précipitation mensuelle: Mai

(b) Anomalie de précipitation mensuelle: Mai

Figure 2: Précipitation et anomalie de précipitation mensuelle obtenue par le produit opérationnel satellitaire GSMaP. L'anomalie de précipitation est la différence entre la précipitation de cette année et la moyenne de 2000-2019.

Analyse hydrologique par télédétection

La télédétection permet la surveillance du bassin Sourou à haute résolution temporelle. Les satellites de la mission européenne Sentinel-2 surpassent la région tous les cinq jours. Cette étude utilise des images composites mensuelles à la base du critère maximisation du NDVI (indice de végétation normalisé). Les données satellitaires permettent à détecter la surface des terres marécageuses en utilisant des indices d'eau et de végétation.



(a) 2020-03

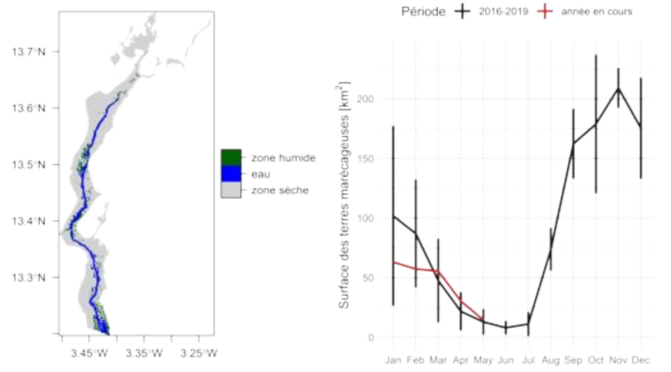
(b) 2020-04

(c) 2020-05

Figure 6: Images composites mensuelles en mode couleur (RVB). Les images de la mission satellitaire Sentinel-2 permettent d'observer le bassin de Sourou à partir de l'espace.

La surface des terres marécageuses de la Plaine Inondable du Sourou montre des variations saisonnières considérables. Pendant les dernières années, la surface du marais a fluctué entre 8 et 210 kilomètres carrées. L'étendue maximale est normalement atteinte en novembre et le minimum entre mai et juillet (voir Figure 6).

L'analyse des surface des terres marécageuses se base sur une classification non supervisée (algorithme d'apprentissage automatique sans étiquetage manuel des données). La classification ne fait pas de différence entre les surfaces naturellement inondées et les terres d'agriculture de décrue. La surface des terres marécageuses en mai 2020 était environ 14.5 km^2.



(a) Résultat de la classification non supervisé: mai 2020.

(b) Comparaison de la surface du marais de cette année avec la surface des années précédentes.

Figure 7: Variations saisonnières de la surface des terres marécageuses de la Plaine Inondable du Sourou. L'étendue maximale est atteinte habituellement en novembre, mais des variations interannuelles sont possibles. La courbe 2016-2019 dans (b) représente la surface moyenne mensuelle du marais et l'écart type.

Opportuntities for Operationalization

- Digital data chain
- Cloud computation does not require expensive local infrastructure (only access to internet)
- Reliance of open-access data
- Where present, straight forward integration into digital Water Information System
- Example from iMoMo Project: Implementation of digital operational hydrology tool in Central Asia Hydrometeorological Agencies

Opportunities for Local Private Sector Developments

- Monitoring innovations offer opportunities for service deliveries through local private sector agents.
- Incubation of local startup scene has to potential to attract real talent.
- Fostering of public-private partnerships to ensure viable business models.

Challenges & Risks

- Remote sensing
  - No final deployment. Support for maintenance and upgrade needs to be ensured even after product co-design and implementation.
  - Relevance of adding new data from new sensors.
- Cloud computing and Storage and online deployment
  - Often considered to be the source of all evil. However, benefits largely outview perceived drawbacks and risks to securities.

Conclusions

- Complementary monitoring revolutionizes the field of hydrological observations and faciliates key improvements in objective, facts-based decision-making for management and planning.
- Cloud-based computational resources using open-source data increasingly provide a most powerful source of essential information, knowledge and intelligence for the water professionals.
- Integration into modern water information systems of digital data from monitoring through local involvement and from remote sensing is straight forward.
- Opportunties for local private sector development and public-private partnerships.