Wetland Monitoring in Semi-arid African Regions using MODIS Time Series

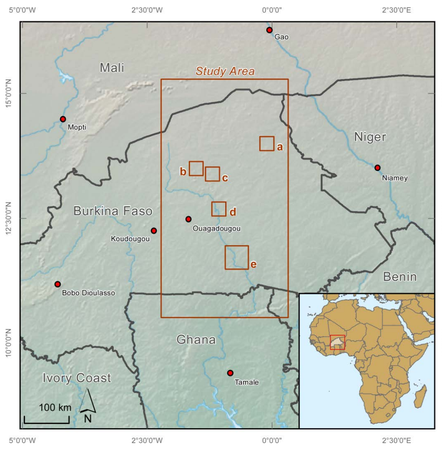
Linda Moser, Stefan Voigt, Elisabeth Schöpfer
German Remote Sensing Data Center, German Aerospace Center (DLR), 82234 Oberpfaffenhofen, Germany

Introduction

Sub-Saharan Africa, particularly the **Sahel** region, has been found to be vulnerable to climate change and variability, and has suffered severe **droughts** in the m**id-1970s**, **mid-1980s** and the **last ten years**. Particularly in drought years **critical lack of available water for livelihoods** is likely to occur towards the end of the dry season, where **pastoralists**, **farmers**, and **villagers** depend on **water availability in surface water bodies** and water points. Increasing **population growth**, **climate change** and **land use change** effects could foster future severe or more frequent water stress events.

Wetlands and Drought

Critical lack of available water for livelihoods



Study Area:

- **Burkina Faso:** West-African **Sahel** and **Savannah**
- **Semi-arid,** latitudinal precipitation gradient (300mm/y to 1000mm/y)
- Prone to **droughts**

Livelihoods:

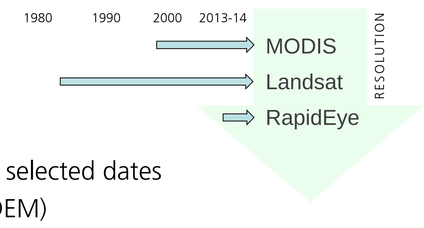
- **Pastoralism, farming** (95% rain-fed, 5% irrigated), **fishing**
- High dependence on **surface water** (dry season), **domestic use**

EO of Wetlands

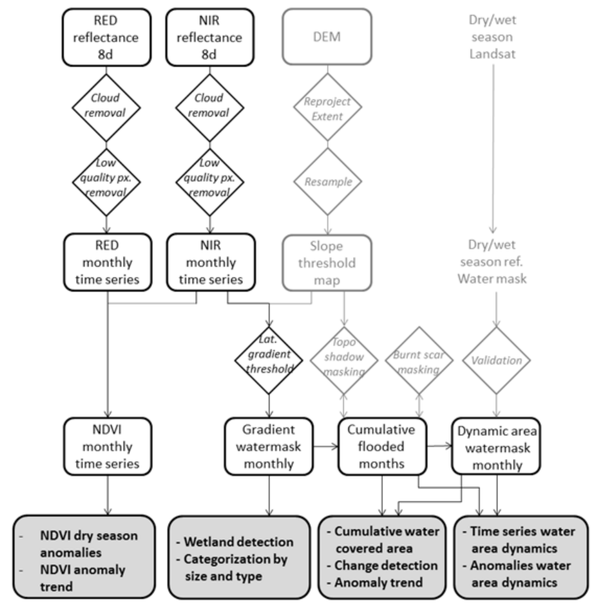
EO = useful tool for water management in Africa: Wetlands are…
…highly **dynamic** → time series (14+ years), narrow intervals
→ changes, trends, seasonal dynamics, linkages
…often **large** & in **remote** areas → areal coverage, missing ground data

Data:

- **MODIS → MOD09 product:** 8-daily surface reflectance composites, 250m resolution, 500m quality flags
- Landsat L1T & RapidEye L1B for selected dates
- SRTM digital elevation model (DEM)

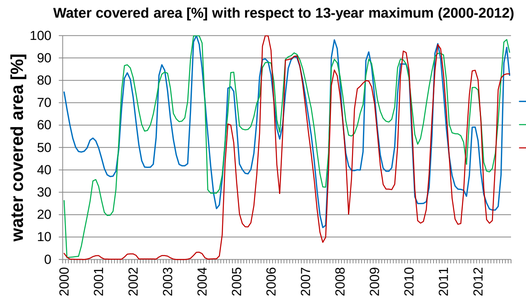


Workflow

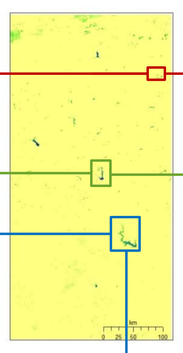


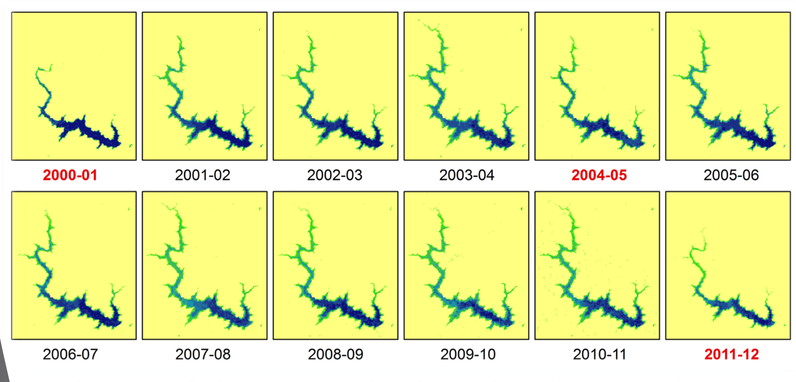
Spatio-Temporal Wetland Dynamics

Water area dynamics



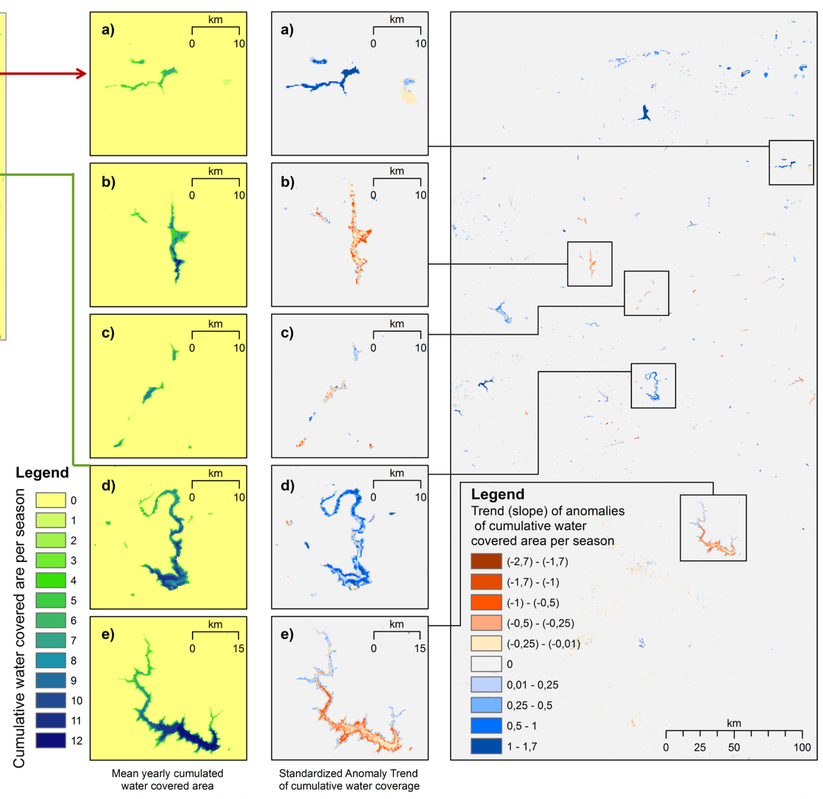
8-daily MODIS time series capture seasonal cycle of surface water in wetlands, timing of dam construction, and vanished wetlands. Time series of water area coverage of 3 artificial wetlands normalized with respect to the 13-year maximum as 100%.





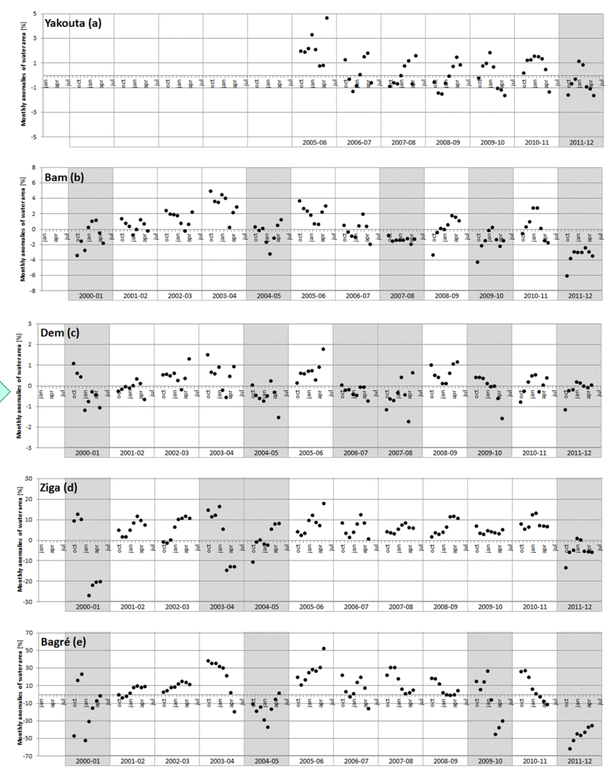
Spatio-temporal dynamics can be detected. Surface water dynamics of Barrage de Bagré (site e), derived via a thresholding approach using the MODIS 250m NIR band, displayed as cumulative water covered surface area (in months per year), from season 2000-01 to 2011-12. Drought seasons are marked in red.

Anomaly trend



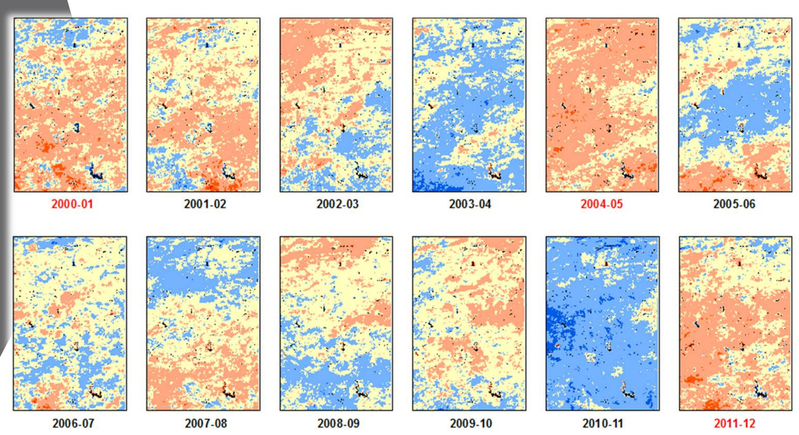
Trends conclude to shorter water coverage duration in natural wetlands, and water spreading out further. Siltation causes lakes to become shallower. Standardized anomaly trend of cumulative water covered area, over 12 seasons (2000-01 to 2011-12) for five case studies: (a) Yakouta, (b) Lac Bam, (c) Lac Dem, (d) Ziga and (e) Bagré. Negative trend values (red) signalize a negative trend towards fewer water covered months per year, and positive values (blue) a positive trend towards longer water coverage.

Anomalies

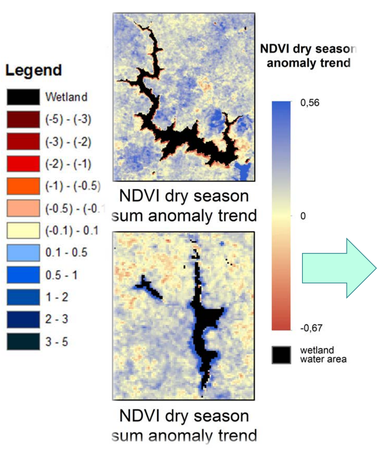


Anomalies correspond to drought seasons. Monthly water coverage anomalies with respect to the 13-year mean of each month, for the dry season (October – May) 2000-01 to 2011-12, for the 5 case studies from north to south: (a) Yakouta, (b) Lac Bam, (c) Lac Dem, (d) Ziga and (e) Bagré. Seasons with significant negative anomalies are shaded grey.

Vegetation (NDVI) anomalies

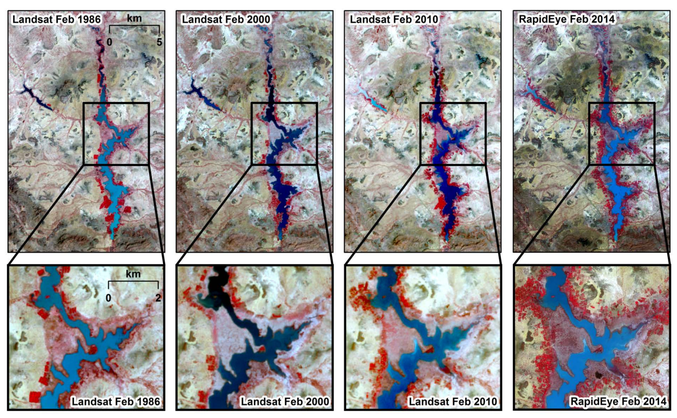


NDVI Anomaly trend



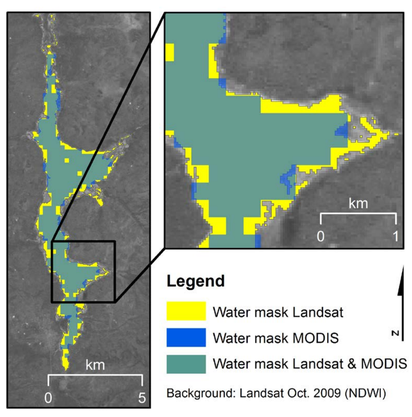
Vegetation anomalies of surrounding areas correspond with drought seasons. Trends can detect cultivation changes. NDVI anomalies of summed NDVI for the dry seasons (Oct-Apr) from 2000-01 until 2011-12. Drought years are marked in red. Right: Anomaly trends of NDVI dry season sums show a negative trend around Bagré but positive trend around Lac Bam, associated to increasing irrigated cultivation.

Explore trends in HR imagery



Combination of MR time series and HR imagery to explore trends. Large increase of irrigated cultivation within the last 4 years. Changes of irrigated cultivation around Lac Bam based on February dry season optical HR data: Landsat TM (1986), Landsat ETM+ (2000), Landsat TM (2010), and RapidEye (2014).

Validation



Validating MODIS water masks. Water mask derived by Landsat NDWI threshold (yellow), and water mask from the MODIS NIR time series composite (blue), showing overlapping regions in green, for Oct 2009.

Conclusions

- **Surface water & vegetation anomalies** → correspond to drought seasons.
- **Time series extraction** → seasonal cycles & timing of dam constructions
- **Spatio-temporal trends** → changing flooding regimes
- **HR RapidEye** and **Landsat** data → validation, exploring trends
- **Indicators:** Vegetation trends → irrigation dynamics, water availability (past months)
  Water dynamics → water availability in coming dry season, droughts

See poster: Wetland Wetland Monitoring Using Dual-Polarized X-Band and C-Band Data of Lac Bam, West-Africa

References:

Moser, L., Voigt, S., Schoepfer, E. and Palmer, S. (2014): Multitemporal Wetland Monitoring in Sub-Saharan West-Africa Using Medium Resolution Optical Satellite Data. IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing (J-STARS), vol.7 (8), pp. 3402-3415. DOI: 10.1109/JSTARS.2014.2336875. ISSN 1939-1404.

Moser, L., Voigt, S. and Schoepfer, E. (2014): Monitoring of Critical Water and Vegetation Anomalies of Sub-Saharan West-African Wetlands. In: IEEE International Geoscience and Remote Sensing Symposium (IGARSS), pp. 3842-3845. IGARSS 2014: International Geoscience and Remote Sensing Symposium, from 13-18 July 2014, Québec, Canada. ISBN 978-1-4799-5775-0/14.

Moser, L., Schmitt, A., Voigt S. and Schoepfer, E. (2015): Remote Sensing of Wetland Dynamics as Indicators of Water Availability in Semi-Arid Africa. In: Earth Observation for Land and Emergency Monitoring - Innovative concepts for environmental monitoring from space. Publisher: Wiley, Ed Heiko Balzter, ISBN 9781118793794. (under review)

Deutsches Zentrum für Luft- und Raumfahrt e.V.
in der Helmholtz-Gemeinschaft

Contact: linda.moser@dlr.de
German Aerospace Center (DLR)
German Remote Sensing Data Center
D-82234 Wessling, Oberpfaffenhofen
www.dlr.de/eoc - www.gionet.eu

Acknowledgments:
F. Betorz Martínez
R. Ouedraogo,
B. M. Somandé

This study is performed under the GIONET project funded by the European Commission, Marie Curie Programme, Initial Training Networks, Grant Agrement number PIT-GA-2010-264509. Data were provided by USGS (MODIS, Landsat), and BlackBridge via RESA/DLR (RapidEye)

German Remote Sensing Data Center