WATER FOR AGRICULTURAL SMALLHOLDERS IN WEST AFRICA:

THE IMPACT OF CLIMATE CHANGE ON WATER BODY DYNAMICS IN THE TAHOUA REGION OF NIGER

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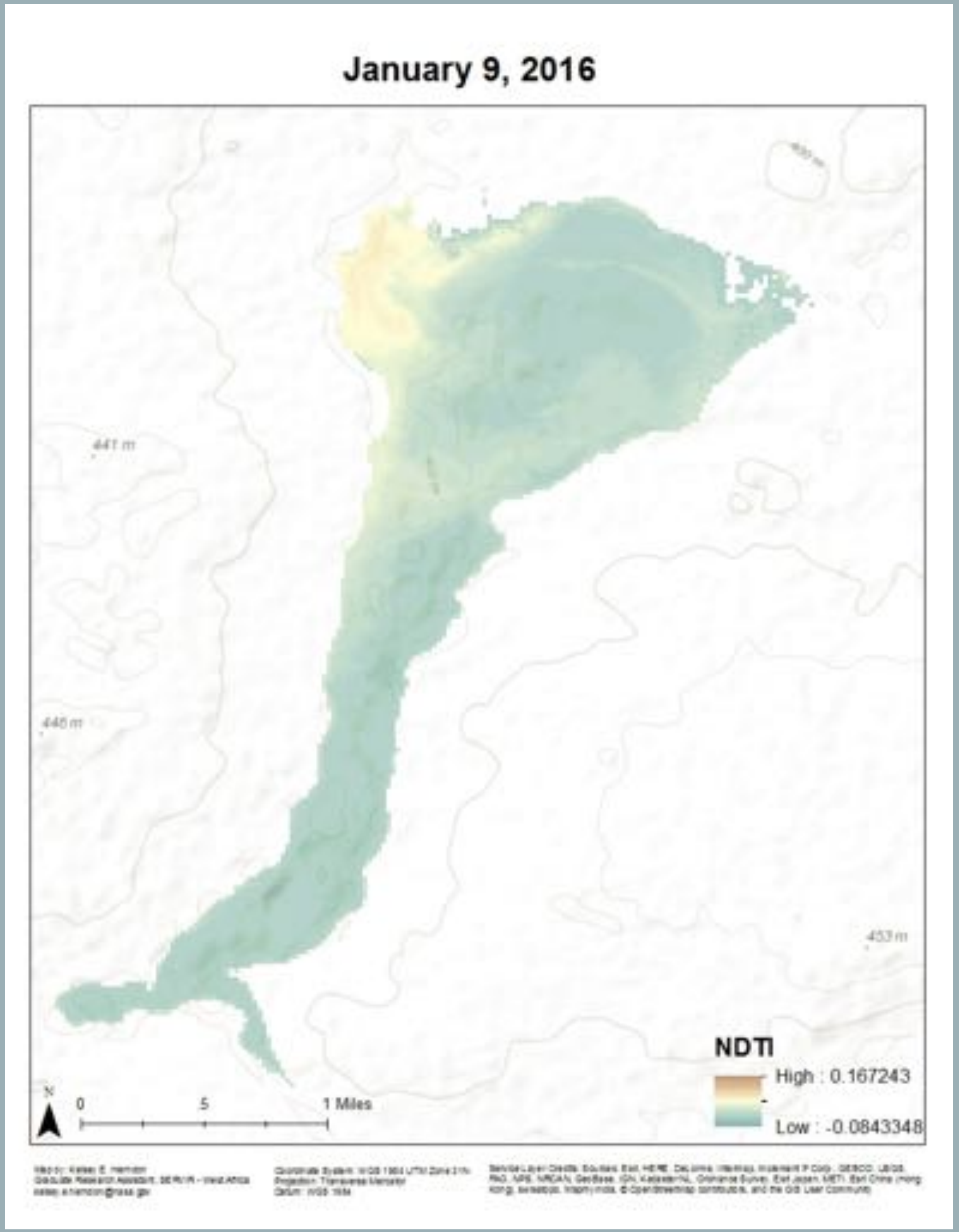

Overview

- Introduction to agriculture in the Sahel
- Conflicts over water in the Sahel
- Description of the study area
- Specific Objectives
- Methods
- Results
- Implications
- Limitations
- Future Directions

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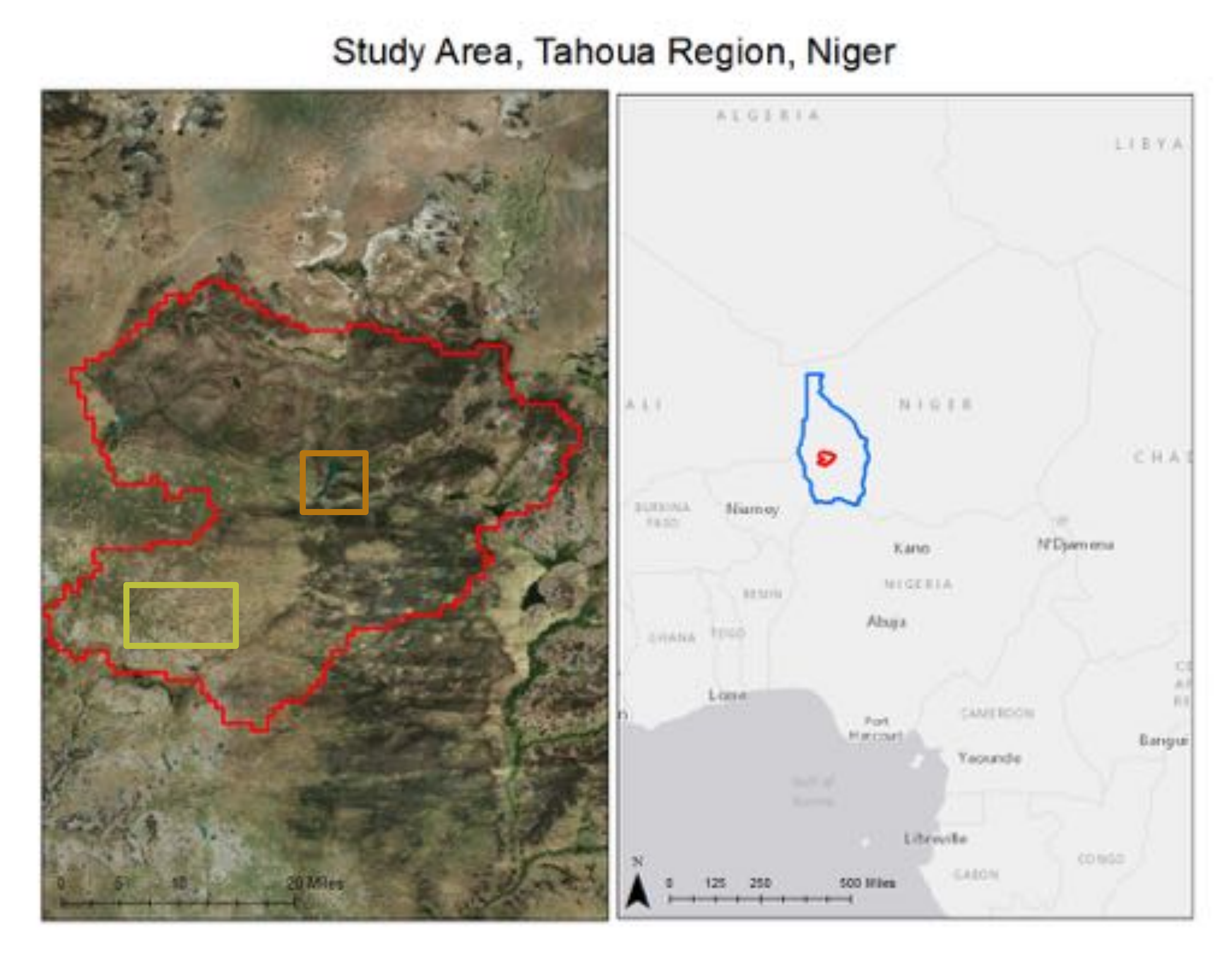
Objectives

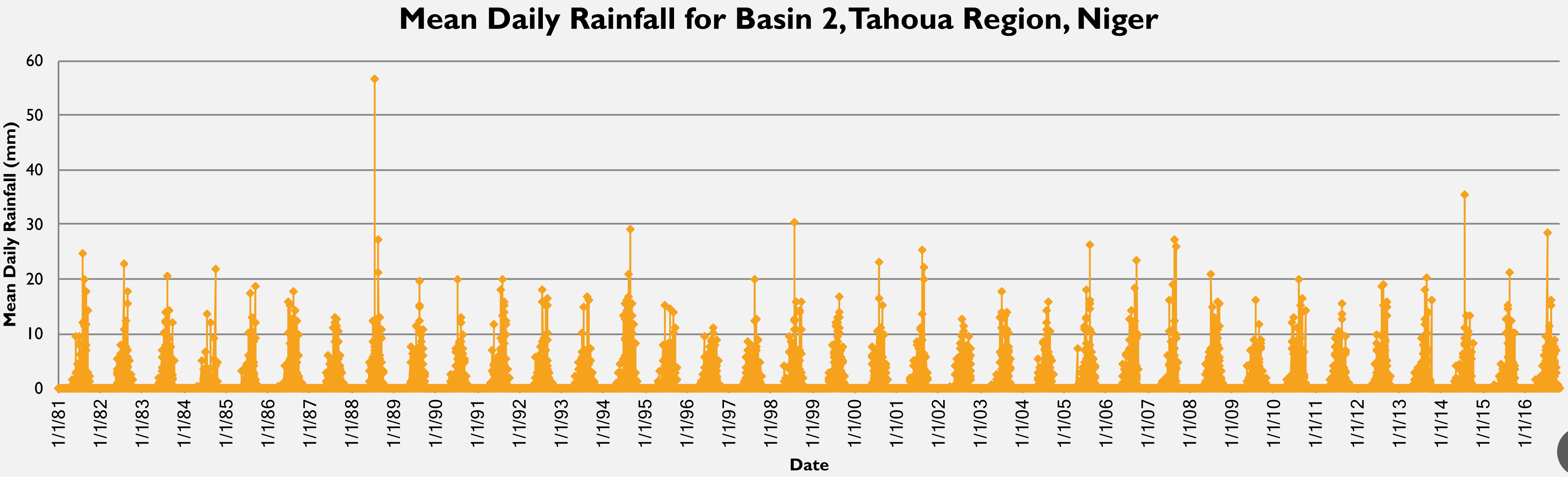
- Create a time series of water bodies for the study area
- Identify the seasonal character of water bodies
- Quantify the responsiveness of surface water extent to changes in precipitation

Study Area


Study Area, Tahoua Region, Niger
0
5
10
20 Miles
ALGERIA
LIBYA
NIGER
Niamey
Kano
N'Djamena
NIGERIA
Abuja
Lome
CAMEROON
Yaounde
Bangui
Libreville
GABON
CONGO
N
0
125
250
500 Miles

Climate Patterns: Precipitation

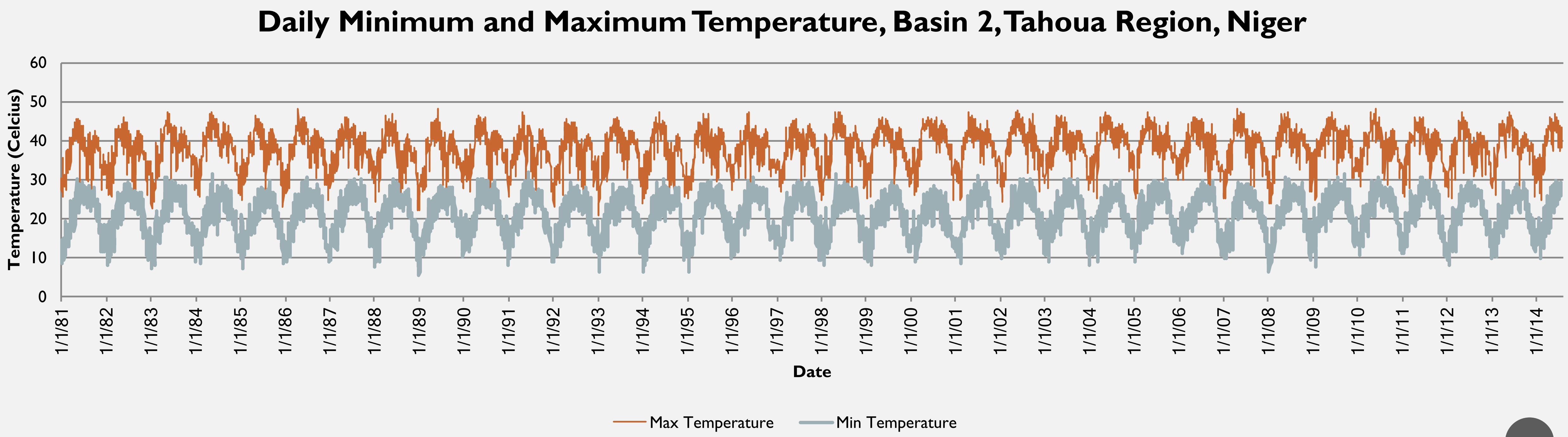
- Overall patterns of precipitation:
  - Annual precipitation has increased about 1mm/ year since 1981



Data from ClimateSERVE (CHIRPS)

Climate Patterns: Temperature

- General temperature trends (1981 – 2016):
  - Miniscule increase in max temperature (<.001 degree C)
  - Miniscule increase in min temperature (<.001 degree C)



Data

- Landsat 4, 5, 7, and 8 surface reflectance
  - United States Geological Survey (USGS) Earth Resources Observation and Science (EROS) Center Science Processing Architecture (ESPA)[1]
- Drainage basin boundary
  - Global Drainage Basin Dataset (GDBD) – Center for Global Environmental Research in the National Institute for Environmental Studies (Japan)[2]
- Meteorological variables
  - CHIRPS daily precipitation data[3]

1. https://espa.cr.usgs.gov/index/
2. http://www.cger.nies.go.jp/db/gdbd/gdbd_index_e.html
4. https://globalweather.tamu.edu

Methods: Water Body Surface Area

- Modified Normalized Difference Water Index (MNDWI)[1]
  - MNDWI = $\frac{Green - SWIR}{Green + SWIR}$

  - Landsat 8 Operational Land Imager (OLI)
    - Green = band 3
    - SWIR = band 6

  - Landsat 4 Thematic Mapper (TM), 5 TM, and 7 Enhanced Thematic Mapper + (ETM+)
    - Green = band 2
    - SWIR = band 5

- Threshold of -.2
  - >-.2 = water
  - < -.2 = non-water

1. Xu, H. "Modification of Normalised Difference Water Index (NDWI) to Enhance Open Water Features in Remotely Sensed Imagery." *International Journal of Remote Sensing* 27, No. 14 (2006): 3025-3033.

Methods: Climate Elasticity

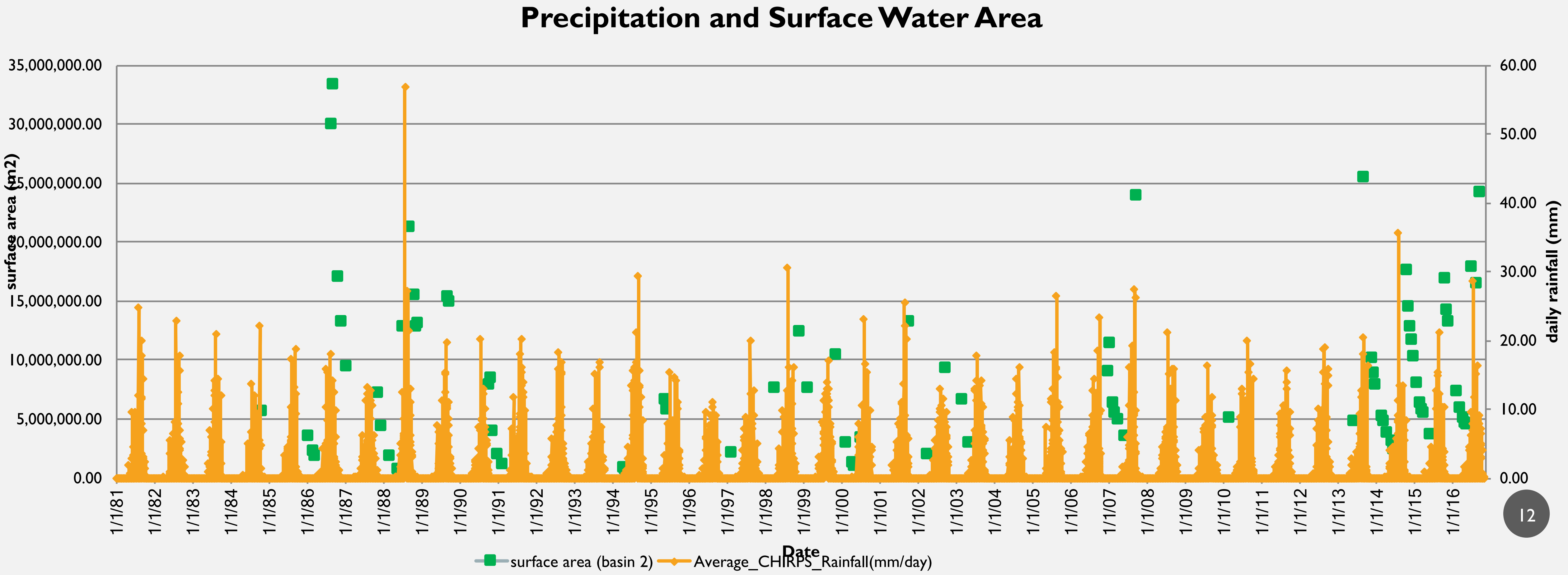
- Non-parametric estimator of climate elasticity[1]:
  - $\varepsilon_P = \text{median}(\frac{Q_t - \bar{Q}}{P_t - \bar{P}} \frac{\bar{P}}{\bar{Q}})$
  - ε_P is precipitation elasticity
  - Q_t is surface area at time t
  - P_t is precipitation at time t
  - $\bar{Q}$ is mean annual surface area
  - $\bar{P}$ is mean annual precipitation

- Results tell us how sensitive water surface area is to changes in precipitation (% change in water surface area with a 1% change in precipitation)

1. Sankarasubramaniam, A., Vogel, RM, and Limburner, JF. 2001. Climate Elasticity of Streamflow in the United States. *Water Resources Research*. 37: 1771-1781. (https://pdfs.semanticscholar.org/a51f/f75286e7d3ac3d3d4ac9664d76e14fc6174e.pdf)

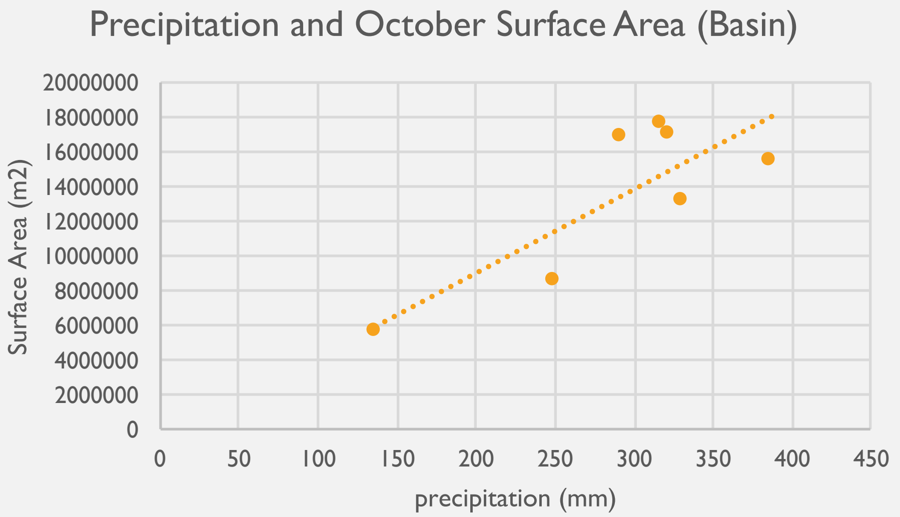
Results: Seasonal Pattern

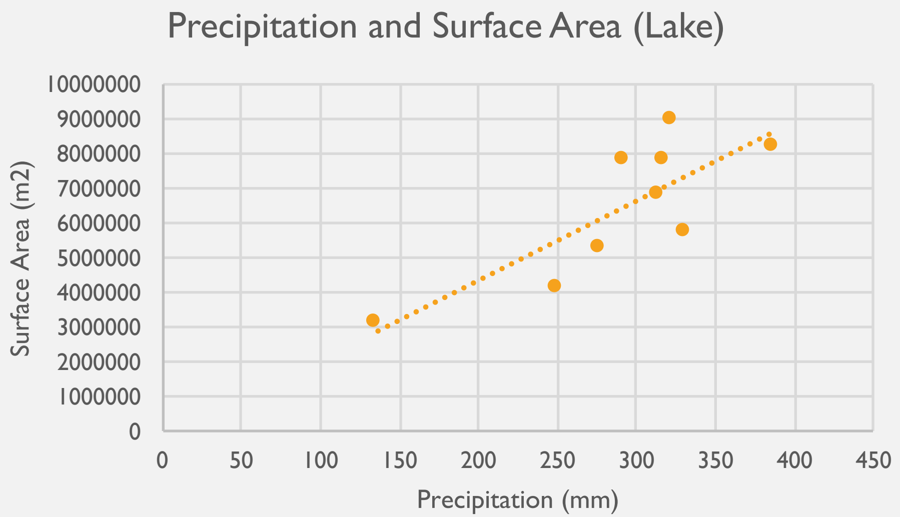
- Surface area tracks with precipitation
- Peak surface area occurs during the rainy season, between August and October
- Minimum surface area occurs immediately prior to the start of the rainy season, in May or June
- Surface area can vary more than 10 fold over the course of the water year

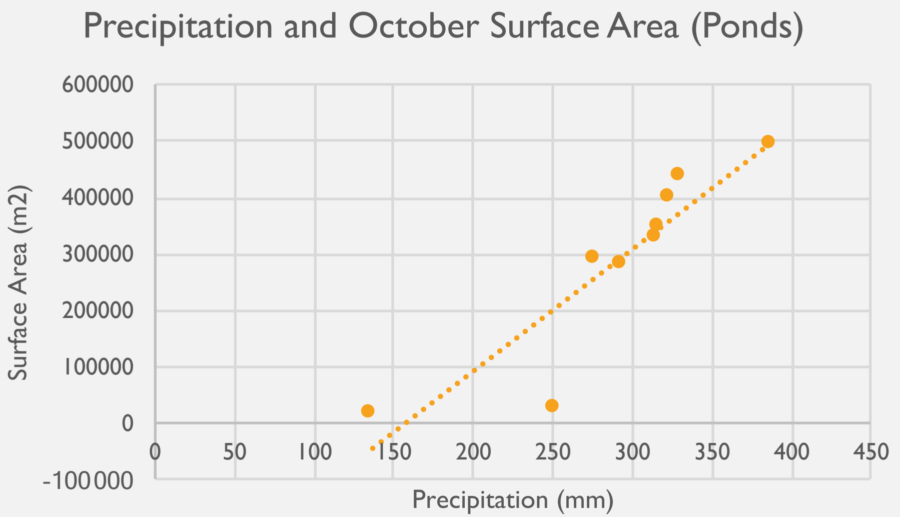


Results: Inter-Annual Pattern

- Linear regression results (October surface area, precipitation)
  - Basin: R = .8154, R^2 = .6650, p = .02537
  - Lake: R = .8081, R^2 = .6530, p = .00840
  - Ponds: R = .9034, R^2 = .8162, p = .00083







Results: Climate Elasticity

- Precipitation:
  - Basin = 2.42
  - Lake = 2.43
  - Ponds = 2.09
- Precipitation elasticity agrees with global studies[1]

1. Chiew, F. H. S., M. C. Peel, T. A. McMahon, and L. W. Siriwardena (2006), Precipitation elasticity of streamflow in catchments across the world, IAHS Publ., 308, 256–262. (http://iahs.info/uploads/dms/13670.49-256-262-08-308-Chiew.pdf)

Implications

- Water bodies in this region are very responsive to changes in precipitation
- Results could be used in designing a forecasting system that could help pastoralists in locating water bodies, allocating water resources, and designing efficient migration routes
- Could help government agencies in planning and managing potential conflict associated with water body scarcity: e.g. years with less rain will have more scarce surface water

Limitations

- Validation
- Resolution
- Uneven time series
- Limitations of climate elasticity

Future Directions

- Validation
- Develop a water body forecasting system or near-real time monitoring system
- Evaluate changes in turbidity and vegetation health
- Evaluate the impact of changes in landcover
- Incorporate Sentinel 1 and 2 data

QUESTIONS?