National Council for Scientific Research
LEBANON

Assessment of chlorophyll-a concentration using Landsat Operational Land Imager in Lake Qaraoun, Lebanon

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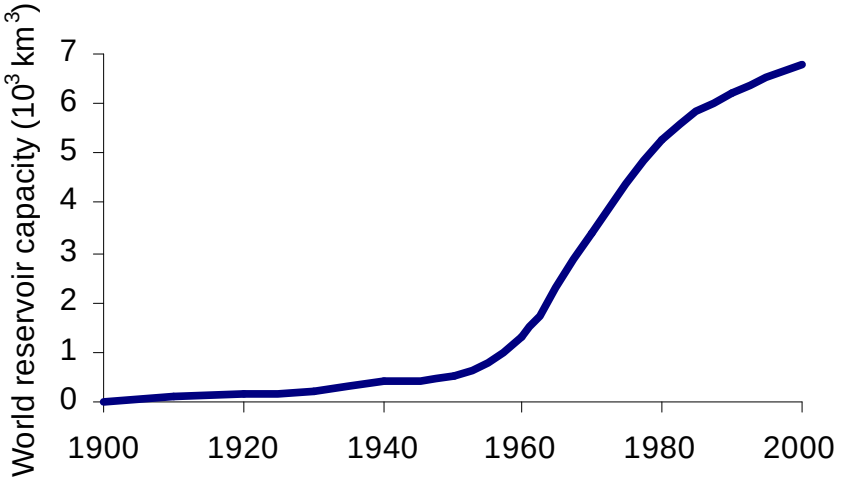
Introduction & problematic

- Worldwide development of reservoir in the 20th century (WCD, 2000)
- Reservoir usages
  - Flood control
  - Power generation
  - Drinking water supply
  - Irrigation, etc.

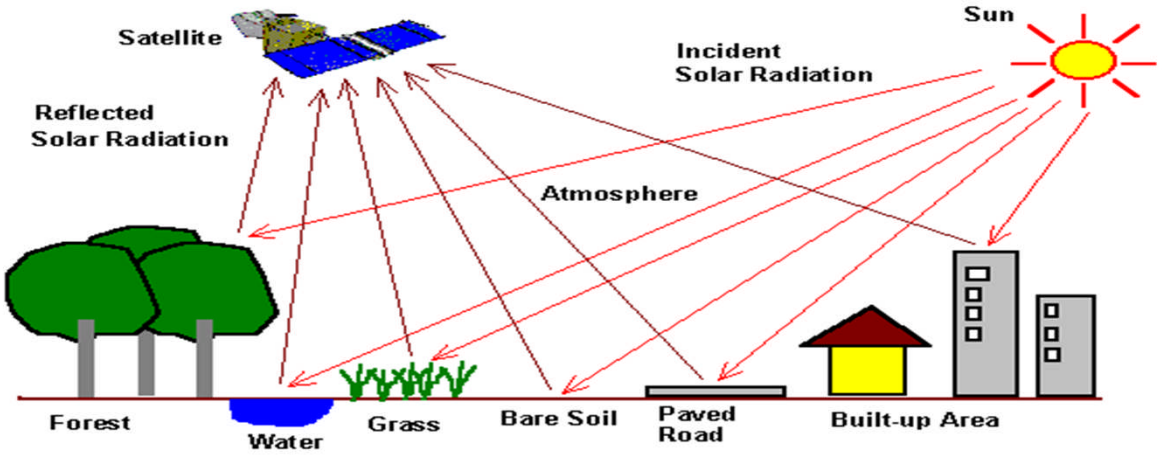


- 40 % of world reservoirs are eutrophic and suffer from harmful algal blooms, mostly cyanobacteria (Jørgensen et al., 2005)

- Problems caused:
  - Health problems (cyanotoxins)
  - Fish kill
  - Skin irritation
  - Liver infection

Introduction & problematic

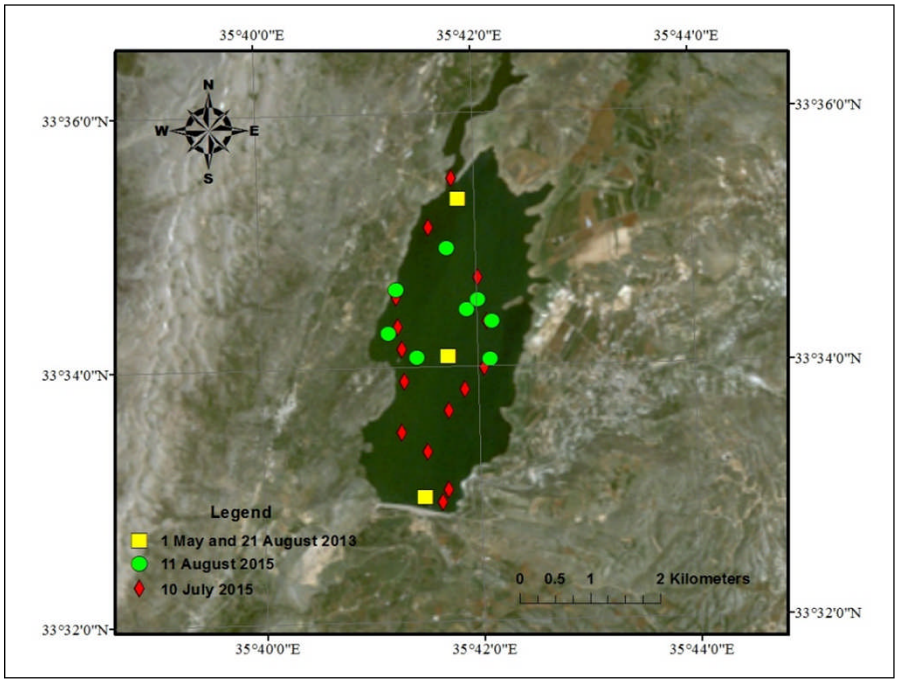
- Water Framework Directive, the European Union uses the phytoplankton community as a biological indicator of the ecological status of water bodies (European Parliament Council 2000).
- Satellite remote sensing imagery like Landsat Operational Land Imager (OLI) can be used to assess and monitor chlorophyll-a in water bodies over large areas in a cost-effective way.
- In this study, the accuracy of Landsat OLI to estimate chlorophyll-a was examined



Study site

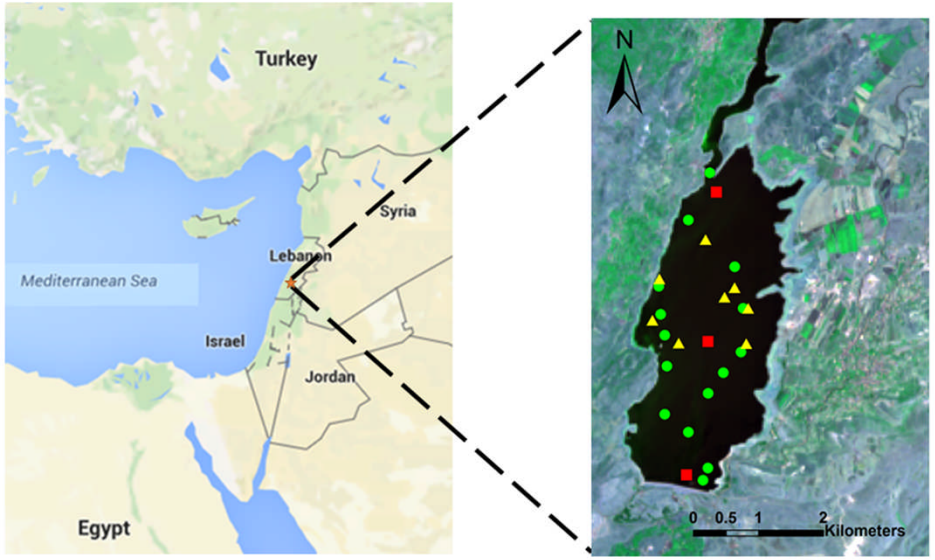
- Karaoun Reservoir (Lebanon)
  - 230 10^6 m^3
  - maximum depth 60 m
  - 12 km^2
  - 860 m elevation
  - Catchment area 1600 km^2
- Used for power generation and irrigation
- 30 meter annual variation of water level
- Semi-arid, no or little precipitation

between May and October



Monitoring program

- Continuous monitoring
  - Fixed-depth temperature sensors (ΔT = 15 min)
- Field measurementsTransparency (Secchi disk)
  - Probe measurements
    - phycocyanin fluorescence (Trios microflu blue)
    - dissolved oxygen
  - Samples at 5 depths for laboratory analyses
    - Microscopic identification and counting of phytoplankton
    - Total chlorophyll-a quantification, triplicates
    - Cylindrospermopsin , triplicates (ELISA, Abraxis)
    - Phosphorus (orthophosphate & total phosphorus)
    - Nitrogen (nitrate and ammonium)

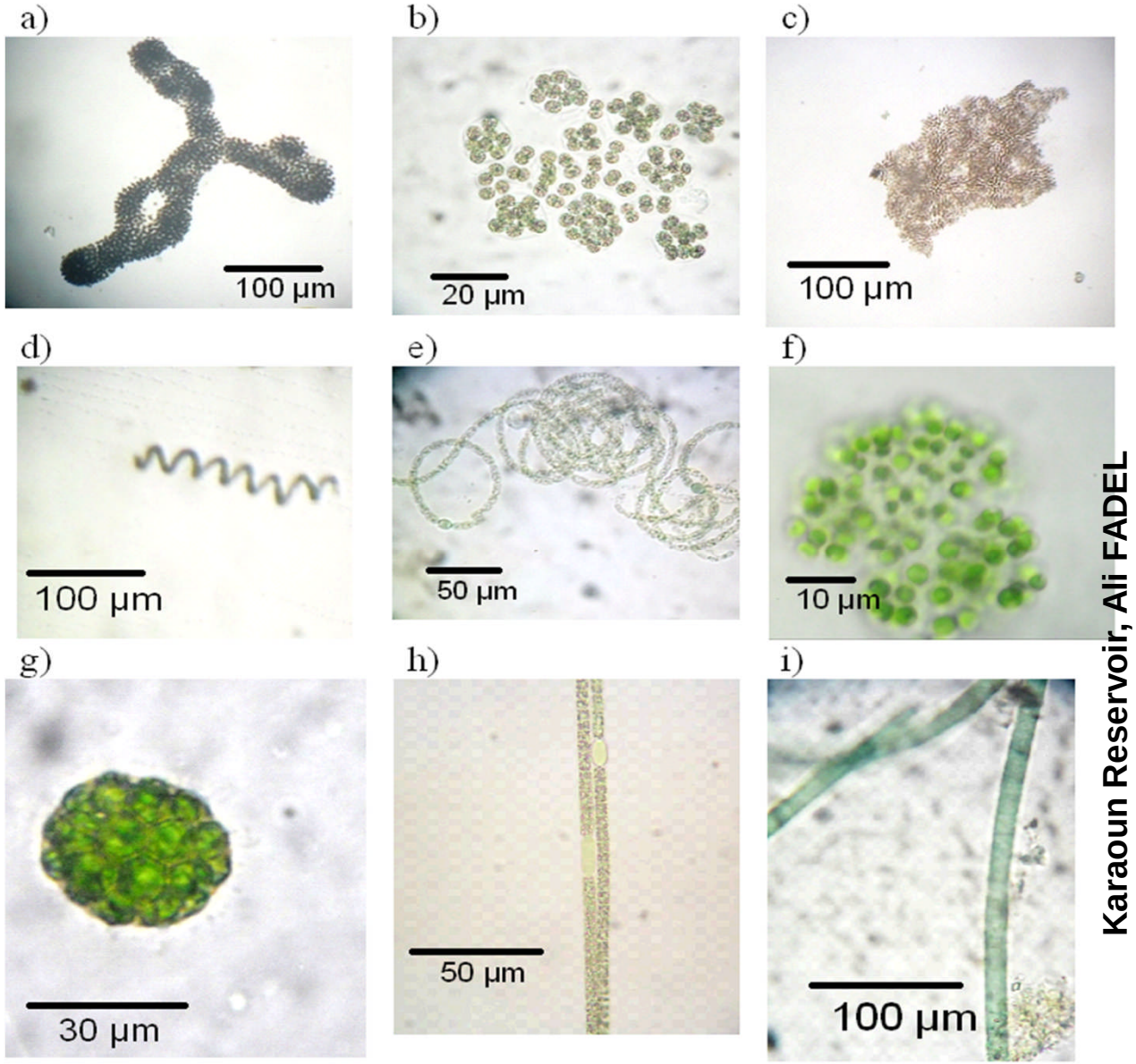


Sampling sites in 26 April and 21 August 2013 (red cubes), 10 July 2015 (green circles), and 11 August 2015 (yellow triangles).

10 cyanobacteria species

a) ***Microcystis aeruginosa***
b) *Microcystis viridis*
c) *Microcystis ichthyoblabe*
d) *Anabaena spiroides*
e) *Anabaena circinalis*
f) *Radiocystis geminate*
g) *Pilgeria brasiliensis*
h) ***Aphanizomenon ovalisporum***
i) *Oscillatoria tenuis*

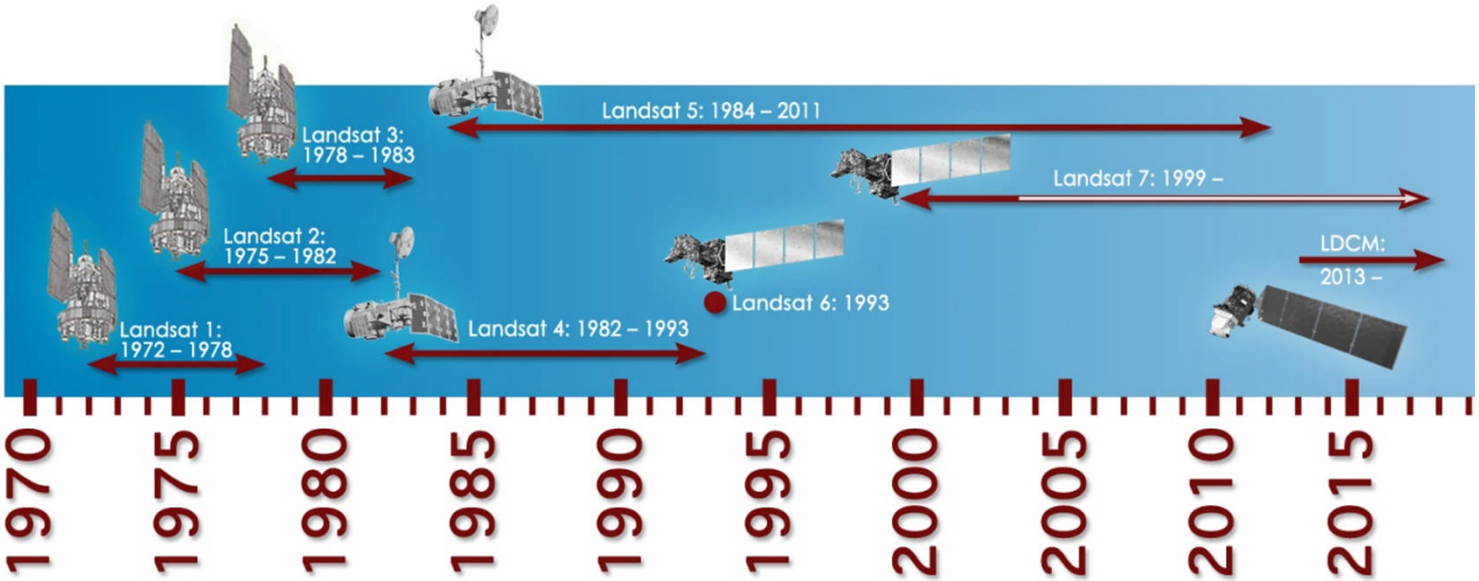
- *Microcystis botrys*



Karaoun Reservoir, Ali FADEL

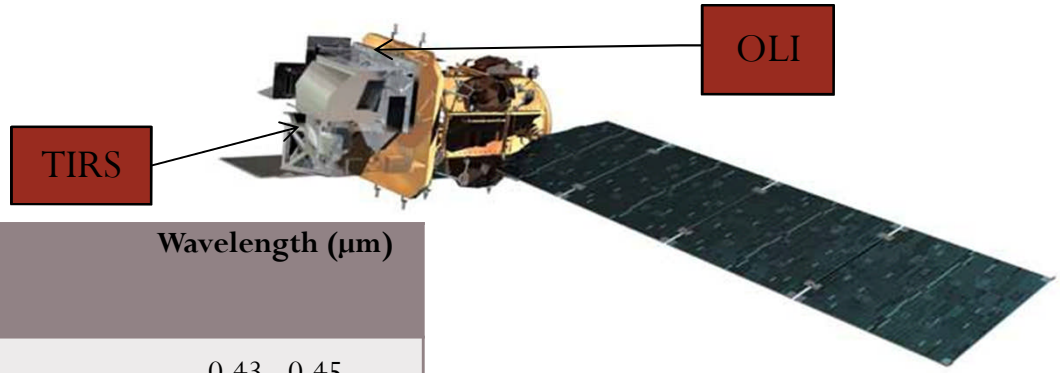
Landsat mission - Landsat 8

- Landsat program is the longest-running enterprise for acquisition of satellite imagery of Earth
- On July 23, 1972 the Earth Resources Technology Satellite was launched
- most recent, Landsat 8, was launched on February 11, 2013
- Images the entire Earth every 16 days
- Spatial resolution of 30 m



Landsat 8 spacecraft status

- Landsat 8, the latest satellite in the Landsat Data Continuity Mission project, launched on February 11, 2013, houses two sensors:
- ✓ The Operational Land Imager (OLI).
- ✓ The Thermal Infrared Sensor (TIRS).



OLI bands used in this study

Sensor	Bands	Wavelength (μm)
OLI	**Band1**	0.43 - 0.45
	Band 2 - Blue	0.45 - 0.51
	Band 3 - Green	0.53 - 0.59
	Band 4 - Red	0.64 - 0.67
	Band 5 - Near Infrared (NIR)	0.85-0.88
	Band 6 - Shortwave Infrared (SWIR 1)	1.57 - 1.65
	Band 7 - Shortwave Infrared(SWIR 2)	2.11 - 2.29
	Band 8	0.50 - 0.68
	Band 9	1.36 - 1.38
TIRS	Band 10 - Thermal Infrared (TIRS) 1	10.60 – 11.19
	Band 11 - Thermal Infrared (TIRS) 2	11.5 - 12.51

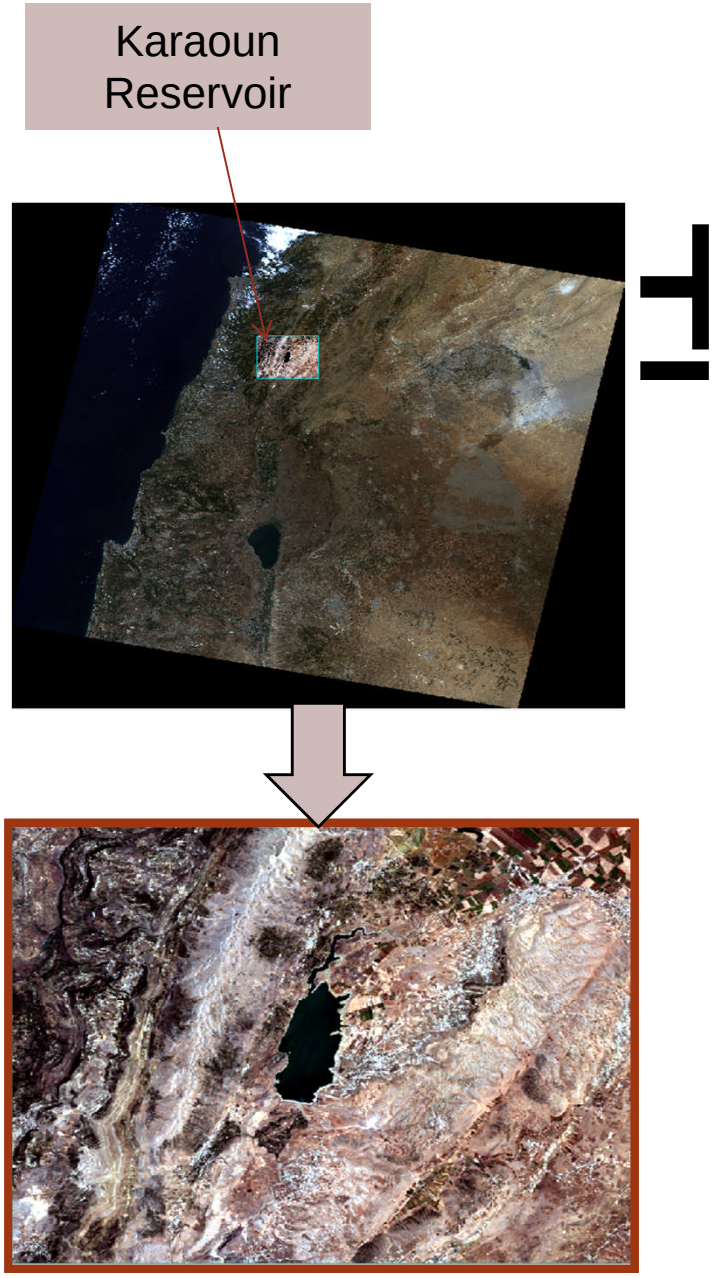
www.landsat.usgs.gov

Data Acquisition

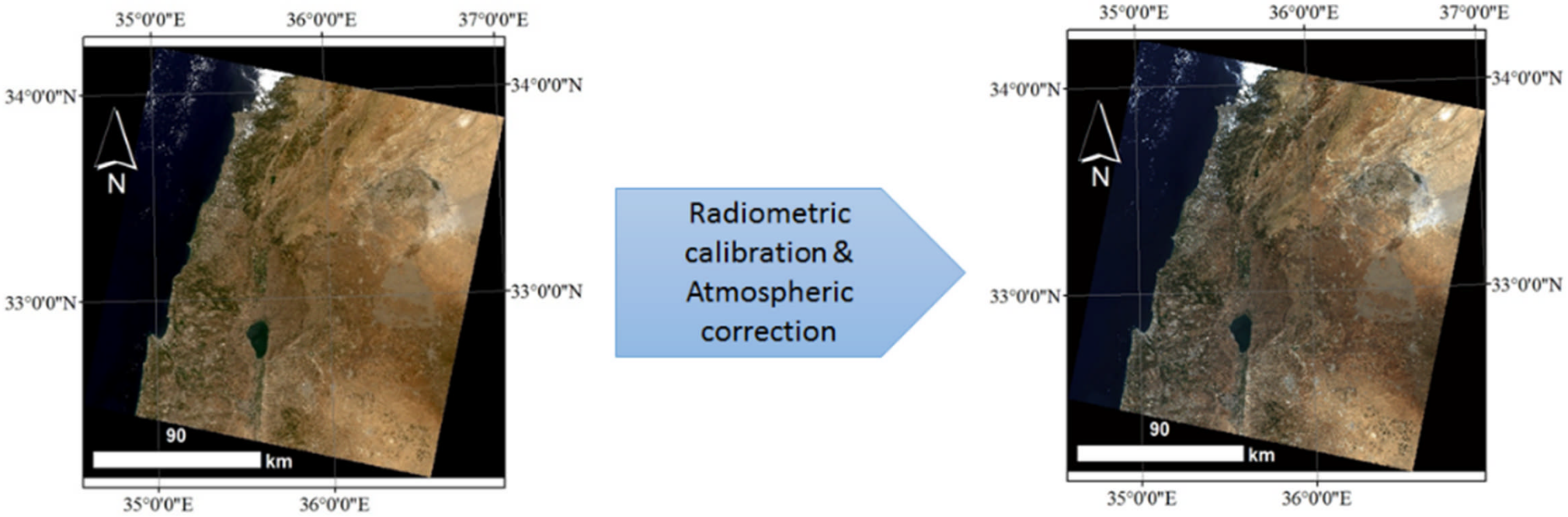
- Four cloud free images were acquired from Landsat 8, concurrently with field campaigns.

- Images were freely downloaded from the USGS website http://earthexplorer.usgs.gov/.

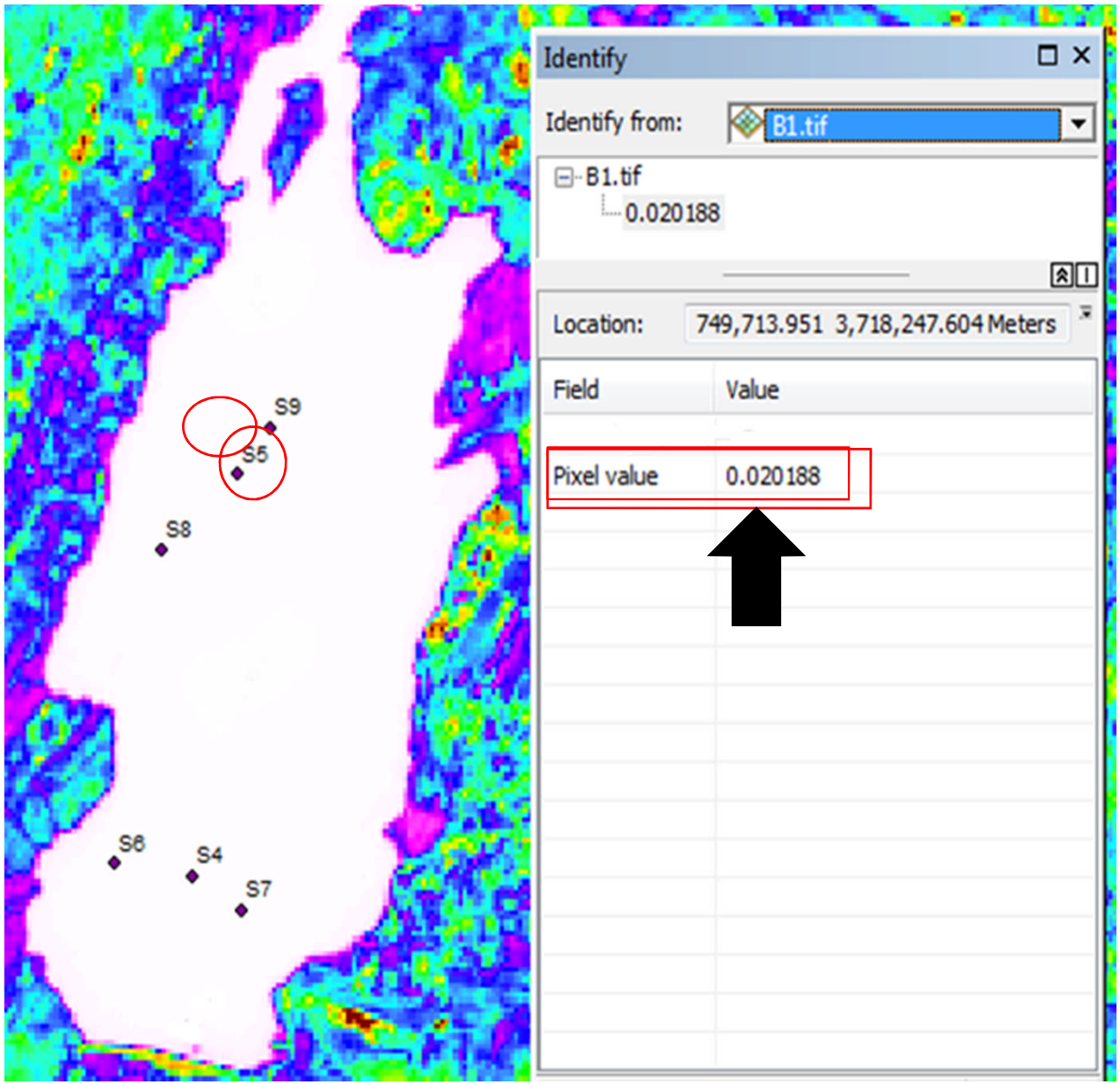
- They are all Level 1T processed, meaning that they have undergone geometric calibration.



Radiometric calibration and atmospheric correction



Radiometric correction carried out for Landsat OLI images using the ENVI Software.



Extraction of pixel values according to OLI band

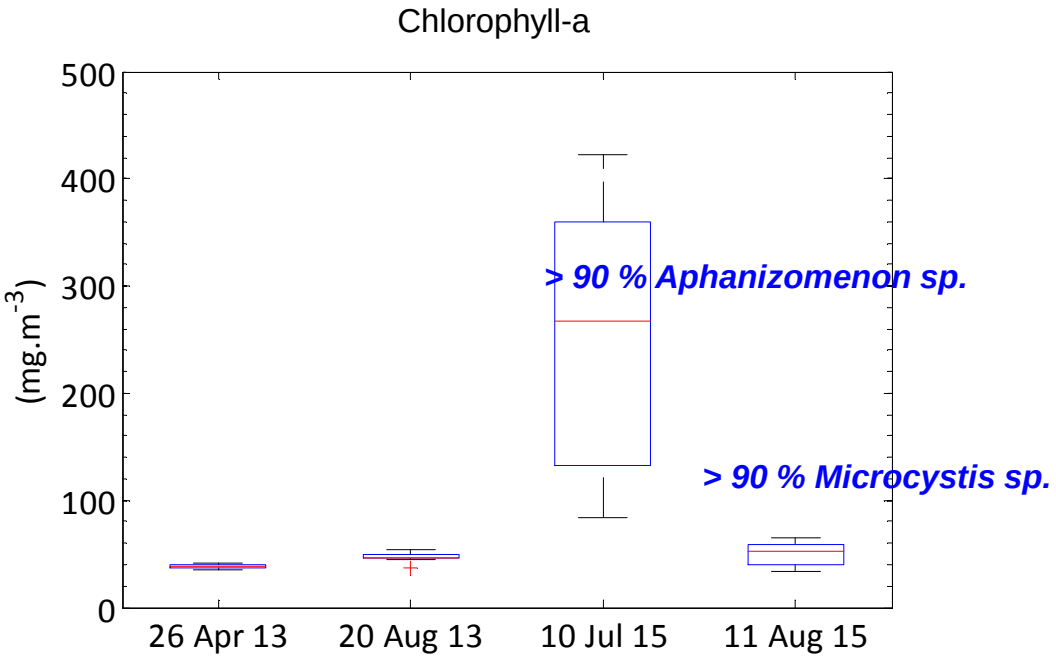
Extraction of pixel values

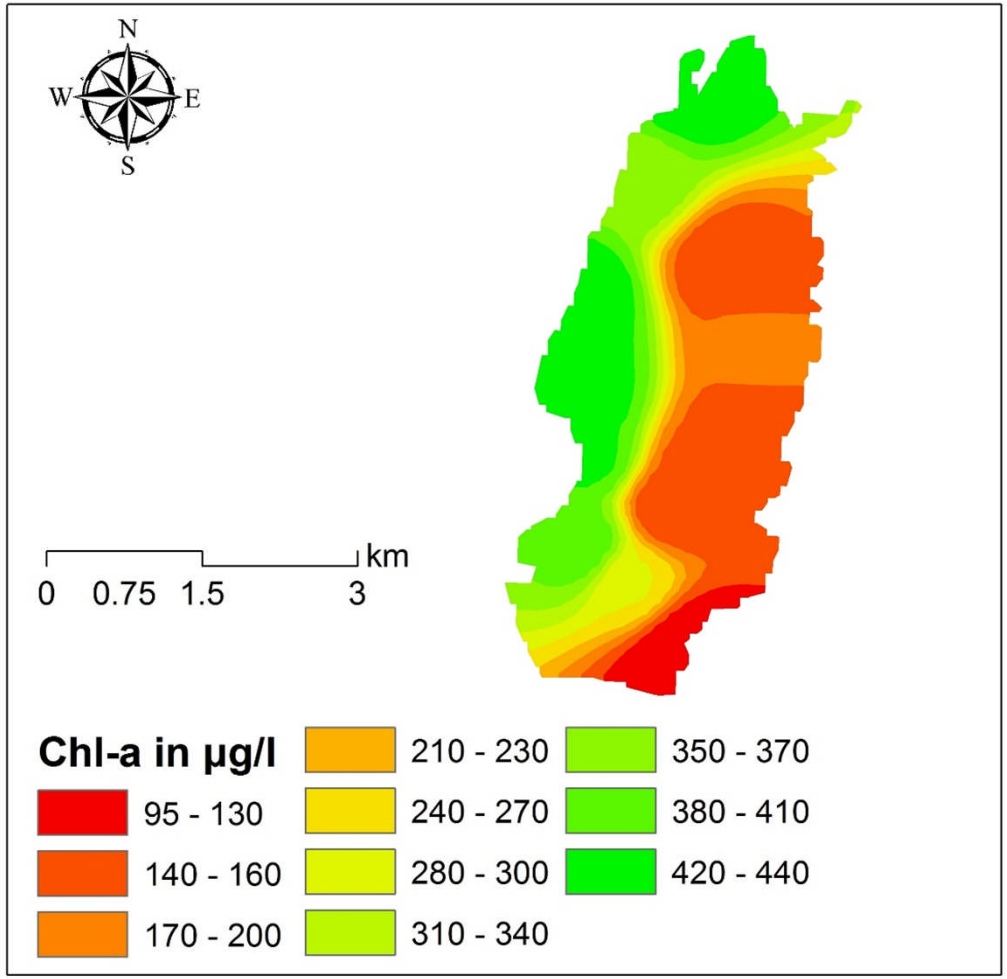
- Atmospherically corrected single band images were added to the **ArcGIS software**, along with corresponding sampling points for each date.
- On a single band level reflectance values were extracted for each point.

Reflectance values

Band 1=0.020188
Band 2=0.01706
Band 3=0.016483
Band 4=0.008231
Band 5=0.010116
Band 6=0.004259
Band7=0.002817

High spatial variation on 10 July 2015





- Higher biodiversity in 2013
- Dominance of toxic cyanobacteria in 2015
- High spatial variability in 10 July 2015

Linear Regression Relationships between *in situ* Chlorophyll-a and Landsat OLI Bands (n=29)

Bands	R	R2	Bands	R	R2
B1	0.34	0.11	B5/B1	0.67	0.45
B2	0.32	0.1	B5/B2	0.52	0.27
B3	0.12	0.015	B5/B3	0.68	0.46
B4	0.08	0.01	B5/B4	0.67	0.44
B5	**0.75**	**0.57**	B1/B2*B5	0.76	0.58
B1*B2	0.33	0.11	B1/B3*B5	0.83	0.68
B1*B3	0.22	0.05	B1/B4*B5	0.84	0.71
B1*B4	0.16	0.02	B1/B5*B5	0.34	0.11
B1*B5	0.77	0.58	B2/B1*B5	0.69	0.47
B2*B3	0.18	0.03	B2/B3*B5	0.82	0.66
B2*B4	0.13	0.02	B2/B4*B5	**0.84**	**0.72**
B2*B5	0.71	0.5	B2/B5*B5	0.32	0.1
B3*B4	-0.01	0.01	B3/B1*B5	0.48	0.23
B3*B5	0.51	0.29	B3/B2*B5	0.55	0.3
B4*B5	0.52	0.27	B3/B4*B5	0.77	0.6
B1*B2*B5	0.7	0.48	B3/B5*B5	0.12	0.01
B1*B3*B5	0.58	0.33	Average (B1;B2)	0.33	0.11
B1*B4*B5	0.55	0.3	Average (B1;B3)	0.19	0.03
B2*B3*B5	0.51	0.25	Average (B1;B4)	0.18	0.03
B2*B4*B5	0.49	0.24	Average (B1;B5)	0.71	0.5
B3*B4*B5	0.2	0.08	Average (B2;B3)	0.19	0.04

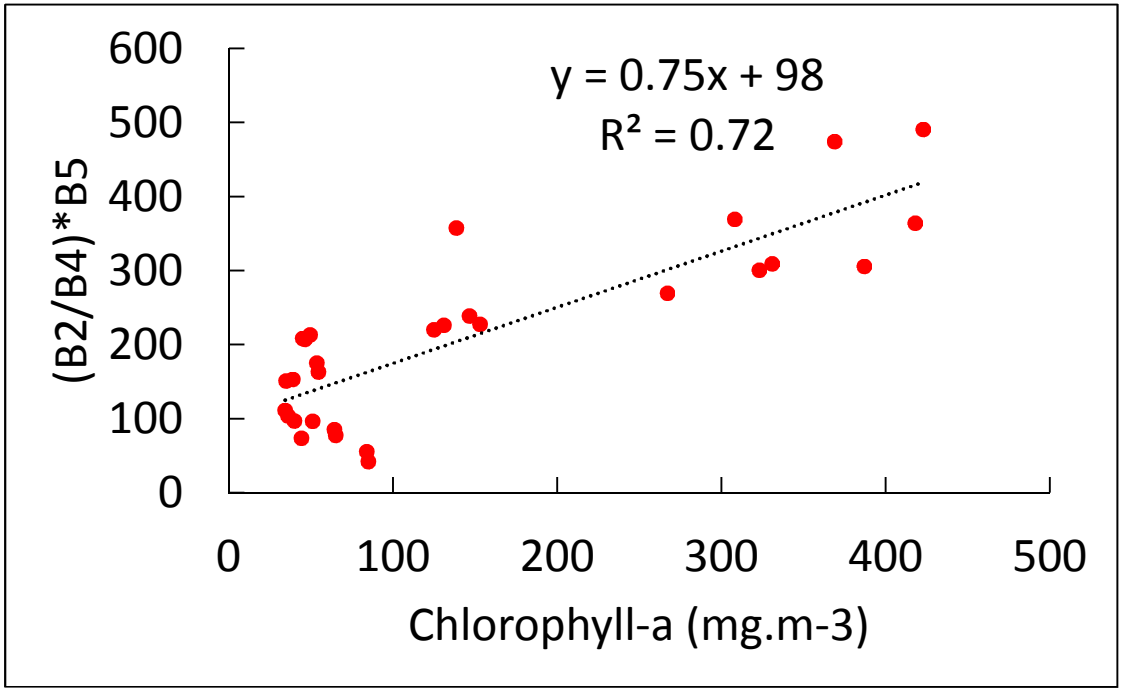
Bands	R	R2	Bands	R	R2
B1/B2	-0.22	0.05	Average (B2;B4)	0.19	0.03
B1/B3	-0.03	0.01	Average (B2;B5)	0.67	0.45
B1/B4	-0.06	0.01	Average (B3;B4)	0.11	0.01
B1/B5	-0.55	0.3	Average (B3;B5)	0.45	0.2
B2/B1	0.2	0.04	Average (B4;B5)	0.52	0.27
B2/B3	0.27	0.07	Average (B1;B2;B5)	0.62	0.39
B2/B4	0.32	0.1	Average (B1; B5)+ Average (B2;B5)	0.69	0.47
B2/B5	-0.51	0.26	Average (B2;B5) - B1	0.67	0.45
B3/B1	-0.13	0.11	Average (B1;B5) - B2	0.68	0.46
B3/B2	-0.27	0.15	Average (B1;B5)+B1	0.58	0.35
B3/B4	-0.07	0.03	Average (B2;B5)+B1	0.58	0.34
B3/B5	-0.53	0.17	2*Average (B2;B5)-B1	0.71	0.5
B4/B1	-0.11	0.01	2*Average (B1;B2)-B5	0.47	0.22
B4/B2	-0.32	0.1			
B4/B3	0.01	0.01			
B4/B5	-0.6	0.36			

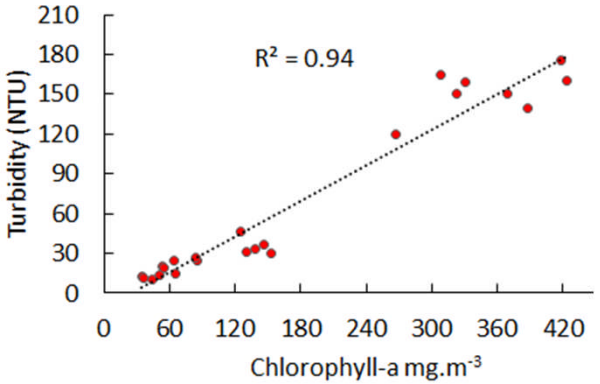
Correlation between in situ chlorophyll- a and best band combination, B2/B4*B5

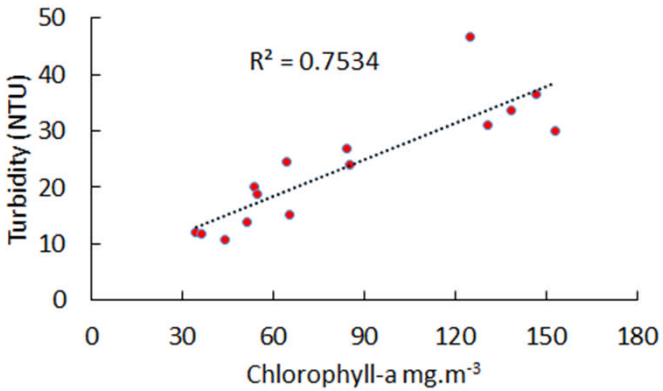
- The use of band combination of B2:B4 band ratio multiplied with B5 resulted in best correlation with measured chlorophyll-a in our study

$$Chl - a = \frac{\frac{B2}{B4}B5 - 98}{0.75}$$

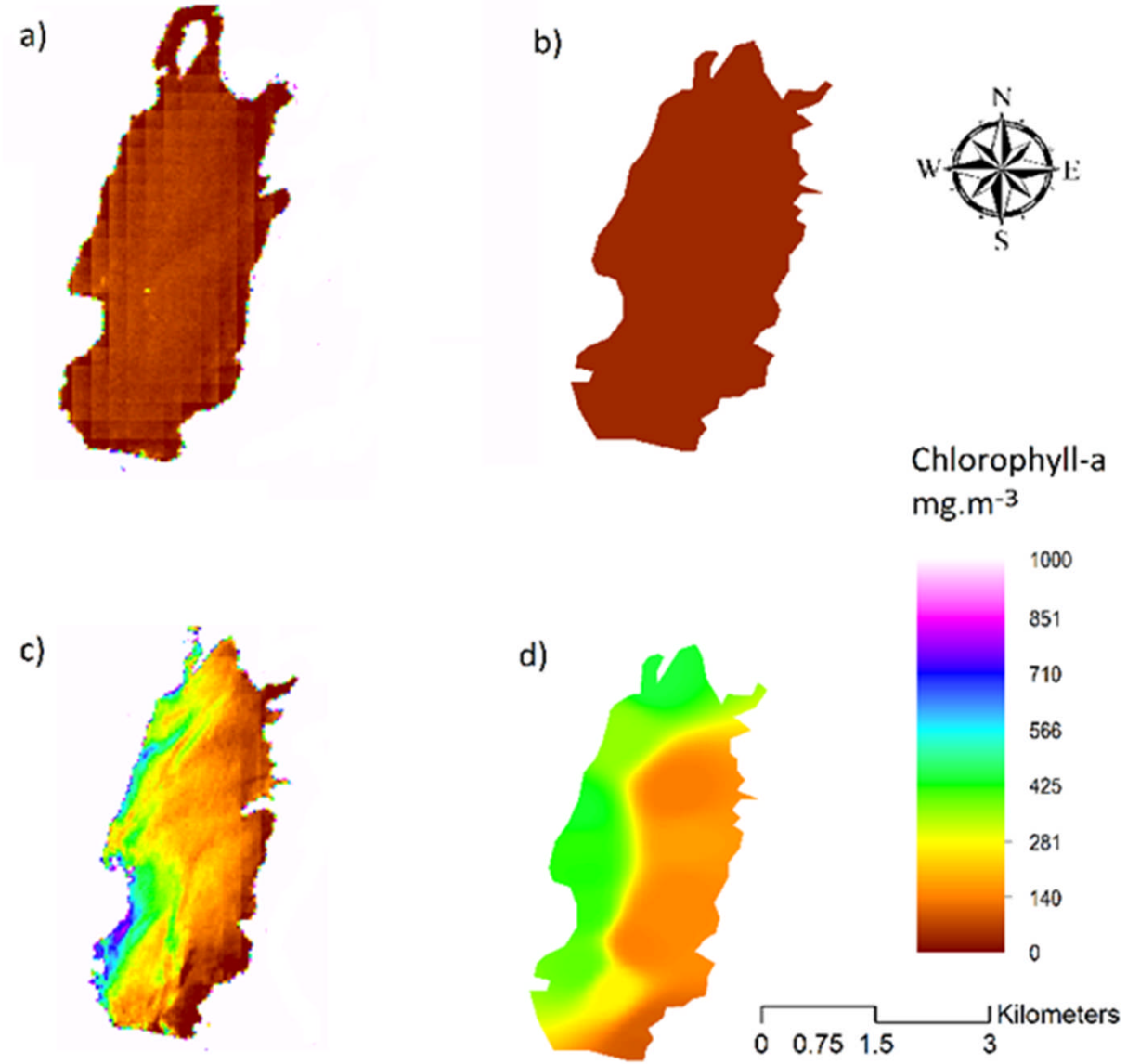
- Low precision at low chl-a concentrations.







Comparison between estimated (a, c) and measured (b, d) chlorophyll-a in 1 May 2013 and 10 July 2015, respectively



Conclusions & perspectives

- The information presented in this study increases the knowledge about chlorophyll-a monitoring in case II waters using Landsat OLI mission.
- High spatial variation of chlorophyll-a concentration can occur in the reservoir.
- A good correlation was found between OLI band 5 and measured chlorophyll-a concentrations in Karaoun reservoir
- The use of band combination of B2:B4 band ratio multiplied with B5 resulted in best correlation with measured chlorophyll-a in our study and shows that Landsat OLI has the potential to be used for analysis of high and not low chlorophyll-a concentrations.
- This monitoring approach using Landsat OLI can be transposed and tested on other eutrophic lakes and reservoir throughout the world.


Thanks for your attention
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