Spatiotemporal analysis of Lake Manchar

Using Landsat 8 and 9 satellite images

Susanna Casarini

February 14, 2025

https://github.com/SusannaCasarini

Introduction

- Lake Manchar is the largest lake in Pakistan.
- Images obtained from the Landsat 8 and Landsat 9 satellites.
- In the summer of 2022, the lake overflowed, causing severe damage.

Analysis:

- **First analysis**: Analysis of Lake Manchar in September from 2021 to 2024 - Source USGS - https://earthexplorer.usgs.gov/
- **Second analysis**: Analysis of Lake Manchar seasonality before and after the flood - Source USGS - https://earthexplorer.usgs.gov/
- **Third analysis**: Analysis of Lake Manchar NASA images before and after the flood - Source NASA Earth Observatory - https://earthobservatory.nasa.gov/images/150306/lake-manchar-is-overflowing

Analysis of Lake Manchar in September from 2021 to 2024

First analysis:

- Temporal analysis of September from 2021 to 2024.
- Use of bands B2, B3, B4, and B5.
- Landsat 8 and 9 satellite.
- The images have been cropped and enhanced for better distinguishability.

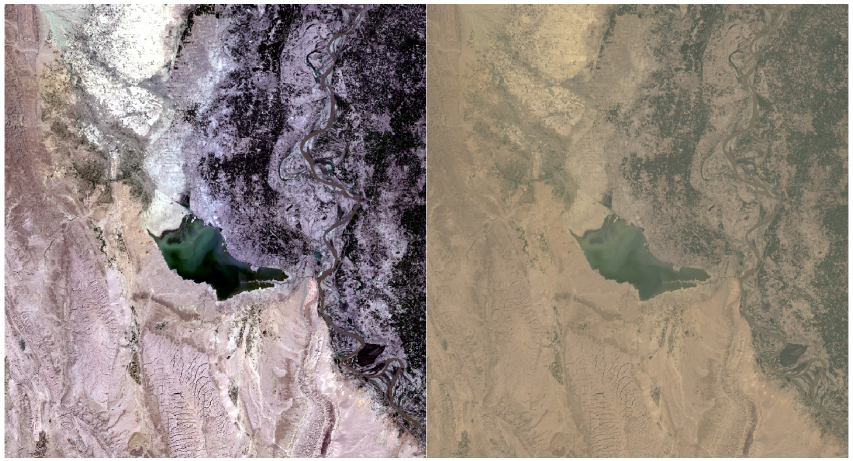


Figure: Natural color - Manchar Lake September 2021

```
extent_crop <- ext(277785+50000, 508215-100000, 2757585+128000, 2992215-20000)
```

```
plotRGB(landsat_rgb_2021, r=1, g=2, b=3, stretch="lin")
plotRGB(landsat_rgb_2021, r=1, g=2, b=3)
```

Analysis of Lake Manchar in September from 2021 to 2024

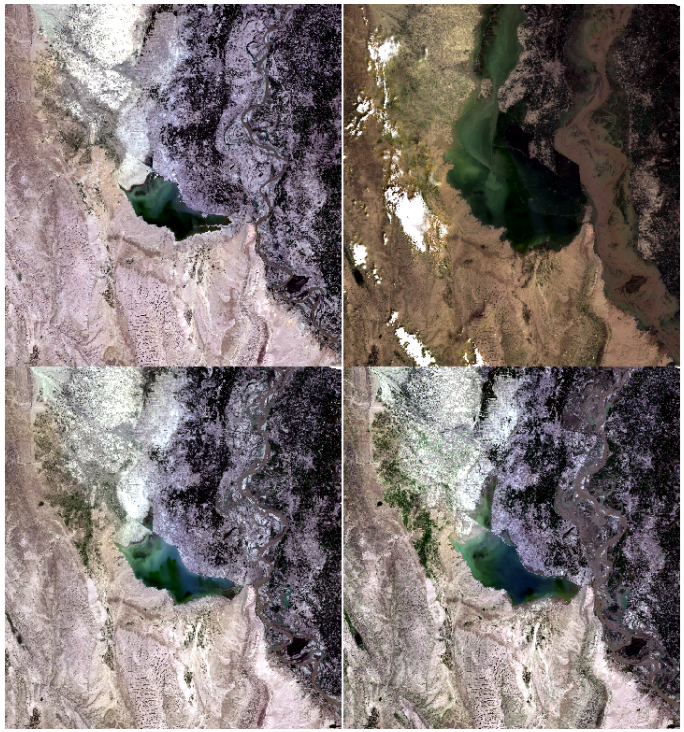


Figure: Natural color images, using bands B2, B3, and B4

Analysis of Lake Manchar in September from 2021 to 2024

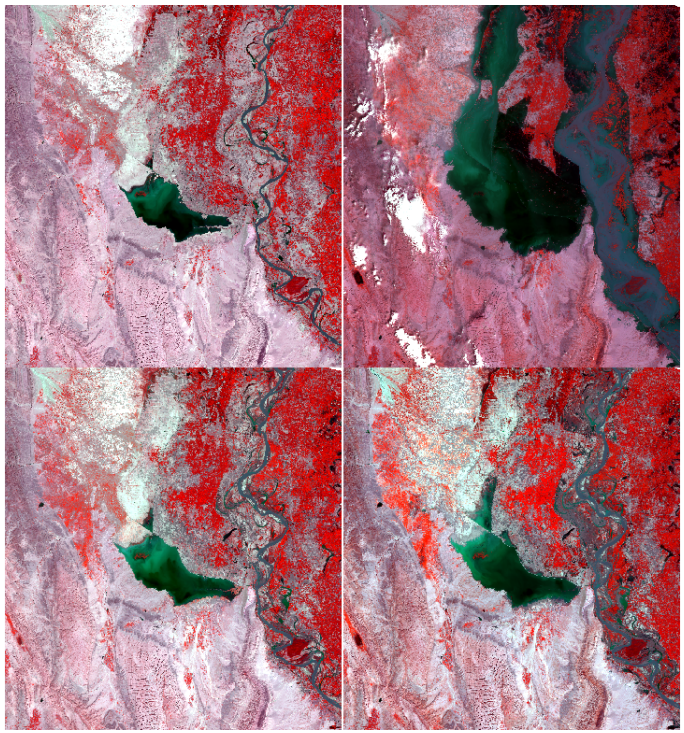


Figure: False color images, using red for infrared (NIR)

Analysis of Lake Manchar in September from 2021 to 2024

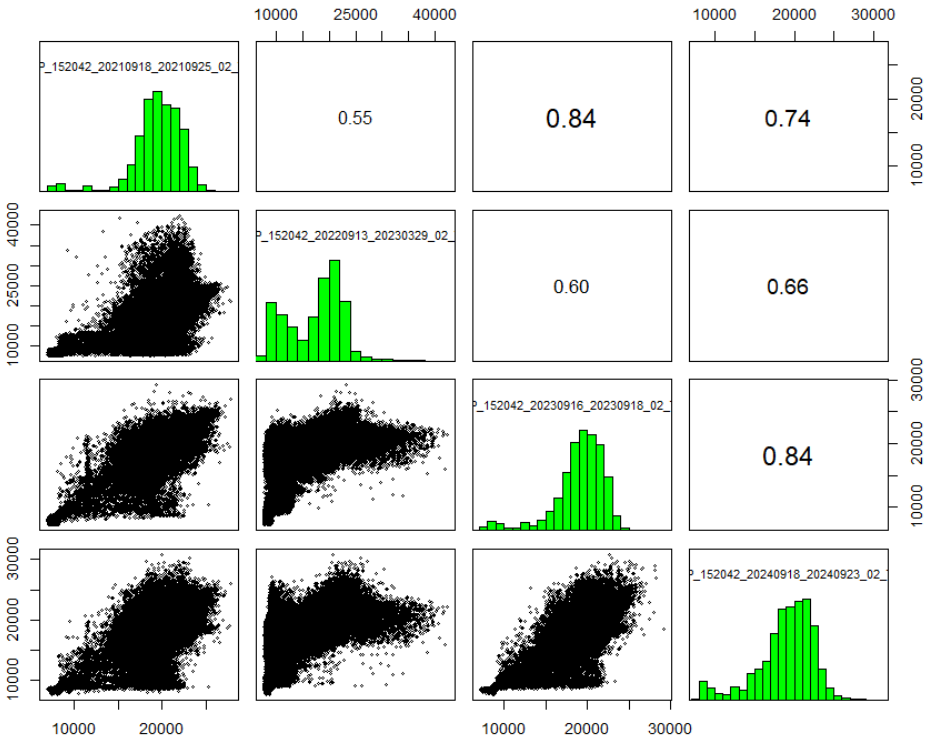
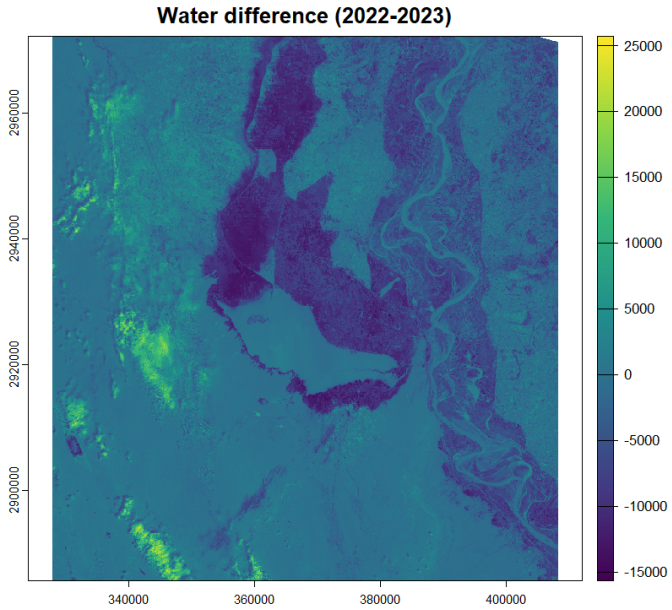
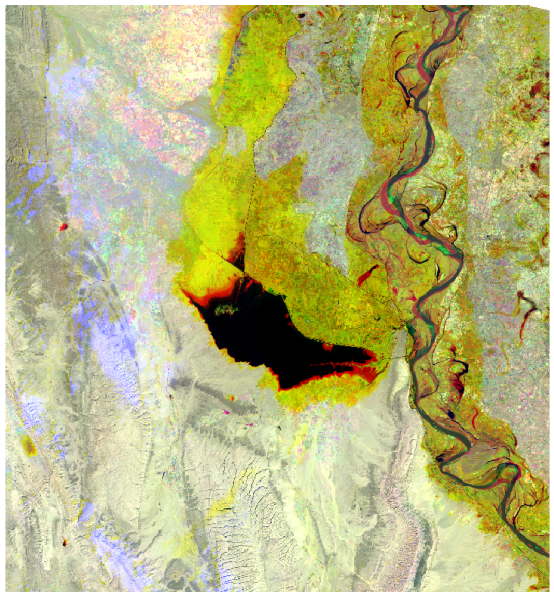


Figure: Years B5 correlation - Low correlation for 2022

Analysis of Lake Manchar in September from 2021 to 2024



Water difference 2022-2023



RGB in years 2021-2023

Analysis of Lake Manchar in September from 2021 to 2024

- Classification with im.classify
- Three classes: water, vegetation, desert

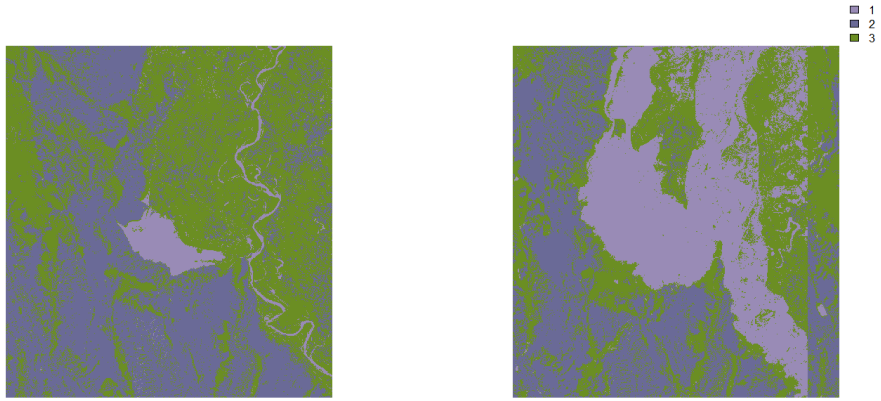
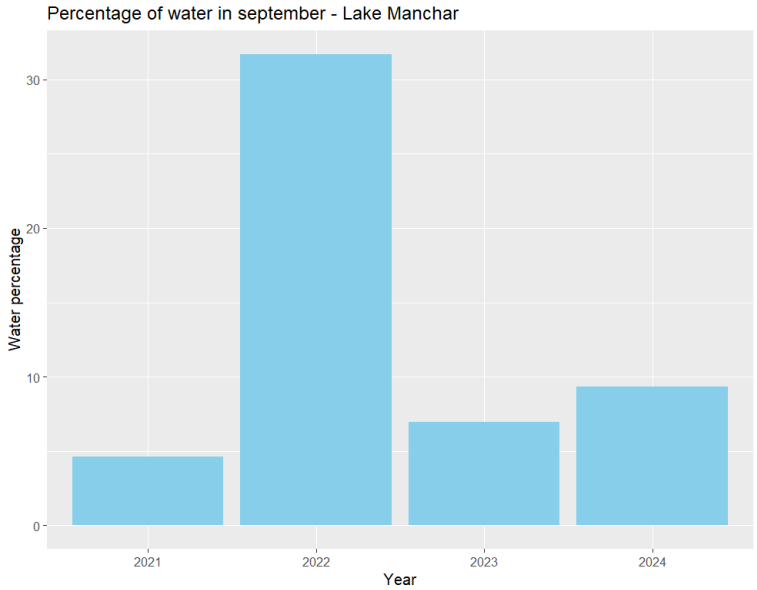


Figure: Classification of 2021 (left) and 2022 (right)

```
set.seed(1234)
b5_class_2022 <- im.classify(b5_2022, 3)
```

Analysis of Lake Manchar in September from 2021 to 2024

Water percentage	
Year	**Water**
2021	4.64
2022	31.71
2023	6.93
2024	9.35




```
f2022 <- freq(b5_class_2022)
tot2022 <- ncell(b5_class_2022)
p2022 = f2022 * 100 / tot2022
p2022
```

Analysis of Lake Manchar in September from 2021 to 2024

$$NDVI = \frac{NIR - RED}{NIR + RED} \tag{1}$$

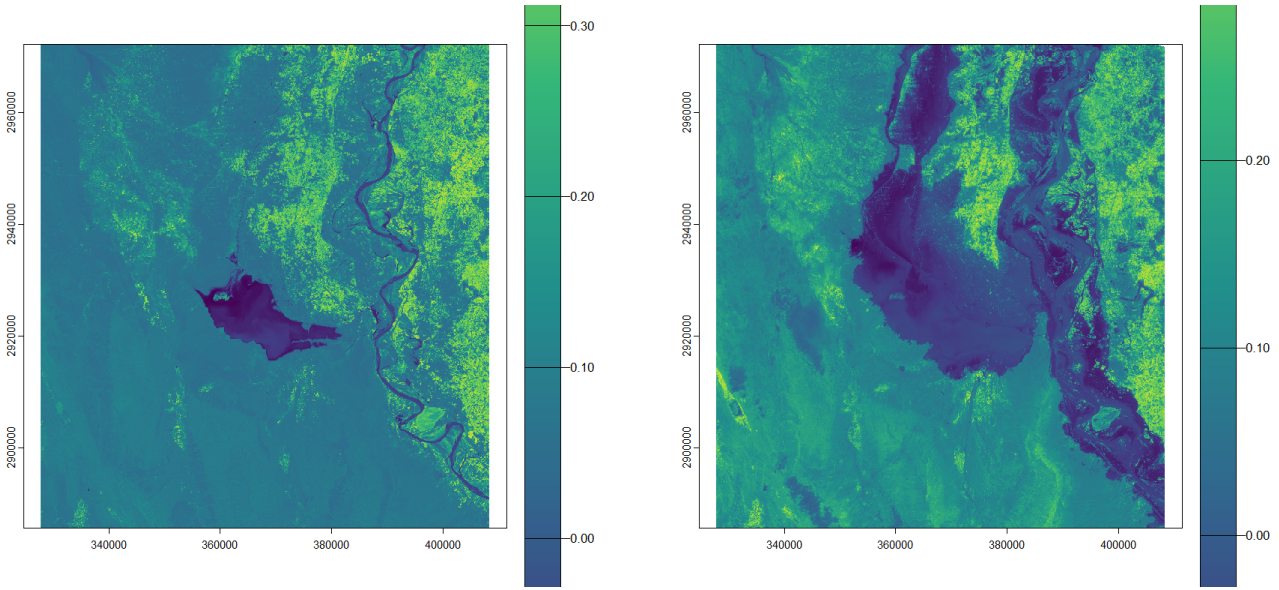


Figure: NDVI index in 2021 (left) and 2022 (right)

Analysis of Lake Manchar in September from 2021 to 2024

Conclusions of the first analysis:

- Comparing the satellite images of the lake from 2021 to 2024, a clear difference in the amount of water present in the images after the flood can be observed.
- The infrared band allowed for better distinction between vegetation areas and lake areas.
- The classification highlighted the differences between the years.

Analysis of Lake Manchar seasonality before and after the flood

Second analysis:

- Comparison of the images in the 4 seasons of the year preceding the flood and the year of the flood.
- Classification and comparison of the percentages of water, vegetation, and desert in the different seasons.
- NIR band.

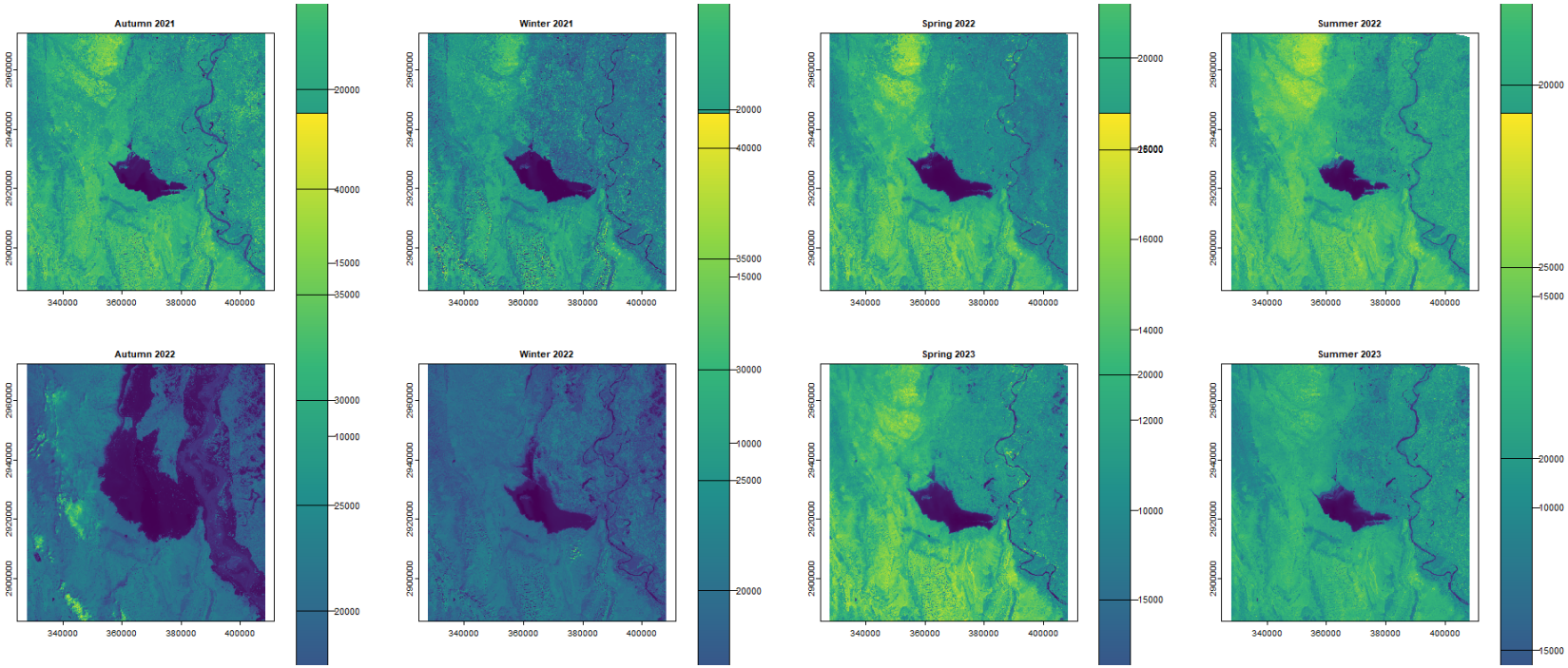


Figure: NIR band for each season - September 2021 - June 2023

Analysis of Lake Manchar seasonality before and after the flood

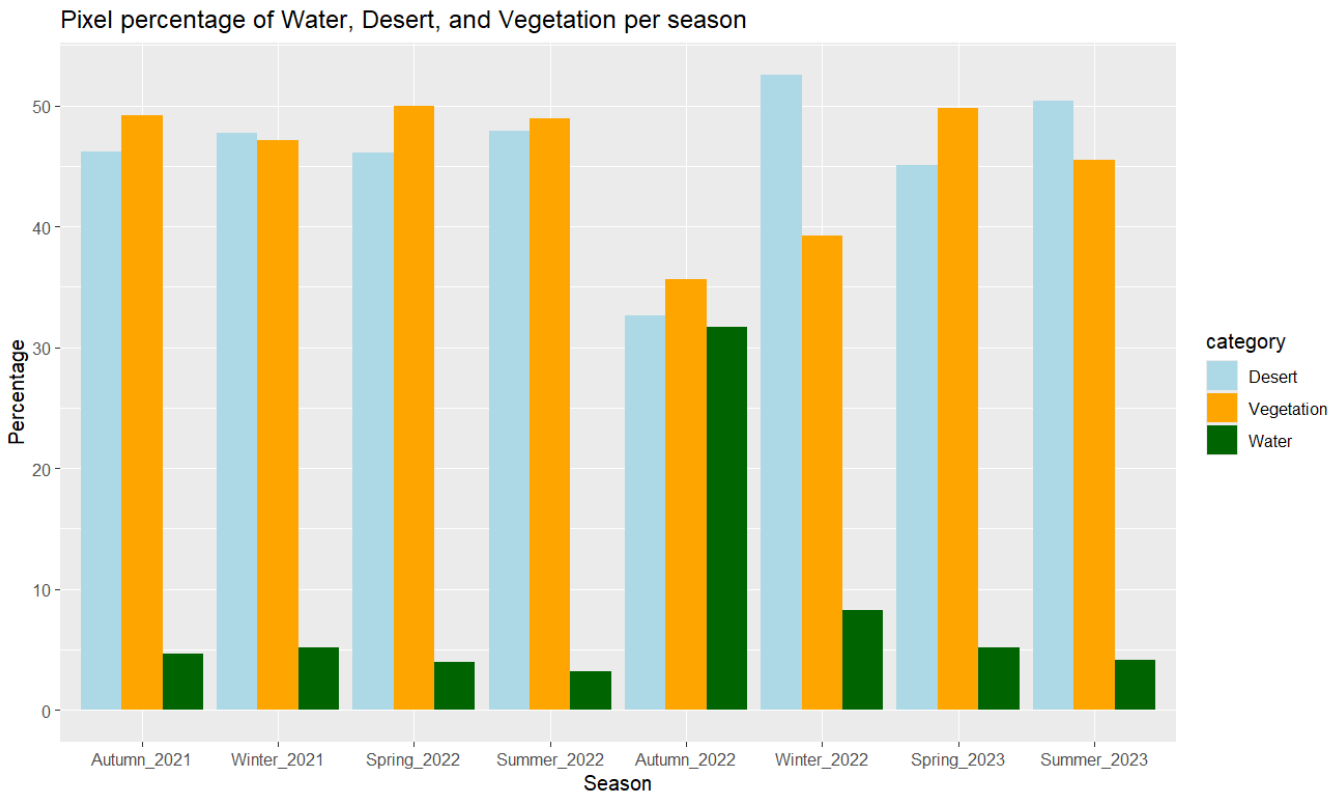


Figure: Clustering and comparison between cluster percentages

Analysis of Lake Manchar seasonality before and after the flood

Conclusions of the second analysis:

- The seasonal differences are not as significant compared to the consequences of the flood.
- In the winter following the flood, the amount of water is higher than usual.
- From spring onwards, the levels return to normal.

Analysis of Lake Manchar NASA images before and after the flood

Third analysis:

- Use of NASA Landsat 8 and 9 images with bands B2, B3, B4 of June 2022 and September 2022.
- PCA analysis of June and September: PC1 variability and differences.
- Density analysis.

Figure: Lake Manchar - June 2022 and September 2022 - NASA source

Code to perform PCA and study variability of PC1

```
# Perform PCA
par(mfrow=c(1,1))
pc <-  im.pca(sept_2022_NASA)
pc1 <- pc[[1]]
plot(pc1, col=cl_vir)
title('pc1 september')
```

```
# sd on pc1
par(mfrow=c(1,2))
pc1sd3 <- focal(pc1, matrix(1/9,3,3), fun=sd)
plot(pc1sd3, col=cl_vir)
title('pc1 standard deviation 3x3')

pc1sd7 <- focal(pc1, matrix(1/49, 7, 7), fun=sd)
plot(pc1sd7, col=cl_vir)
title('pc1 standard deviation 7x7')
```

Analysis of Lake Manchar NASA images before and after the flood

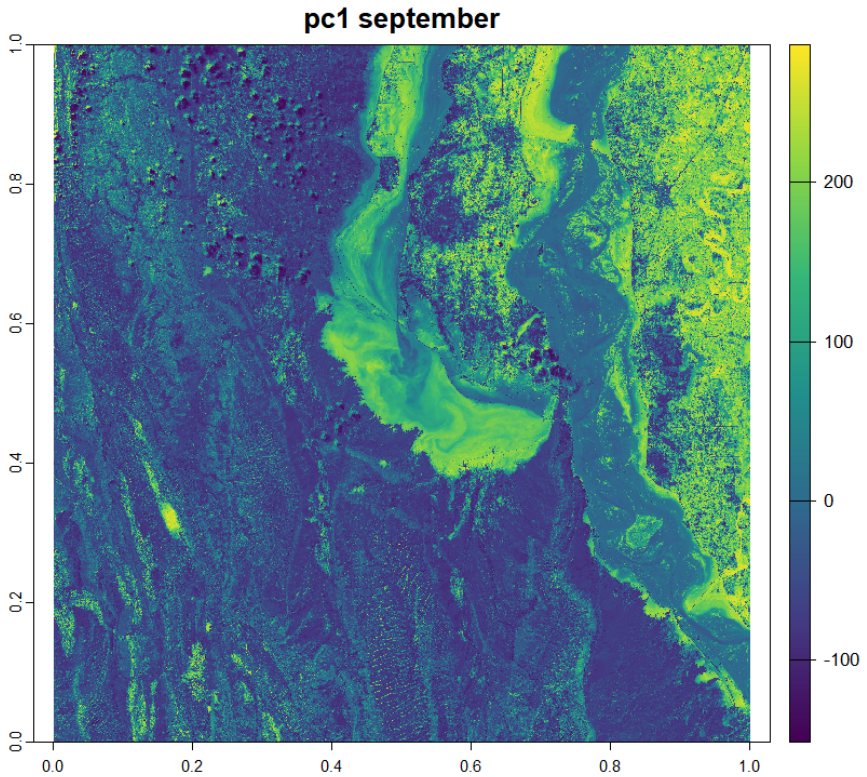


Figure: First principal component of September 2022

Analysis of Lake Manchar NASA images before and after the flood

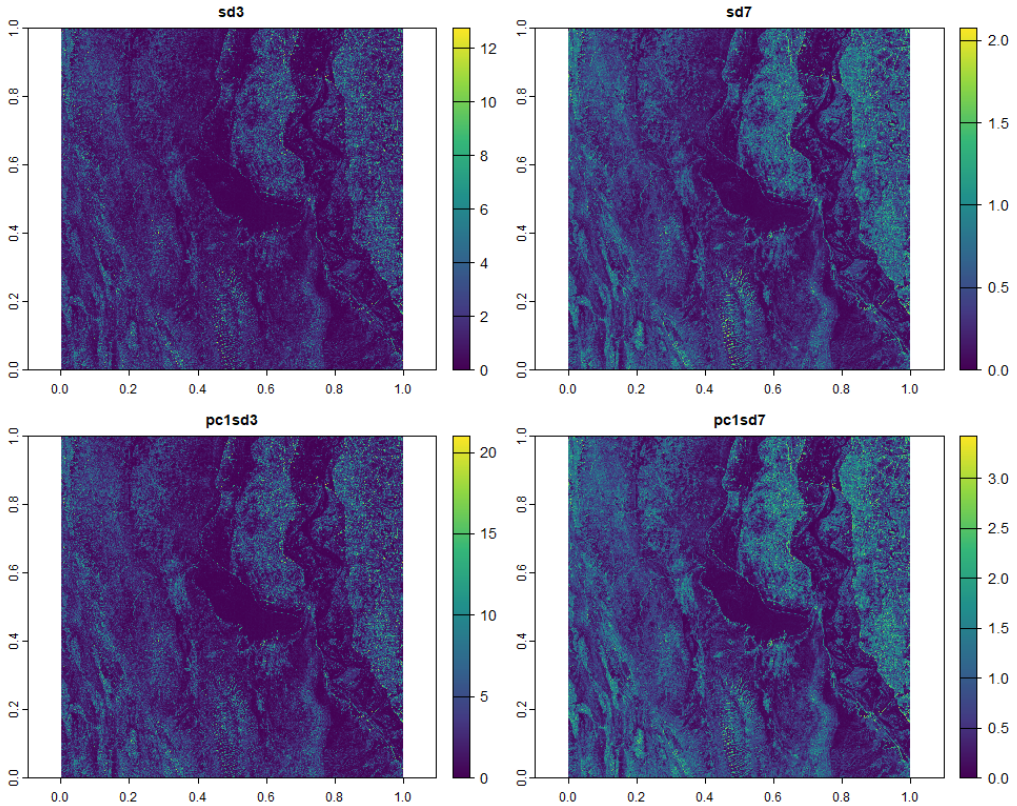
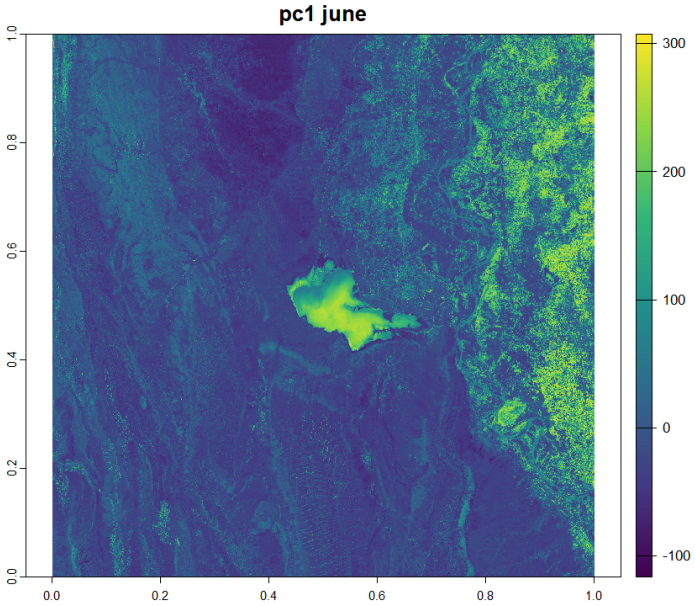
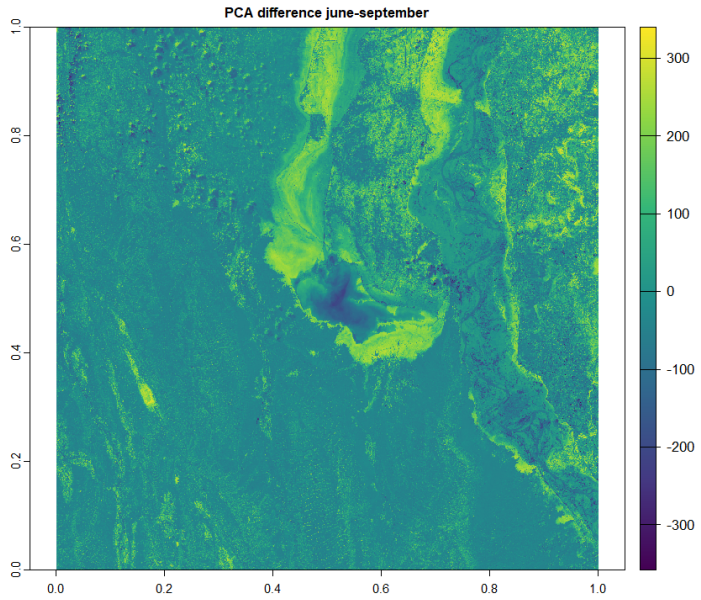


Figure: September variability of the first component

Analysis of Lake Manchar NASA images before and after the flood



June PC1



September/June differences

Analysis of Lake Manchar NASA images before and after the flood

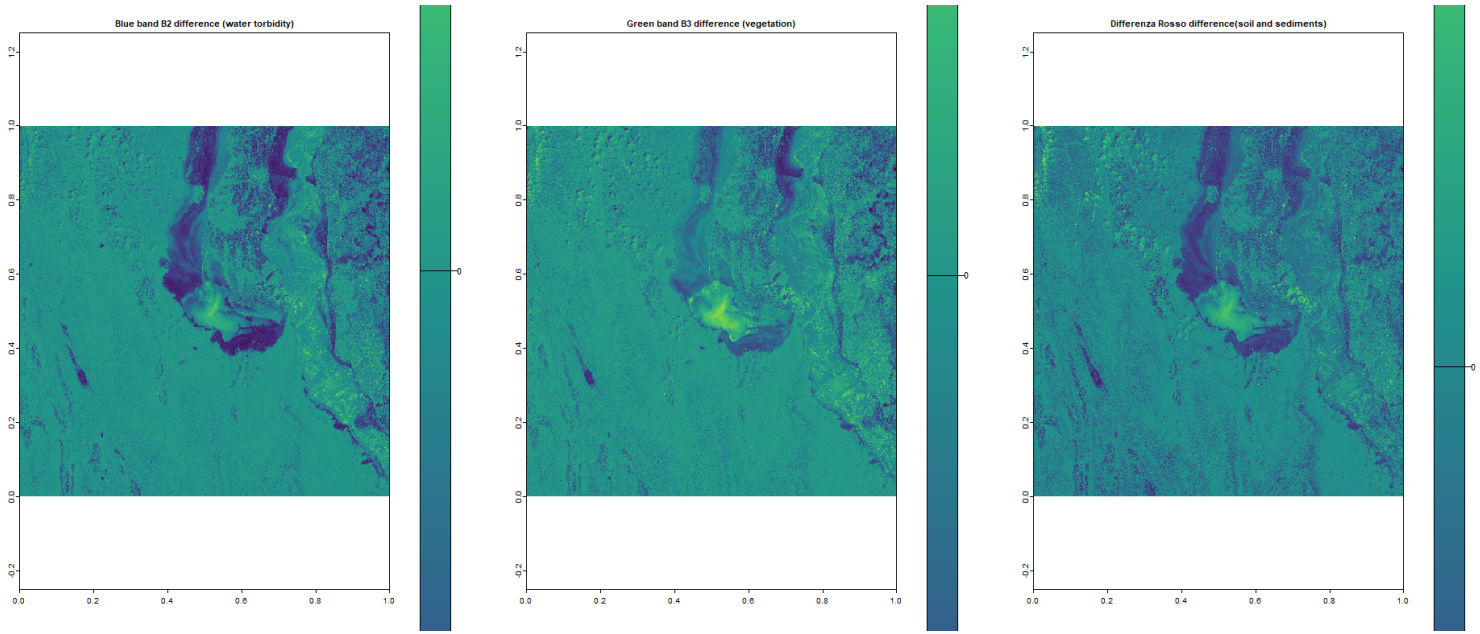
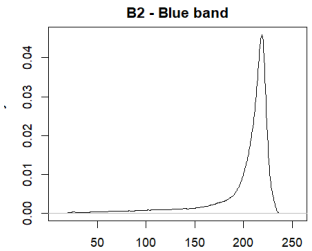
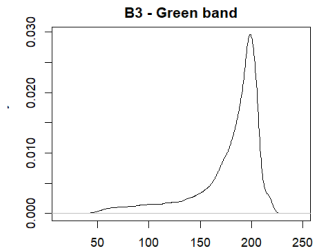


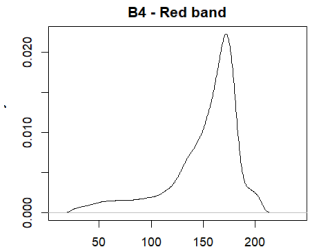
Figure: B2, B3 and B4 band differences between September and June

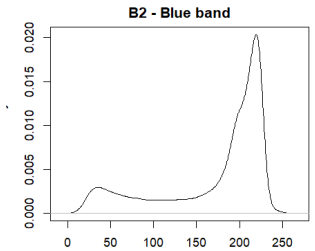
Analysis of Lake Manchar NASA images before and after the flood

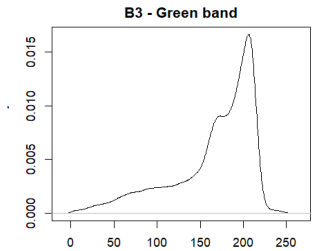
Bands density in June and September

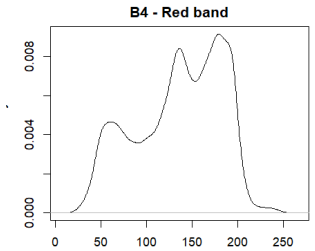













```
names(june_2022_NASA) <- c("B2 - Blue band","B3 - Green band","B4 - Red band")
density(june_2022_NASA)
```

Conclusions

Conclusions:

- The amount of water in the months following the flood is much higher compared to the quantities in previous years.
- Seasonality usually does not significantly affect the amount of water and vegetation, compared to the increase in water caused by the flood.
- It is observed that within a few months, the water levels returned to normal, although in December 2022 a higher amount of water is seen compared to the previous winter.
- The NIR band proved useful for distinguishing water and vegetation, but it was also possible to perform an accurate classification and study the images using bands B2, B3, and B4.

Thank you!