Remote Sensing and Machine Leaning: Spatiotemporal Change of Surface Water quality in Lake Arlington

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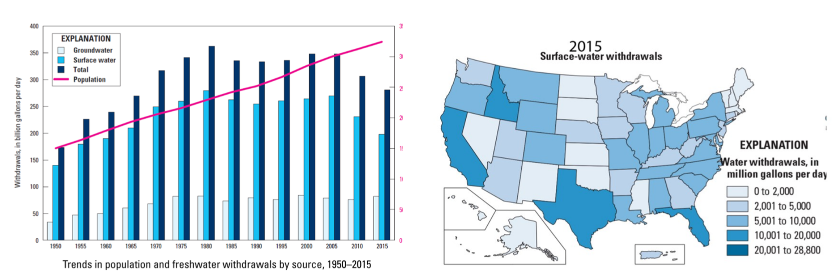
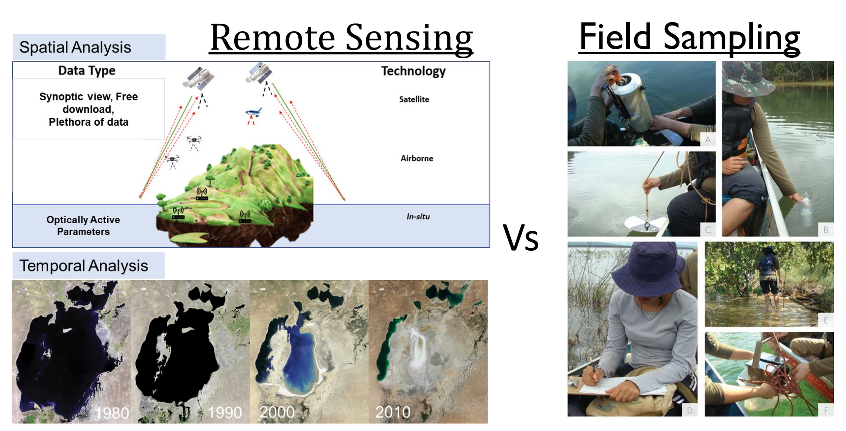
INTRODUCTION

Current field sampling assessments of water quality in lakes can be significantly improved by leveraging recent advances in remote sensing and algorithm development for a faster and more cost-effective approach. This study leveraged satellite- (Landsat 7/8 and Sentinel-2) and UAV-based remote sensing datasets to detect and monitor changes in key water quality parameters (Chlorophyll-a (Chl-a) and Secchi Disk Depth (SDD) within the epilimnion of Lake Arlington (Texas) during the past 20 years. In addition, remote sensing algorithms were developed to capture the spatial variability of the water quality parameters across the entire extent of the water body. A regression model, using satellite-based and historical in-situ observations (2002 – 2020), was developed to predict the targeted water quality parameters across the extent of the lake.



- Surface water is the main source of freshwater used daily in the united States
- Population increase = Increased water Demand

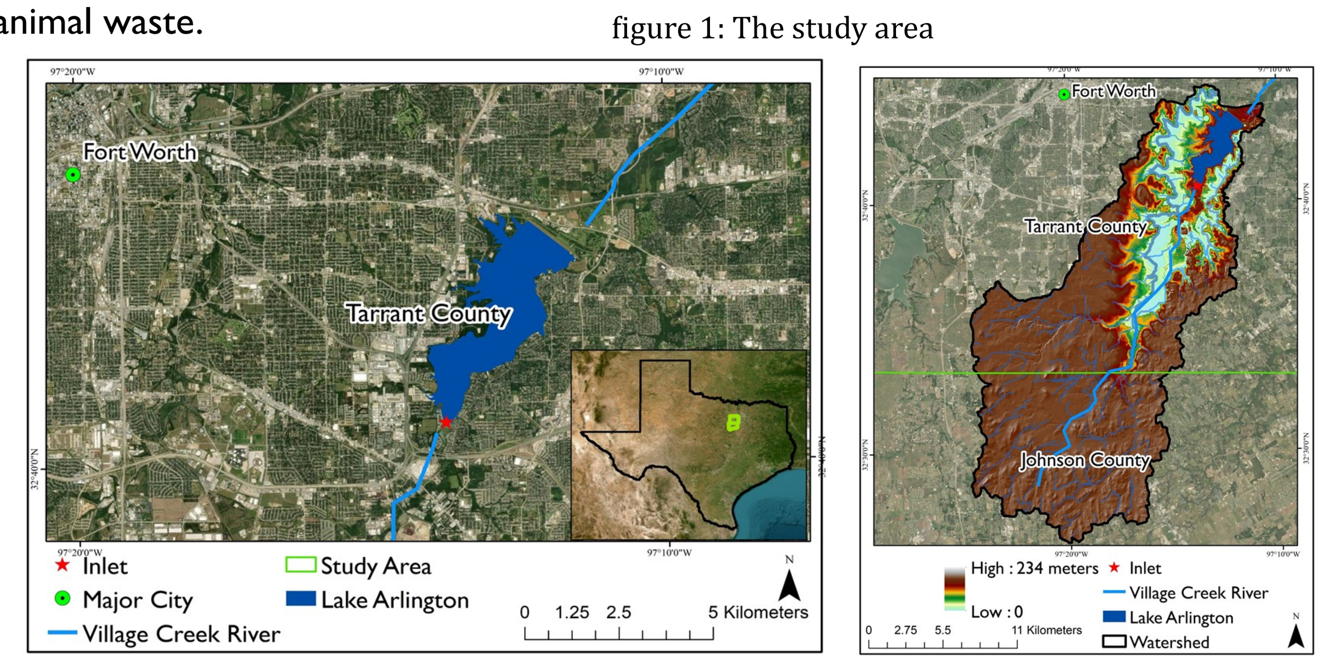


Integrating remote sensing analysis into water quality monitoring methods will improve existing field methods by incorporating Temporal and Synoptic analysis

THE STUDY AREA

- Lake Arlington (figure 1) is an urban lake located in Arlington, Texas with 1926 acres of surface area.
- Lake Arlington serves as a drinking source of more than half a million people in the Dallas Forth worth region.
- Lake Arlington has been struggling with algal growth, fish kills, and hypoxia.
- In 2015, the EPA established a Watershed Protection Plan to protect the water of Lake Arlington with the goal of mitigating algal growth.
- The main source of contamination were illegal waste dumping, excess nutrients, and animal waste.

figure 1: The study area



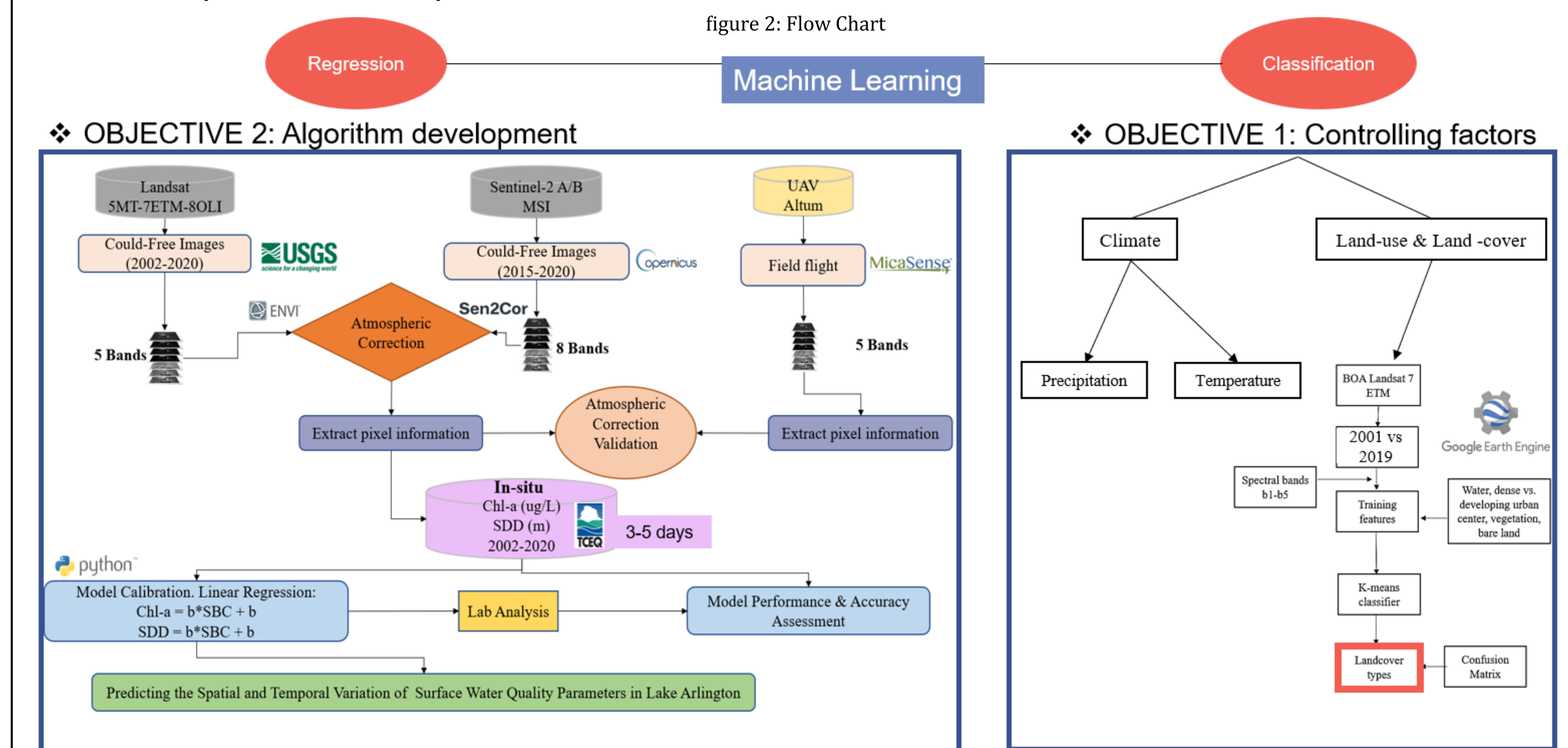
OBJECTIVES

1. Understanding key controlling factors of water quality in the lake.
2. To develop an algorithm for assessing the surface water quality of Lake Arlington using remote sensing techniques

DATASETS & METHOD

- The datasets and analysis results were evaluated in a GIS environment and Jupiter Notebook (Python) in search of spatial relationships and interactions between the various datasets.

figure 2: Flow Chart



The Drone (Matrice RTK 300) mounted with a multi-spectral camera (Altum Micascence) was used to capture images below cloud cover/ atmospheric effect, to validate the Sen2Cor algorithm used to perform atmospheric correction on Sentinel-2 Images.

RESULTS — IN SITU

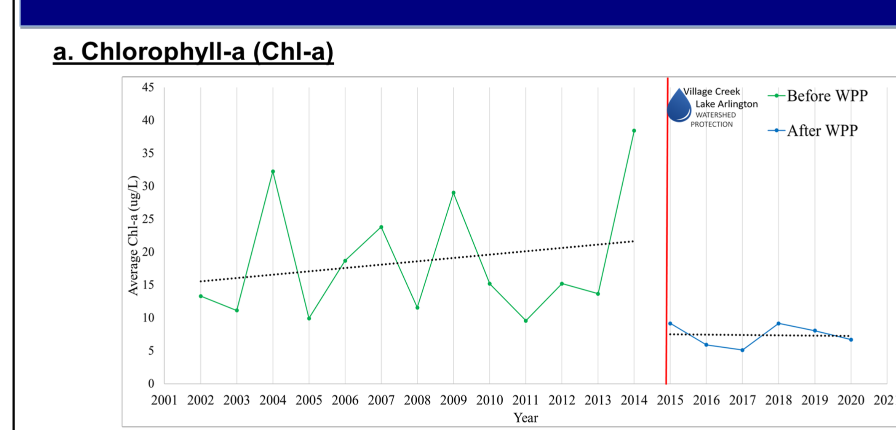


Figure 3. Yearly average of Chl-a levels in Lake Arlington from 2002 to 2020

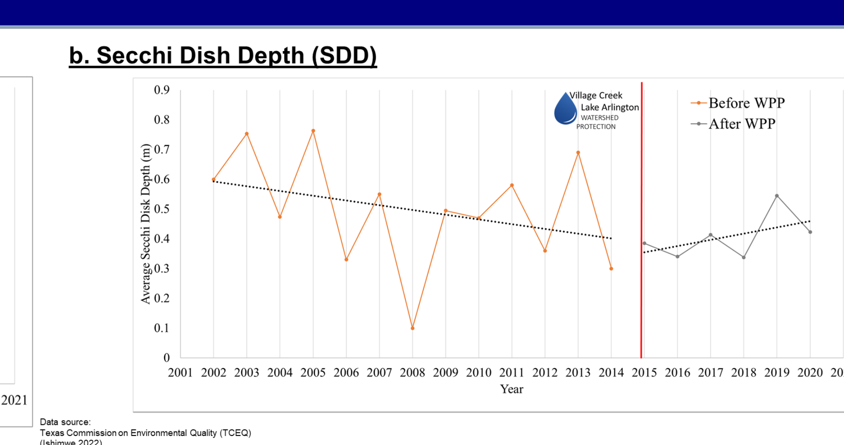


Figure 3. Yearly average of SDD levels in Lake Arlington from 2002 to 2020

- Lake Arlington is classified as a Eutrophic Lake by the TCEQ based on its levels of Chl-a (figure 3).
- Chl-a levels in the lake show a decreasing trend after 2015 (figure 4).
- SDD is a measure of water transparency. A high value of SDD mean the water is clear, a low number means the water is turbid.

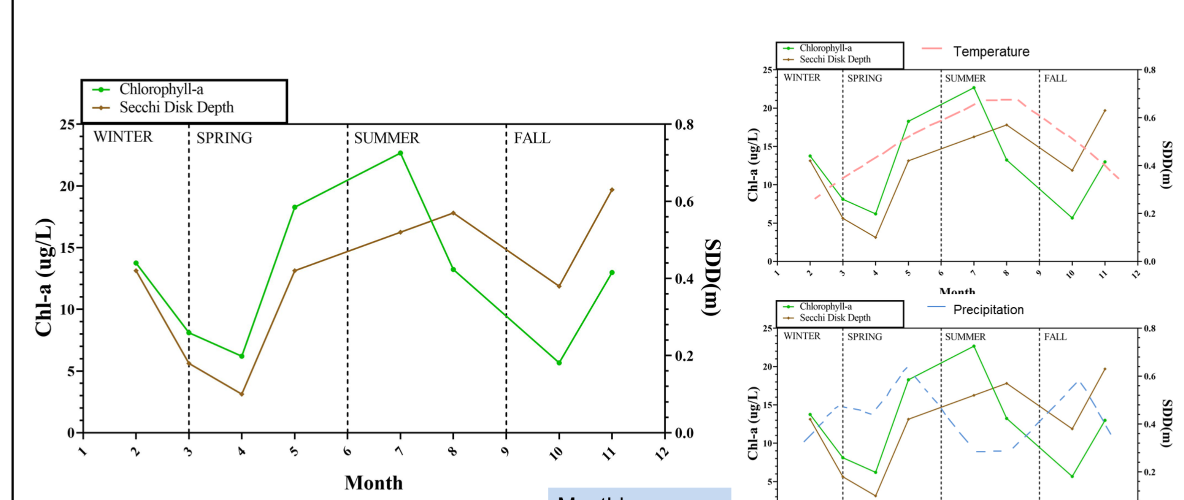


Figure 5. Average Monthly variation of Chl-a and SDD levels in Lake Arlington

- The spring & summer are the peak season for highest Chl-a and SDD levels (figure 5).
- May and October are the months with the highest precipitation around Lake Arlington, Figure 5c

RESULTS—REMOTE SENSING ALGORITHMS

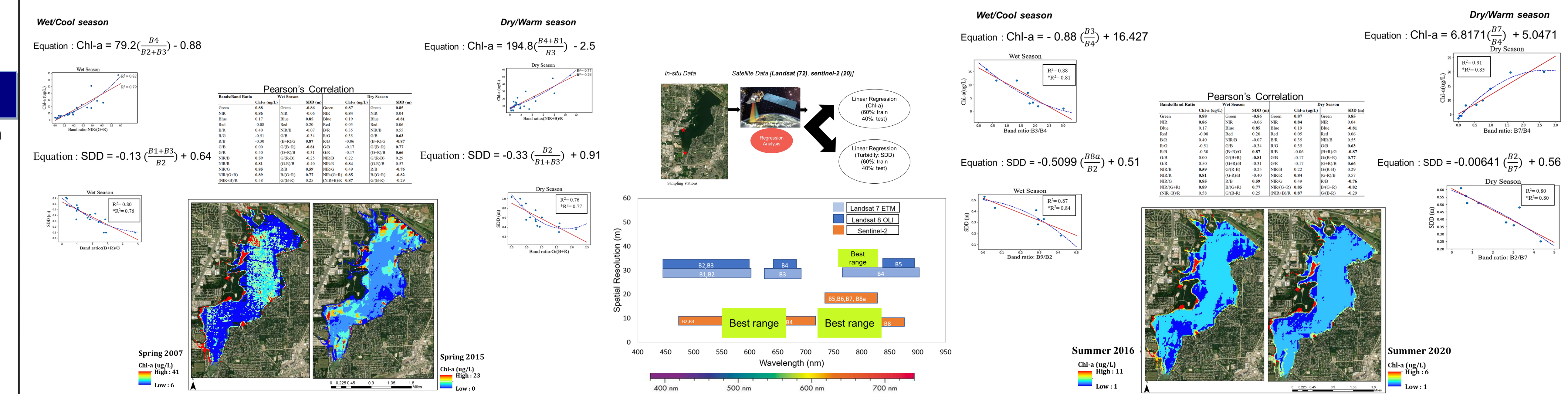


figure 6. Spatial and Temporal prediction of the progression of algal growth on Lake Arlington from 2007t o 2015 using Landsat prediction model

	Landsat				Sentinel-2			
	Wet Season		Dry Season		Wet Season		Dry Season	
	Chl-a(ug/L)	SDD(m)	Chl-a(ug/L)	SDD(m)	Chl-a(ug/L)	SDD(m)	Chl-a(ug/L)	SDD(m)
RMSE	6.73	0.07	6.08	0.10	2.07	0.04	1.87	0.05
BIAS	3.1	-0.2	4.5	0.74	-1.2	-0.12	0.8	-0.1

Table 1. Model performance for both Landsat and Sentinel-2 imagery.

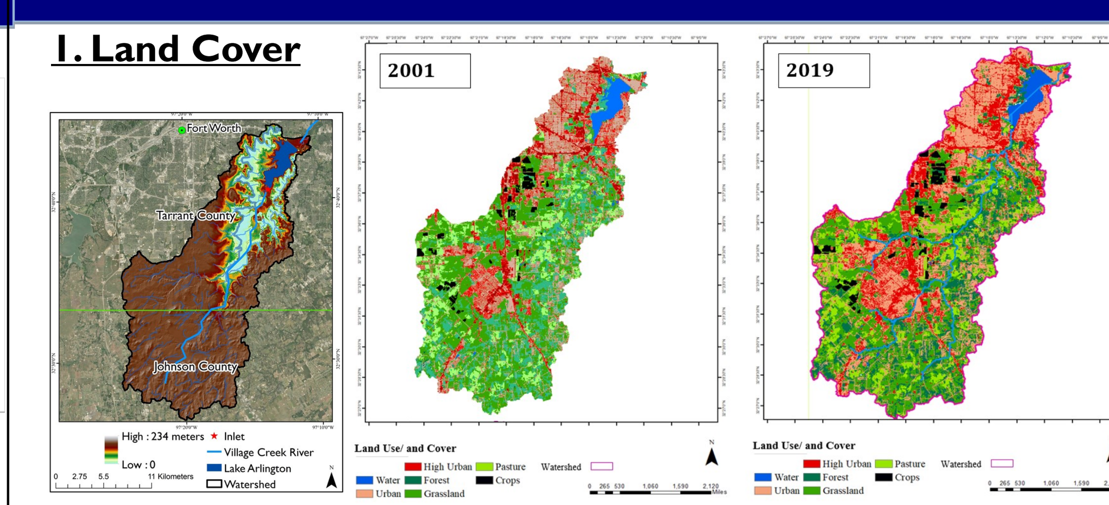
figure 7. Spatial and Temporal prediction of the progression of algal growth on Lake Arlington from 2015 to 2020 using Sentinel-2 prediction model

DISCUSSION

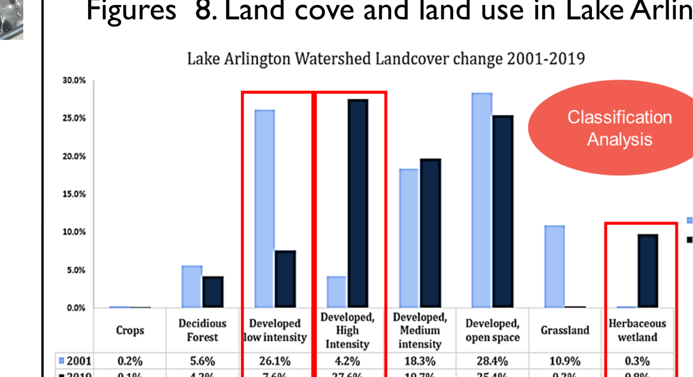
- The Landsat model predicted that Chl-a levels were measured during the spring of 2007 was between 41ug/L and 6µg/L, figure 6 season which is 4 times higher than the recommended levels for surface waters.
- The Sentinel-2 model predicted that Chl-a levels significantly decreased across the lake during the summer of 2016 was between 11– 1µg/L and 2020 was between 6-1µg/L, figure 7
- The remote sensing analysis shows that the spatial distribution of Chl-a around the edge of the lake is the highest in all seasons. However, there is a clear distinction between the spatial distribution before and after the established of the WPP in 2015.
- The Landsat satellite imagery analysis overestimated the level of Chl-a and turbidity in the lake during the spring season, while the Sentinel-2 satellite imagery analysis had a better performance due to its wider spectral bandwidth
- The optimum spectral band to detect Chl-a was found to be 590-880nm for Landsat and 665-940 nm for Sentinel-2. Statistical analysis of the Landsat and Sentinel-2 prediction algorithm results were significant with a p-value<0.5.

DISCUSSION—CONTROLLING FACTORS

1. Land Cover

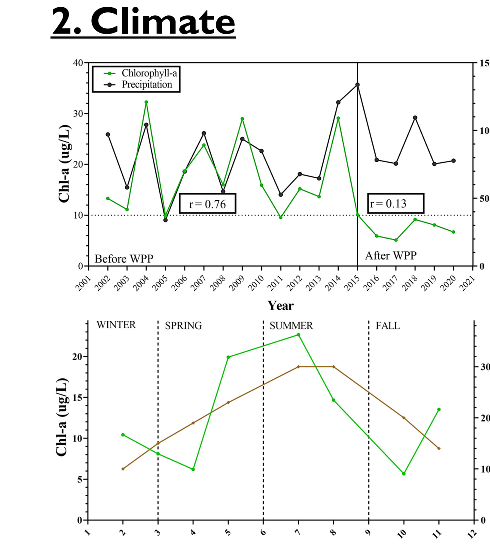


Figures 8. Land cove and land use in Lake Arlington watershed



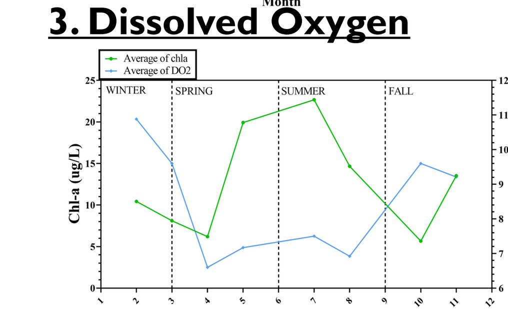
- Urban areas increased from 4.2% to 27.6%
- Grassland decreased from 10% to 0.2%
- Wetlands increased from 0.3% to 9.8%

2. Climate



- The yearly trend in Chl-a levels had a direct correlation with precipitation trends before the establishment of the WPP.
- After the WWP, Chl-a levels in the lake reduced regardless of the precipitation rates.
- This implies that the WWP was effective in reducing the amount of influents into the lake that were the cause of algal growth and tarnish the water quality.

3. Dissolved Oxygen



- The decrease of Grassland in the watershed could have influenced the increase in Wetlands around the lake, which would have contributed to the reduction of nutrient run off in the lake.

CONCLUSION

- We applied an integrated study approach based on three different remote sensing datasets to analyze the water quality of a small inland urban lake, identified the optimum spectral bands for detecting the targeted water quality parameters, modeled the spatial distribution of Chl-a and turbidity across the extent of the lake, and investigated the controlling factors that indirectly or directly contribute to the lake water quality as outlined on the objectives of the study.
- Our analysis reveals that precipitation, and landcover change within the watershed and are the leading controls for the Lake Arlington water quality change. Additionally, that the establishment of EPA Watershed Protection Plan was crucial in improving the water quality of the lake.
- Some limitation of this study were: no field water samples were collection in the middle of the lake to validate the performance of the model at that region
- Future studies suggestion for this study include, collection more field samples to improve the performance of the models