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GEOG 342_Remote Sensing
Prof. Jennings
Final Project

Drought and a Golf Course

Summary

Through the use of remote sensing and digital analysis methods, I set out to see the effects of years drought had on a local golf course. For the study area, I chose a grouping of fairways and holes from the Haggin Oaks Golf Complex in Sacramento, CA. Once the study area was determined, I located aerial photography from an online source for years before, during, and after the point the drought was at its highest severity. Finally, I employed tools and analysis on the imagery using ESRI ArcGIS software to come to my final determination of the impact of the drought on the golf course.

Purpose

The purpose of this project is to measure the amount of healthy vegetation present on the golf course throughout the most recent California drought.

Image Processing Steps

Find the Data

The most recent California drought spanned more than five years through the year 2017. In April, Gov. Brown issued Executive Order B-40-17 which" officially ending the drought state of emergency in all California counties except Fresno, Kings, Tulare, and Tuolumne."*(1)* At the peak of the drought, it encompassed "over 98% of the state, [with] more than 44% in 'exceptional' drought – the worst level of drought." *(2)*

The data used for this project is NAIP aerial imagery from the California Department of Fish and Wildlife's website. Luckily, I was able to use data from before (2010), during (2012 and 2014), and towards the end of the drought (2016). Years 2010 through 2014 have a resolution of 1 square meter, while 2016 is .6 square meters. All four raster datasets include 4 Bands using the following configuration:

Band 1: Red Band 2: Green Band 3: Blue Band 4: Near Infrared

Load Data and Find Project Area

Using ESRI's ArcMap, I loaded each year's layer and then found my project area. Since the datasets were statewide, I had to zoom in and scroll around until I located the golf course. Once the desired extent of was in the window, I used the Clip tool in the Image Analysis menu.

(Statewide imagery_2016)

(Project Area_2016)

Isolate the Grass Areas

I again used the Clip tool isolate the grass areas from the image. To do this, I used the Draw tool to create polygons on the desired area. This was a tedious process of drawing around trees, shadows, and other questionable areas. I then turned on each layer with the polygon overlaying it to make sure that each year was appropriately represented.

(Clip polygon overlay_2016)

(Product of clipped grass area_2016)

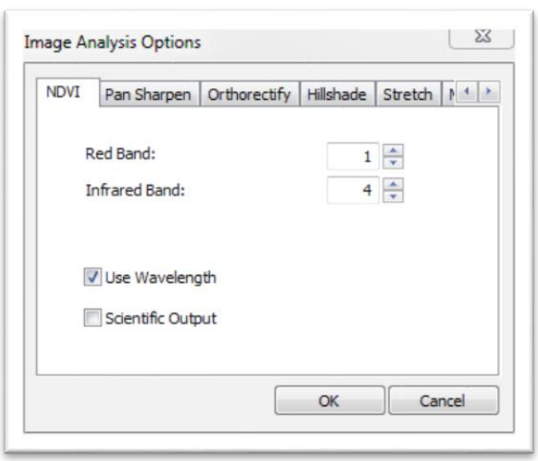
Perform NDVI Analysis

In order to calculate the healthy grass in my project area, a Normalized Difference Vegetation Index (NDVI) analysis was performed in ArcMap. Essentially, this formula uses the Near Infrared which plants strongly reflect, and Red light which plants strongly absorb, to accentuate healthy vegetation. NDVI is calculated using the following formula:

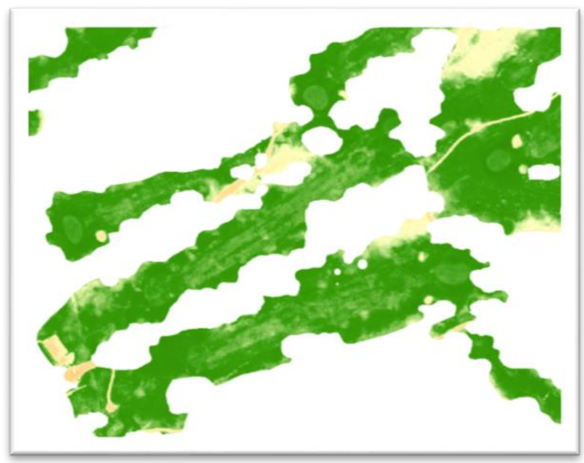
$$NDVI = (NIR - R)/(NIR + R)$$

Wavelength

In the Image Analysis Options button, the Use Wavelength box is preselected. I then had to change the Red Band to 1 since Red was used in Band 1 for the initial dataset. After that, I simply clicked the NDVI button and waited for the results.



(Image analysis options_Use Wavelength)

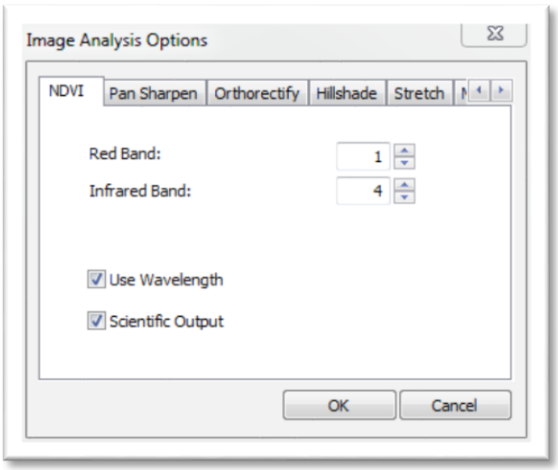


(Output_2016)

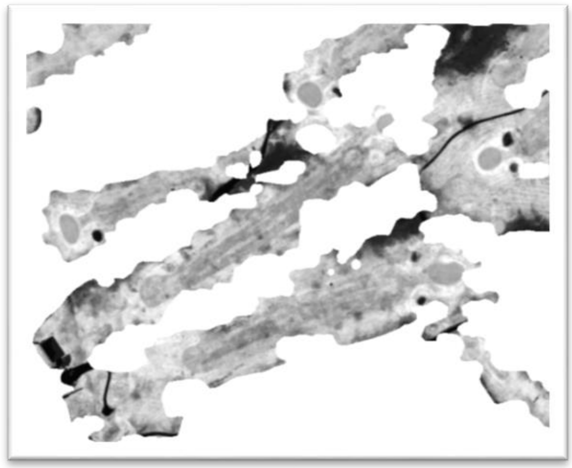
This NDVI with the Use Wavelength assigned each pixel a value between 0 and 255, where the higher values represent healthy vegetation (green colors), and the lower numbers represent features such as bare ground and structures (beige to red). It also conveniently provides a color ramp, where the healthy vegetation is represented with different shades of green.

Scientific Output

In the same Image Analysis Options as before, I selected the Scientific Output box and ran the NDVI formula again.



(Image analysis options_Scientific Output)



(Output_2016)

This Scientific Output uses the Band Arithmetic function and outputs values between -1.0 and 1.0. Healthy vegetation is represented by values closer to 1.0 (lighter color), while values closer to -1.0 represent bare ground or structures (darker color).

Determine Healthy Vegetation Threshold

After trying to find out the threshold for healthy vegetation using ArcMap's NDVI Wavelength output, I was unable to determine a definite pixel value. While reviewing a previous project from this class and listening to a recent presentation, they created raster calculations starting with values 110 and 139. So, I decided to just do a visual inspection of my data, used the Identify tool to get a range of pixel values, and made a determination based on what I believed best represented my data. I settled with value 136.

After some online searching, I was able to find a reliable source that will help me identify they healthy vegetation based on the Scientific Output. Per a page on the United States Geological Survey's (USGS) website, "Sparse vegetation such as shrubs and grasslands or senescing crops may result in moderate NDVI values (approximately 0.2 to 0.5). High NDVI values (approximately 0.6 to 0.9) correspond to dense vegetation such as that found in temperate and tropical forests or crops at their peak growth stage." *(3)* With this information, I can decide whether to do a calculation between the shrubs and grassland range (0.2 to 0.5), or just to include all vegetation above the 0.2 vegetation threshold.

Use Raster Calculator

Next, I used ArcMap's Raster Calculator tool to determine the total acreage of healthy grass in my project area. To do this, I created conditional statements for both the Wavelength and Scientific outputs, as shown below.

Wavelength

Con("Wave_2016_RC" >= 136, 1)

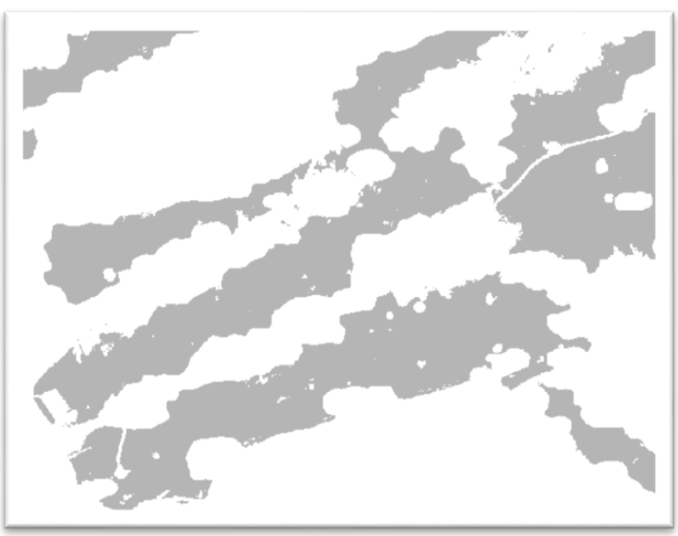
This formula will assign all values above 136 a value of 1.

(Results_2016)

Scientific Output

Con("Scientific_2016_RC" >= .2, 1)

This formula will assign all values above 0.2 a value of 1.



(Results_2016)

Determine Total Acreage

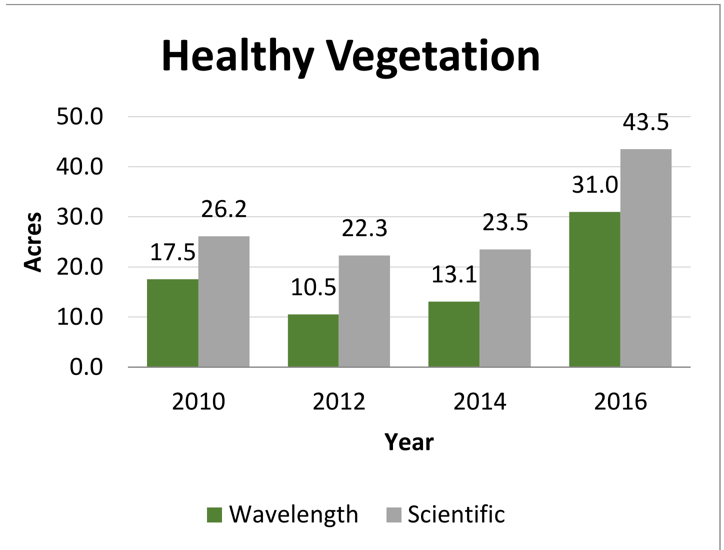
After the Raster Calculation, there is only one pixel value remaining. By looking in the Attribute table, the total number of cells that represent my desired healthy grass are already calculated. I simply have to convert my cell size to acres.

Wavelength

Year	Count	Acres	% Change
2010	70958	17.53	Base Year
2012	42614	10.53	-40%
2014	52992	13.09	-25%
2016	209108	31.00	77%

Scientific Output

Year	Count	Acres	% Change
2010	105829	26.15	Base Year
2012	90344	22.32	-15%
2014	95118	23.5	-10%
2016	293608	43.5	66%



Note

2010, 2012, 2014 are measured in a cell size of 1 meter   1 m = .000247105 acre

2016 is measured in a cell size of .6 meter   .6 m = .000148263 acre

Results

With the total acres of healthy vegetation measured for each year, I can now use this information to determine if the drought had an effect on the golf course.

Although the acreage differs between the two methods, there is definitely a common pattern between the two. In 2010 (before drought), there are noticeably more acres of healthy vegetation as compared to years 2012 and 2014 (during drought). What is surprising is that in 2016 (end of the drought), there is a spike of nearly double the acreage when compared to the base year of 2010.

Challenges

One of the first challenges that I came across was determining my project area. At first, I was going to include the entire golf course but later decided against it. It did not have to do with the size of the data, but instead with the scale. The NDVI analysis of the entire course does make as much as a visual impact when compared to just using a few fairways. So eventually I only have about 5 fairways instead of 18.

The next challenge had to do with the clipping. I started with the 2016 raster image because it had the most shadow. After that clip layer was created, I overlaid it on the other years and cut out additional shadows and canopy cover. In the 2010 image, there were even some trees that had been removed by 2012. This process was not difficult, just tedious. It was all worth it though because I was able to isolate the grass area create a surface that works for all four years.

Another lesson I learned was that I need to pay attention to my data. Throughout the semester we had been using data with bands where Red = 3, Green = 2, Blue = 1 and NIR = 4. So when I preformed the NDVI analysis I assigned Red = 3 and NIR = 4. The results looked ok, but there was not enough variation for the bare ground and less healthy vegetation. So I completed the project with this data.

Eventually, while writing this report and saw that the raster images that I was using had the following band configuration: Red = 1, Green = 2, Blue = 3, and NIR = 4. I then reran the NDVI analysis using Red = 1 and NIR = 4. This gave a much better representation of bare ground and variation on vegetation, because I was finally using the correct inputs, Red and NIR. Good times.

The final challenge that I experienced was determining the healthy vegetation threshold. To determine the pixel value, I went through each year, found an area with a good variation of bare ground to healthy grass, and clicked individual cells to get their values. I then clicked the NDVI layer and the NAIP image on and off for a real life representation of the surface. In the end, I essentially estimated which value looked just “healthy” enough for my purposes, and landed on value 136.

Analysis and Conclusions

The purpose of this project was to measure the amount of healthy vegetation on a golf course throughout the California’s last major drought. Once the acreages were calculated for each year, it was clear that the drought had an impact.

The decreases in healthy vegetation during 2012 and 2014 are expected. During those years the drought was at its most severe level, and by April 2015 there were statewide mandates for both commercial and residential properties to reduce water consumption by 25 percent. In order to meet this requirement, golf courses employed several different methods. Some courses replaced lawn with artificial turf, some replaced rough grass and trees with drought-tolerant plants, and others limited watering to specific areas. *(4)*

What really surprised me was how the healthy vegetation really rebounded and nearly doubled by 2016 (as compared to 2010 as the base year). My first thought was that golf courses received an exemption from the mandated water reduction, but further research disproved that. I then double checked my calculation from meters to acres to see if it was a calculation error, but I am confident it is not the issue either. The only other thing that I can think of is that there was more rainfall that year, or at least more rain leading up to the time when the NAIP aerial imagery was taken in 2016. The closest data I was able to find was article that breaks down annual rainfall from October 1 to February 10 for the downtown Sacramento area. The annual rainfall totals are as follows and are measured in inches: 2010 = 12.08”, 2012 = 5.4”, 2014 = 4.4”, 2016 = 9.4”. *(5)* Based on that data, it is possible that the increase in rainfall from 2014 to 2016 accounts for the increase in healthy vegetation.

Potential Future Project

For this report I included all grass on the course and clipped out tress and shadows. If I wanted to see more dramatic results, I could limit my project area to just the golf course fairways. Generally speaking, there is a “rough” area surrounding each fairway that has fuller vegetation growth. The fairways themselves generally have short grass and would show more bare ground or less healthy vegetation due to water reduction. Just by visual inspection alone of the raster calculated layers prove this theory, as there are more holes in the fairways during the 2012 and 2014 years.

References

1) U.S. Geological Survery. “California Drought: Is the drought over?” California Water Science Center, May 31, 2017.
https://ca.water.usgs.gov/data/drought/

2) Seametrics Blog. “17 Interesting Facts About the California Drought.” Apr 20, 2015.
http://www.seametrics.com/blog/california-drought-facts/

3) U.S. Geological Survery. “NDVI, the Foundation for Remote Sensing Phenology.” Jan 12, 2015.
https://phenology.cr.usgs.gov/ndvi_foundation.php

4) CNN Tech. “How California golf courses are surviving the drought.” Goldman, David. Apr 2, 2015.
http://money.cnn.com/2015/04/02/technology/california-golf-course-drought/index.html

5) The Sacramento Bee. “Sacramento on pace for wettest year in a century.” Reese, Phillip.Feb 17, 2017.

http://www.sacbee.com/news/state/california/water-and-drought/article133301329.html