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From Lakes to Plants: Spatial Assessment of Vegetation Dynamics Along 52 Disappearing Lakes in the Boreal Forests of Alaska from 1984-2009 in the Yukon Flats Wildlife Refuge

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Abstract:

A spatial assessment of vegetation change along the areas of shrinking lakes was conducted in 2011. The analysis utilized Landsat TM/ETM imagery bands 3 and 4 to calculate NDVI (normalized difference vegetation index) from 1984 to 2009 and applied cell and zonal statistics to measure the change as well as create an animation of the change. Also, three 30 meter bands and the zonal averages for the maximum values were assessed. The band in the 60-90 buffer bands has the greatest ratio amount of the maximum vegetation values when compared to the 0-30 meter and the 30-60 meter buffered bands. Additionally, there appears to be slight trends towards higher maximum vegetation values when it in dryer, cooler and later season.

Table of Contents

Introduction

The purpose of this project was to look at the intersection of lithosphere and biosphere and analyze how vegetation is responding around the areas of disappearing lakes. The artic is undergoing change within the boreal forests of Alaska, and on the landscape scale it is becoming more brown (Verbyla, 2008), additionally there appears to be a trend towards the drying of closed basin lakes (Riordan et al, 2006). This capstone research project interpreted a normalized difference vegetation index's (NDVI) relationship to the former lake beds in a backdrop where there less overall vegetation biomass occurring in the boreal landscape.

This project looked at drying lakes and measured the change of the vegetation index (NDVI) to determine how much it is fluctuating in greenness, such as foliage, biomass, and canopy over time. This study addressed the question of where and how the vegetation is changing in its greenness over a twenty-five year time period within shrinking lakes in the boreal region of Alaska. Furthermore, the project analyzed 52 individual lakes that are based upon a 1950's mask (derived from digitized vectors from 1950's aerial photographs from) of former surface lake areas, this dataset was provided from University of Alaska, Fairbanks PhD candidate, Jennifer Roach. Then the analysis took 21 images of Landsat TM/ETM satellite imagery from the time periods of 1984-2009 and the images were acquired on or near the maximum date of vegetation greenness for the given year of the entire study site for the Julian dates of 170-220 (Verbyla, 2008). Ultimately, this project interpreted and visualized the vegetation dynamics amongst the decreasing waters over twenty-five years.

Study site for this project:

Figure 1. The study site site in the interior of Alaska in the boral forest within the Yukon Flats Wildlife Refuge.

Study site characteristics:

The Athabascan people of the Kutchin language group were the earliest people of the Yukon Flats Wildlife Refuge, where subsistence is a large component of social and cultural ways of life. Presently, there are seven villages within the wildlife refuge--Beaver, Birch Creek, Chalkyitsik, Circle, Fort Yukon, Stevens Village, and Venetie. In addition to the villages the Federal Government and a Native regional corporation, Doyon Ltd., owns land within the Yukon Flats Refuge. There is about 2.5 million acres of land that are maintained by First Nation ownership. The refuge boundary contains approximately 8,630,000 acres of federal land.

The birds, mammals and fish that reside in the Yukon Flats Wildlife Refuge include:

- Birds: With over 20,000 lakes, the wild life refuge makes a great habitat for birds. There are more than 150 different species of birds and waterfowl in the summer season during the long hours of daylight. The refuge provides breeding habitat for a variety of water birds; including ducks, loons, geese, swans, and shorebirds. There is national and international significance as there are waterfowl that travel to the Yukon Flats from 11 countries, 8 Canadian provinces, and 43 of the states in the United States. The refuge hosts as many as two million ducks annually, and supports the highest breeding densities in Alaska.
- Mammals: Beaver, fox, lynx, marten, muskrat, otter, weasel, wolverine, and wolves, as well as black and grizzly bears inhabit the refuge. In summer moose are found dispersed throughout the refuge, typically near ponds and marshes. Caribou and sheep are found in low densities in the upland regions on the outer edge of the refuge
- Fish: Arctic grayling, burbot, northern pike, and several species of whitefish can be found in the refuge waters. In addition to chinook

(king), chum (dog), and coho (silver) (United States Fish and Wildlife Refuge of Yukon Flats, modified in July of 2008)

Wetlands:

The Yukon flats topology is a relatively flat area of land very rich in water surrounded by uplands and highlands. There are about 6.5 million acres of land which is mostly flat; the study site where this analysis took place is within the lowlands region. The lowlands are filled with many meandering, braided, interconnecting, streams and oxbow lakes. The main river drainage running through the region is the Yukon River where it drops 200ft in elevation in in 300miles within this area. Flooding can inundate large tracts of the region. The uplands have numerous river terraces, alluvial fans, and flood plain deposits. The terrain overall has gentle rolling hills. And, the surrounding mountains range from gentle slopes to flattop summits with elevations reaching to 2,500ft.

The majority of the refuge is covered in open spruce forests, shrubs, and bogs and coarse and fine rubble. Several factors influence the overall complexity of refuge habitats including: wildland fire, sediment deposition during periodic flooding, a braided drainage system, and discontinuous permafrost.

Trees are dominant from the low lands up to the higher elevations. The 5 trees that make up the region are:

- Picea glauca (white spruce)--found near stream channels and in higher elevations.
- Picea mariana (black spruce)—are common throughout the refuge. Can be found as open stands and sites with restricted drainage, such as muskeg and north-facing slopes (usually with a shallow thaw zone).
- Betula papyrifera (white birch)--characteristically an upland species, and often occurs mixed within white spruce.
- Populus tremuloides (quaking aspen)—found on well drained and south facing slopes.
- Populus balsamifera (balsam poplar)—generally located within white pine stands.

Trees are a very large component of the Yukon Flats Wildlife Refuge; however the lakes basins of interest for this analysis are most likely to include: grasses, herbaceous plants, shrubs and some trees.

The shrubs that are generally in the area of interest are the shrub communities of *Salix spp.* (willow) and *Alnus spp.* (alder). Willow and alder are the most abundant shrub species on riparian sites. Dwarf shrubs, such as *Chamaedaphne calyculata* (leatherleaf) and *Andromeda polifolia* (bog rosemary), are typical species of poorly drained and rich organic soil.

The herbaceous plants in the Yukon Flats Wildlife refuge that are most abundant in dwarf shrub communities include *Eriophorum vaginatum* (sheath cottongrass) and *Carex bigelowii* (Bigelow sedge). Herbs also predominate as emergents on pond or lake margins – *Carex aquatilis* (water sedge) and *Equisetum fluviatile* (water horsetail) – and as aquatics such as *Nuphar spp.* (pond lily) and *Potamogeton spp.* (pondweed).

This is a very rich and complex region. The analysis addresses the following research concepts. How is the vegetation changing in areas of the shrinking lakes? Will the shrinking lakes have higher value vegetation buffered at 30 meters from the lake edges when compared to 60 meter or 90 meters (with 30 meter bands)? Where is the greatest amount of maximum vegetation comparing these three distances? And, how does the maximum NDVI vegetation value change with variables such as, wet or dry, hot or cool, or early or late in the season?

This study contributes to this field of research by helping explore and visualize aspects of what is happening spatially to the vegetation of the region that was once a lake fifty years ago. Ideally, this approach to analysis would draw more interest for researchers, wildlife biologists and conservationist about the value and usefulness of temporal data for management practices. In light of this approach, one could be curious about waterfowl data and migration patterns, and a manifold of other questions could be queried and visualized from the perspective of the land use over time. In addition, there are other contributions of the project which provides unique offerings for this analysis which uses remote sensing methods to look at the long-term vegetation dynamics of shrinking lakes. And, minimal peer-reviewed articles relating to long-term remote sensing information on NDVI/plant succession of lakes are in existence.

Literature Review

The purpose of this project was to look at how vegetation is responding around the areas of disappearing lakes from 1984-2009. The arctic is undergoing change within the boreal forests of Alaska, and the landscape is becoming more brown (Verbyla, 2008). Given that this study will take place within a region of Alaska it is necessary to identify the unique changes that are taking place throughout this area. There are many aspects that build upon and affect the vegetation dynamics that is taking place in the world and in the higher latitudes. Alaska is generally experiencing increased climate warming and higher average temperature which contribute to the following conditions.

- Longer growing season.(Hollister,2005)

- Melting permafrost. (Yoshikawa & Hinzman, 2003)
- Areas with shrinking lakes.(Riodorian, 2006)
- Increasing vegetation biomass.(Walker et al, 2006)
- Tree and shrub mortality from disease and insects. (Verbyla,2008)

This context determines what specific datasets will be needed to address the question of measuring vegetation change for the region of interest. Research conducted by, University of Alaska, Fairbanks examined shrinking lakes in Alaska from the 1950's to early 2000's and the affects climate change and had on lakes within Alaska. Their study confirmed the trend that the interior closed basin lakes appear to be shrinking.

> The reduction in the surface area of closed-basin lakes that we have detected in this study may be the initial signal of more widespread changes that are occurring in low lying areas of interior Alaska. In particular, this signal may be indicative of widespread lowering of the water table throughout low-lying landscapes in interior Alaska. A lowering of the water table would affect the structure and function of wetlands adjacent to lakes and would likely drive vegetation dynamics from the conversion of wetlands towards upland vegetation. (Riordan et al, 2006)

In addition to water loss other major findings indicated that as the lakes recede, vegetation and plant succession begin to develop. There are many factors that can influence phenology and timing of vegetative events. Listed below are a number of factors influencing phenology that was generated from the USGS, (Markon, 1999):

- Plant species
- Plant part(s)
- Plant sociability (individual, group, community)
- Vector induced disturbance (insect and disease)
- Anthropogenic disturbance (logging)
- Local or regional climate (including episodic events)
- Soils/nutrient supply
- Water supply
- Natural disruptive events (volcanic eruptions, fire, flooding)
- Latitude
- Slope, aspect, elevation (micro, local, regional, global)
- Timeframe (daily, monthly, yearly, decadal)

A study conducted in the Kenai Peninsula of Alaska, located in the south central region of the state, investigated vegetation change around drying lakes in a different region, and made comparisons with two different snapshots, 1950 and 1996, from aerial photos and ground sampling.

In 1950, the sample points were classified as follows:

> Wooded (57%), open (31%), wet (5%), and water (7%). Therefore, approximately 12% of the region could be inferred as having some level of wetness. The results in 1996 showed that the proportion of cover classes were as follows: wooded (73%), open (20%), wet (<1%), and water (6%), indicating some degree of drying. For the sample data, there was a 28% increase in the wooded class and decreases of 34% for open, 88% for wet, and 14% for water. (Klein and Dial, 2005)

While this study takes place over hundreds of miles south of the Yukon Flats Wildlife Refuge, Klein and Dial's study addresses the vegetation succession. This analysis varies from this research in that there are only two snapshots of time and seasonal variability within this assessment could be a limitation. Additionally, the Klein and Dial study varies because it utilizes field surveying and general description and does not involve satellite imagery and the movement of images over time with variation between seasons and years. The vegetation dynamics are a key component to this research project as well as being set in the higher latitudes.

Research from Hollister in 2005 address vegetation change in the arctic and consider how vegetation is responding in the high latitudes. There are numerous studies underway to try and determine and predict the future landscape of the arctic regions. Hollister's, research notes how individual plants and communities respond in the context of climate change.

> The finding that nearly every species showed an individualistic response to warming was commensurate with other studies examining the response of multiple species to warming (Chapin and Shaver 1985a, Henry and Molau 1997). There were no clear patterns of plant response within growth forms or phylogenetic groups. The most consistent pattern was among species within the same community. However, this similarity of response was only for one trait, and there were no clear groups of species with similar response when multiple traits were examined.(Hollister, 2005) The responsiveness of tundra plants growing in their natural environment to small increases in temperature underscores the importance of accounting for changing climate temperatures when predicting the state of arctic vegetation. However, many of the direct effects of warming may be masked by natural variability in the trait, and may take many years before they lead to, or could be attributable to, community change. The individualistic response of plant species necessitates the use of empirical information gained by studies such as this to assist in formulating predictions of plant community response. (Hollister, 2005)

While Hollister looked at how the community of plants changes, Goetz analyzed tree ring growth data and looking at several tree species of the boreal forest and observed how different species are responding in the boreal forests in context of a changing climate.

> In addition to the changes documented in tundra vegetation, there have been several recent advances in understanding boreal tree responses to changing climate in the Arctic. The recent declines in productivity of many boreal forest areas, aside from recently disturbed areas, suggest that warming may not produce a negative feedback to additional warming (i.e., increased CO2 sequestration), as had widely been expected. Moreover some positive feedbacks may result from advances of latitudinal tree-line, as has been widely documented in areas experiencing increased temperatures (e.g., Lloyd 2005), and these changes would also alter energy feedbacks associated with albedo changes. (Goetz, 2010)

This project was set within the context of climate change in the higher latitudes and most of the lakes appear to be closed basin (lakes which do not have inlet or outlet attributes), but verification of this is extremely difficult given that the lakes have not been ground truthed. Determining if a lake is designated as closed basin is based on imagery inspection and the resolution or pixel size of the resolution is not fine enough to verify if there are inlets or outlets. However, closed basin lakes are of importance because they are sensitive to changes in climate in semiarid regions such as interior Alaska (Barber and Finney, 2000).

A study by, Riodrdan et al, examined closed basin lakes in interior boreal regions of Alaska and revealed a trend of closed basin lakes towards drying.

> Since the 1950s, surface water area of closed-basin ponds included in this analysis decreased by 31 to 4 percent, and the total number of closed-basin ponds surveyed within each study region decreased from 54 to 5 percent. There was a significant increasing trend in annual mean temperature and potential evapotranspiration since the 1950s for all study regions. There was no significant trend in annual precipitation during the same period. The regional trend of shrinking ponds may be due to increased drainage as permafrost warms, or increased evapotranspiration during a warmer and extended growing season. (Riordan et al, 2006)

Additionally, an article from Verbyla found that the decreasing NDVI trend in interior boreal forests may be due to several factors including: increased insect/disease infestations, reduced photosynthesis and a change in root/leaf carbon allocation in response to warmer and drier growing season climate. Verbyla's research also establishes that the annual maximum NDVI from arctic tundra areas are strongly related to a summer warmth index, while there were no significant relationships in boreal areas between annual maximum NDVI and precipitation or temperature. The boreal region of Alaska is decreasing ($r2 = 0.41$, slope = -0.0024, $P = 0.002$) in mean annual maximum NDVI.(Verbyla, 2008)

Among boreal climate station buffers, the early spring NDVI (1–15 May) was linearly related to the boreal spring warmth index ($r2$ ranging from 0.48 to 0.58, $P < 0.01$). There were no significant ($P > 0.16$) linear relationships between annual maximum NDVI as a function of early spring NDVI for boreal buffers ($r2$ ranging from < 0.01 to 0.09) Unlike the arctic tundra stations, there were no significant linear relationships between annual maximum NDVI and current or lagged summer warmth index values ($P > 0.30$, $r2 < 0.10$).Bunn *et al*. (2005) found that the previous spring minimum temperature was an important variable in predicting summer NDVI in coniferous and broadleaf boreal areas of Canada. In this study, the linear relationships of annual maximum NDVI as a function of previous spring temperature were weak ($r2$ ranging from < 0.01 to 0.22). The linear relationships of annual maximum NDVI as a function of August through July precipitation were also weak ($r2$ ranging from 0.06 to 0.24).The 1982–2003 pattern of an increasing NDVI trend in northern arctic Alaska and a decreasing trend in interior Alaska also was evident from the pixel-level linear regressions. The highest rate of increase occurred along the central and eastern Arctic coastal plain, while the highest rate of decrease occurred in basins of interior Alaska (Fig. 3). (Verbyla, 2008)

The interior of Alaska has a trend toward shrinking lakes (Riodoran et al, 2006) and decrease in overall biomass for the boreal forest (Verbyla, 2008) and this is all set in a very complex systems interactions (Chapin, 2004). Verbyla (2011) stated (personal communication) that when undertaking a NDVI analysis in regards to shrinking lake there are several responses to consider with Landsat-based NDVI along shrinking lakes.

1) Wet years (example: July 2003, 2006, 2008) would cause a decrease in NDVI due to flooding.

2) Dry years (example: July/Aug 2004, 2009) would cause a decrease in NDVI due to early senescence of sedge meadows, yet an increase in NDVI of woody plants due to a lag in response due to wet years of 2003, 2008.

There is considerable change taking place in the arctic regions, with many complex and highly interconnected systems (Chapin et al, 2004). As well as the closed basin lakes undergoing abundant change, the vegetation is decreasing in its greenness. “At the largest spatial scale of polar, boreal and maritime regions, the strongest trend was a negative trend in NDVI within the boreal region.

While Chapin et al observe the effects of climate change on the boreal forests, they address an important question: are the vegetation changes gradual or abrupt in response to climate change? Additionally Chapin et al ask how the environment will respond to these changes. Species may be very resilient to climate change, at least until some threshold is surpassed. (Chapin et al, 2004)

Design and Implementation

The polygons of the lakes for the study site were acquired from the University of Alaska, Fairbanks and were used to identify the shrinking lakes and narrow down the general study site for the project. However, historical fire, insect damage, pest damage regions polygons excluded some of the lakes from the analysis. The next process entailed using Landsat TM/ETM imagery, bands 3, 2 and 1 to visually inspect the scene in natural color. Band 4 and Band 3 were used and referenced and NDVI was calculated for the twenty-one images available from 1984-2009. These images were reclassified to integers of 1, 2, and 3 for low medium and high vegetation values, which was influenced by NASA's classifying structure on the Earth Observation website (accessed July, 15 2011). Then a mask was generated from the polygon of the shrinking lakes basin to create a raster basin for all the years, which provided the ability for cell statistics to be performed to obtain the maximum value for each cell (raster pixel) through all the years. Analysis was then performed on the maximum values through descriptive statistics, visualizations, and zonal statistics. The analysis was able to acquire mean value for all lakes basins, and each buffered region as well as comparing hot and cold, wet and dry, and early and late images to each other.

Listed below is Table1.1, which provides Landsat Imagery for the dates the images where taken with the TM/ETM sensor for the analysis of lakes of interest.

Table 1. The tabular data was derived from Landsat TM/ETM imagery for the area of interest, available images that aare from 1984 to 2009, which were error free and withing in growing sezon from the Juliam dates of 170-220.

Landsat Image Date
• 6/18/1984
• 8/1/1985
• 6/17/1/986
• 7/3/1986
• 7/10/1989
• 7/14/1993
• 7/25/1994
• 6/28/1999
• 7/31/1999
• 7/8/2000
• 6/25/2001
• 7/27/2001

• 7/30/2002
• 7/18/2003
• 8/4/2004
• 6/28/2005
• 7/14/2005
• 7/22/2005
• 6/20/2008
• 7/17/2009
• 7/9/2009

The Design and implementation follow a course of downloading Landsat imagery, running geospatial analysis, and generating the data and information into visual displays of various charts and animations.

The initial stage of the project was the obtainment of a shrinking lakes geodatabase/shapefile from, Jennifer Roach at the University of Alaska, Fairbanks. Roach is a PhD candidate looking at long-term surface water lake change in the Yukon Flats Wildlife refuges of Alaska. After Roach developed a lake boundary database from the 1950s to 2008, her team joined and merged all of the lakes from the previous years to create an individual lake basin for the lakes. The lakes surfaces were calculated using band 5 of Landsat TM imagery which allows for over estimating of water. Roach generously offered to share her data for this vegetation analysis project.

Upon receiving the shrinking lakes geodatabase from Roach, lakes were removed that were in historical fire areas or historical pest and plant disease regions. Then, further data was gathered form three sources to help determine which lakes should be included in the study. Temperature and weather information was use to integrate into the vegetation dynamics of the region from http://www.wrcc.dri.edu/summary/Climsmak.html . The historical fire polygons were derived from Alaska Interagency Coordination Center http://afsmaps.blm.gov/imf_firehistory/imf.jsp?site=firehistory . The insect damage and plant disease polygons were collected from Forest Health Monitoring Clearinghouse http://agdc.usgs.gov/data/projects/fhm/ . All of these datasets were used to help analyze and visualize the vegetation dynamics.

Once the historical fire data and the forest health monitoring data of plant disease and pests were put into a geographic information system, any of the shrinking that intersected these historical fire areas or plant damage regions were excluded from the analysis resulting in fifty-two lakes adequate for analysis. After the lakes were defined as the lakes of interest for the analysis, Landsat imagery was searched for and obtained from the United States Geological Survey website of Glovis http://glovis.usgs.gov/ . The Landsat imagery TM band 4 and band 3 were collected and images of the 52 lakes of interest were downloaded based off of visual inspection which was cloud free, free of satellite scanner errors, and imagery that was within the generalized peak growing region for the area for the Julian dates between 170 to 220.(Verbyla, 2010)

When the images appeared adequate for the region, they were downloaded, and inspected with GIS software in natural color (RGB) to determine if there were any errors or problems with the imagery. Additionally, the dates of the images were assessed with historical climate data from the tabular data of western regional climate center. This processes allowed the research to verify that none of the imagery corresponded to weather when it was more than two standard deviations above the mean. The images were then geo referenced to see if there was any error with alignment. Then, band 4 and band 3 were used to calculate NVDI for the greenness change around the drying lakes. Following this method band 4 and band 3 were calculated to account for NDVI with this equation:

$$NDVI = \frac{NIR - R}{NIR + R}$$

The Landsat images were then clipped to Roach's lake basin dataset. Alongside of the process of the creation of NDVI for the area of the shrinking lakes, another method was in process. The fifty-two lakes, the shrinking lake basins of interest, were converted from a polygon to a polyline. Once the polyline was created it was buffered at 30 meters, 60 meters and 90 meters. Then the 60 meter buffer was erased from the 90 meter buffer and the 30 meter buffer was erased from the 60 meter buffer. This created 4 areas for the spatial research to take place: the entire lake basin, and three 30 meter band (starts at the lake edge and goes towards the center of the lake 30 meters), 0-30 meter band from 30 meters to 60 meters inside of the lake perimeter and lastly a 30 meter band from 60 meter to the 90 meters inside of the lake. This can be visualized in figure.2.

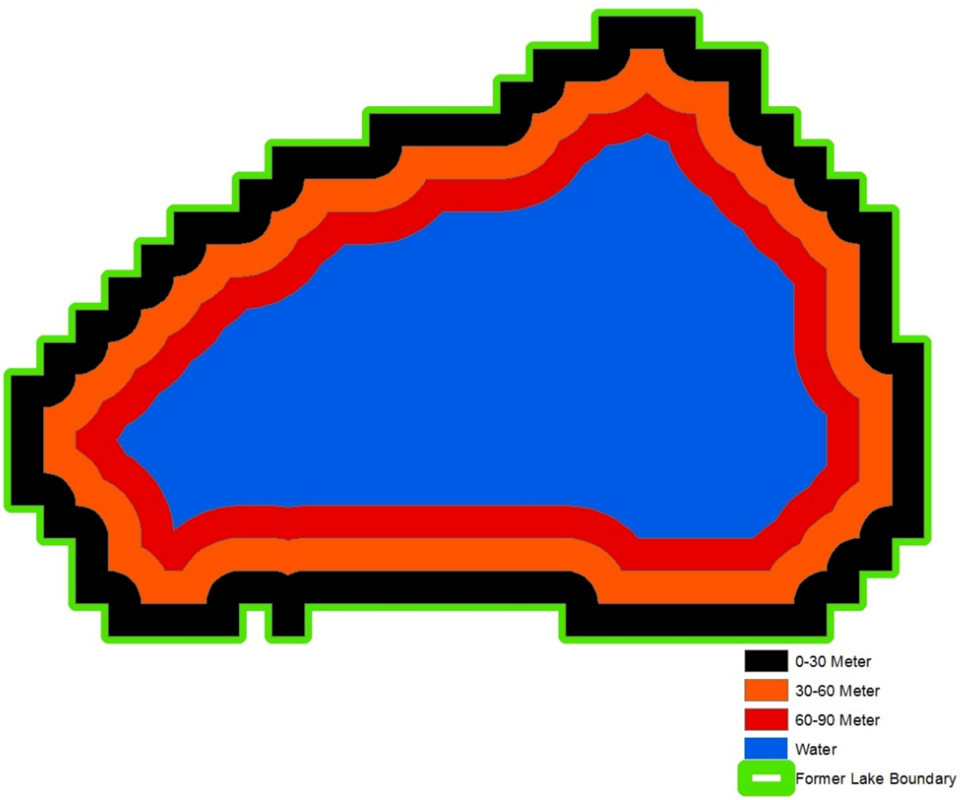


Figure 2 Lake basin example of showing the green line as the outline of the former lake perimeter and the balck, orange, and red as the three 30 meter bands of interest.

The NDVI images that were created from batch processing in the raster calculator in ArcGIS ™ were gathered for analysis. Following this process the 21 NDVI (normalized difference vegetation index) raster images were batch processed to extract by the mask of the fifty-two shrinking lakes. The next geo processing step involved taking the floating value of the raster and converting it to an integer as well reclassifying the raster images to low, medium and high values relating to low medium and high vegetation values.

1) Low (based on 0.2-0.3 NDVI value)
2) Medium (based on 0.3-0.6 NDVI value)
3) High (based on 0.6-0.8 NDVI value)

According to John Weier and David Herring, the categories of low, medium and high are based off of grouping from NASA's relating to vegetation and its amount of greenness (NASA Earth Observatory accessed June of 2011). The lower NDVI value relates to low shrub, the medium is closer to healthy vegetation and the high is lush/dense vegetation.

Once the (1) Low, (2) Medium and (3) High categories for the NDVI categories were established the cell statistics tool was used from the ArcGIS™ local toolbox and the maximum cell value was calculated for the twenty images for the lake basins of interest. This tool takes maximum cell value from all the images and places that value in a new raster images displaying the low (1), medium (2) and high (3) values for the maximum cell statistics raster. This process was completed for the entire lake basin the 0-30 meter band, 30- 60 meter band and the 60-90 meter bands and had the maximum cell statistic process preformed upon them as well. Thus, the entire lake basin, the 30 meter, 60 meter and 90 meter buffer bands all have maximum cell statistics performed. . From the charts, graphs, and visualizaition generated of the general characteristics of the vegetation values, these tools calculate the maximum statistic per cell value for the 21 images. Additionally, the zonal statistics tool was performed on the entire lake basin maximum cell value for each of the fifty-two lakes basins. Furthermore, the zonal statistics tool, 'zonal statistic to table tool' was used to get tabular information about the entire lake basin mean (of the max cell values over time)--the 0-30 meter band, the 30-60 meter band and the 60-90 meter band. From these four regions an overlay was generated displaying each lakes mean vegetation value at the basin level and for each band area. Finally, from the original extracted NDVI raster, all twenty-one of the images were batch converted from floating to integer/reclassify. These images were converted from raster files to polygons. Upon completing the previous processes, a video file was created for exploring purposes. Once the polygons/shapefile for each image was created all of the polygon files were merged together into one file, from this file the animation layer was activated by adding time field into a new field. Then this information was visualized and exported in with the time-slider toolbar in ArcGIS and edited further with ArcGIS and Windows Movie Maker to generate a video file of the animation.

A further analysis examining all of lakes for the entire basin, 30 meter band, 60 meter band and 90 meter band involved looking at 6 other variables: wet vs dry, early vs late, hot vs cold. The historical weather data for each of these 6 categories are comparing two categories against each other, wet as opposed to dry, early or late in the growing season, and hot or cold temperature. All of these categories related to the image capture date of NDVI and when the information was derived from the satellite. To determine whether the particular image was wet or dry, the historical precipitation data for the months and years of the images were put into a spreadsheet. The average precipitation in millimeters was calculated and anything over the average was categorized as wet, whereas anything below the average was labeled as dry. A similar methodology was conducted for the historical temperature data of the image dates and these were put into a spreadsheet and averaged. The individual values for the Landsat capture dates above the average temperature were then designated as hot, whereas the values below the average temperature were labeled as cold. The category of early verses late is just the mean date in the growing season, so the Landsat imagery that had a day and month below the mean was marked as early and after the date would be marked as late. Once the categories were broken down for each of the Landsat imagery into early/late, hot/cold, wet/dry, the local toolbox with the cell statistic was used to calculate the maximum value through the years of the wet, dry, early, late, hot and cold. This process reveals the cell value that is a maximum value through the history of the series of images. When these image groupings have cell statistics performed, a raster images is the result which is used for creating some graphs and charts displaying the differences in between as displayed in graphs and counts.

The analysis looked at the maximum value for all 21 of images and is displayed as charts, graphs for the entire lake basins. Additionally, the images are displayed in an animation (attached in the appendix). The maximum vegetation for three buffered bands with the lake basin at 0-30 meters, 30-60 meters and 60-90 meters the variable of wet vs dry, hot vs cold and early vs late were also analyzed.

Results

Overall the findings of this analysis yielded some unexpected results. In general there tends to be a greater amount of vegetation in the dry, cool, and late image capture dates. However, a more unpredicted result was a greater amount of the maximum vegetation, specifically the high NDVI value at the 60-90 meters lake edge when compared with the other buffered bands or the entire lake basin. The ratio of the maximum NDVI in comparison to the entire cell count for the buffered band area, represented in figure.4, reveals that the ratio of the High NDVI value has the greatest ratio in the 60-90 meter category. Optical support for this conclusion is also verified by inspecting animation files of the maximum NDVI values.

Mean of the four categories:

Figure. 3 represents the zonal mean of max value for the entire lake basin, 0-30 meters from edge, 30-60 meters from edge and 60-90 meters from edge. The mean for each zone shows that the 0-30 meter band for the black region in figure.2 is greater than the mean for the entire lake basin of the 30-60 meters bands and the 60-90 meter bands. This result is easily deduced when one looks at a shrinking lake that is being succeeded with vegetation. Figure.4 displays the max value as derived from the cell statistics for the entire lake basin, 0-30 meters from the edge, 30-60 meters from the edge and 60-90 meters from the edge.

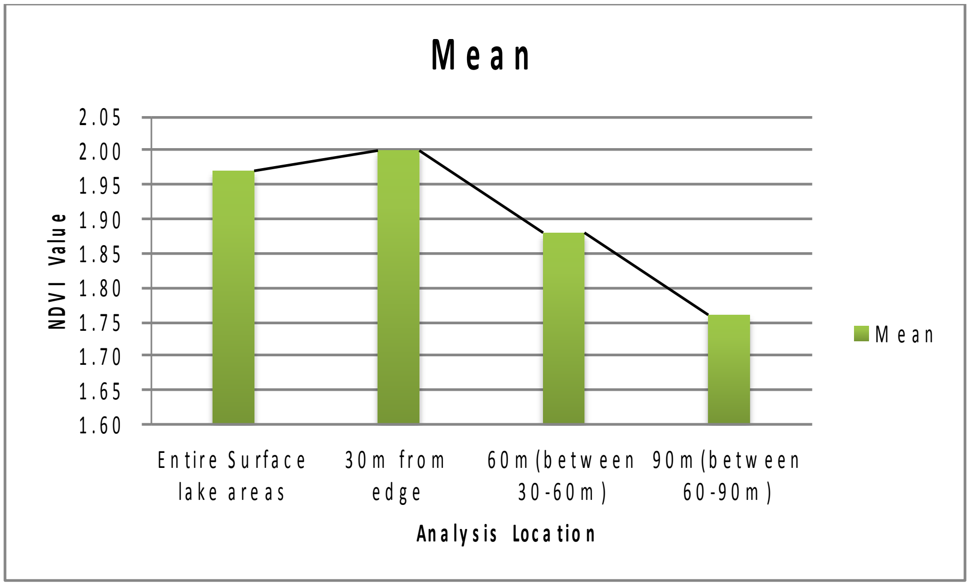
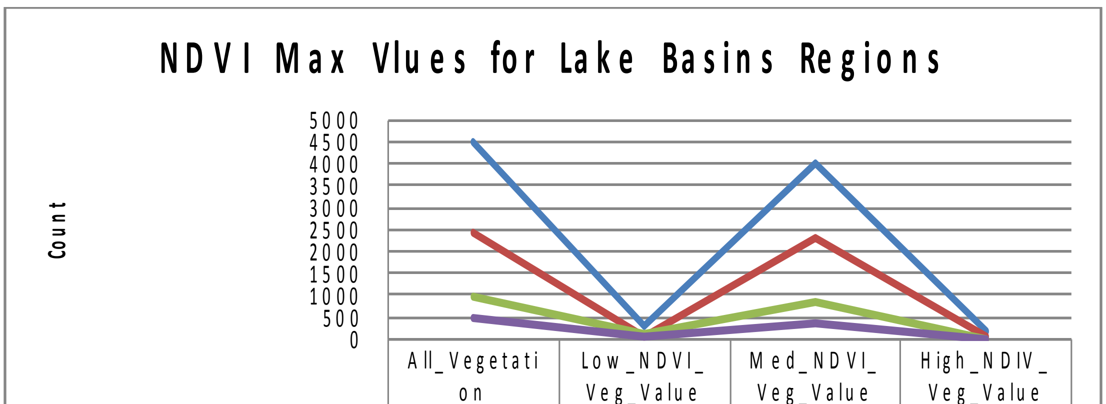


Figure 3. The depiction is of the Mean of the maximum NDVI values for all of the lakes comparing the NDVI average of the entire lake basin, the 0-30 meters from the edge, 30-60 meters from the edge to 60-90 meters from the former lake edge.



	All_Vegetation	Low_NDVI_Veg_Value	Med_NDVI_Veg_Value	High_NDIV_Veg_Value
Entire Lake Basin Area	4496	312	4017	167
30m from edge	2423	53	2307	63
Between 30m-60m from edge	997	100	873	24
Between 60m-90m from edge	479	85	373	21

Figure 4. The line graph show the maximum value NDVI as obtain from using ArcGIS cell statistics of how NDVI values are distributed thru the various regions of the lake basin.

The following figures, .5, .6, and.7, depict the maximum count changes in a graphical form of a pie chart. The graphics of figures.5, 6 and 7 show that the 0-30 meter has the greatest amount of vegetation in total numbers for each vegetation category of low, medium and high. It is interesting to note that the ratio of high NDVI is greatest for 60-90m category in figure.4

Entire Lake Basin:

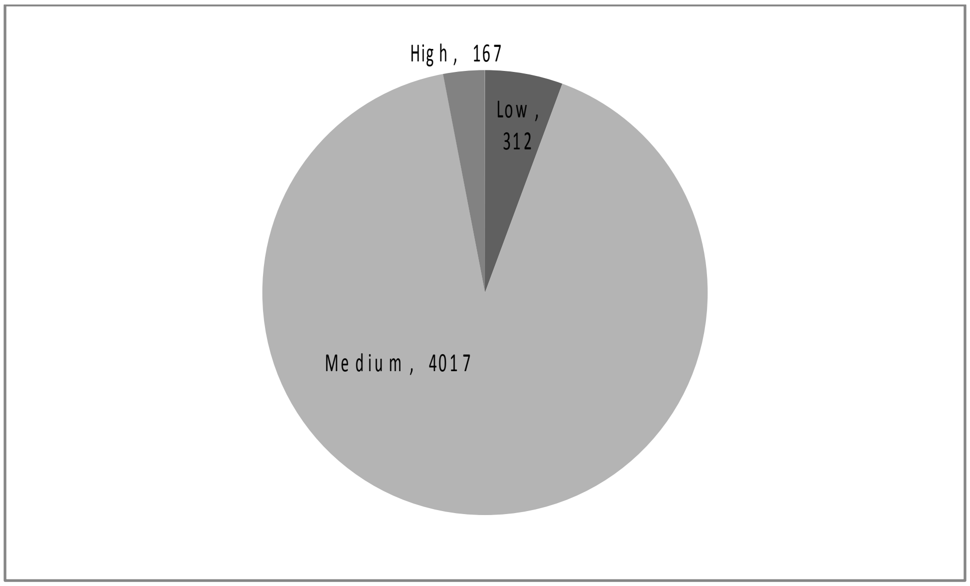


Figure 5. For that entire lake basin of all 52 lakes in High, Medium and Low NDVI value category. These counts are represented in count of the maximum value for each pixel. Where the Low value has a count of 312, the medium has a count of 4,017 and the high has a count of 167.

30 meters from Edge:

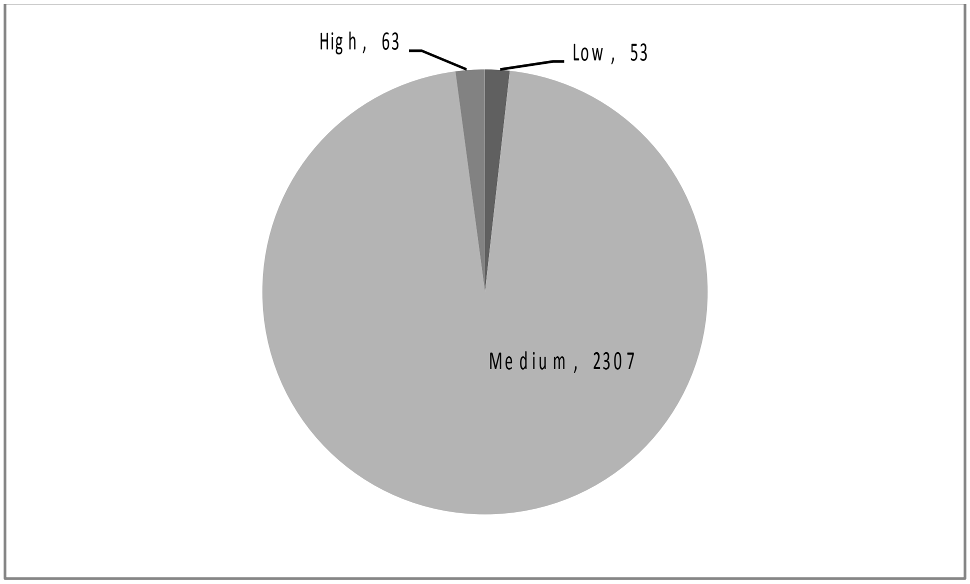


Figure 6. For that former lake edge (0) to 30 meters of all 52 lakes in High, Medium and Low NDVI value category. These counts are represented in count of the maximum value for each pixel. Where the Low value has a count of 53, the medium has a count of 2,307 and the high has a count of 63.

60 meters from edge

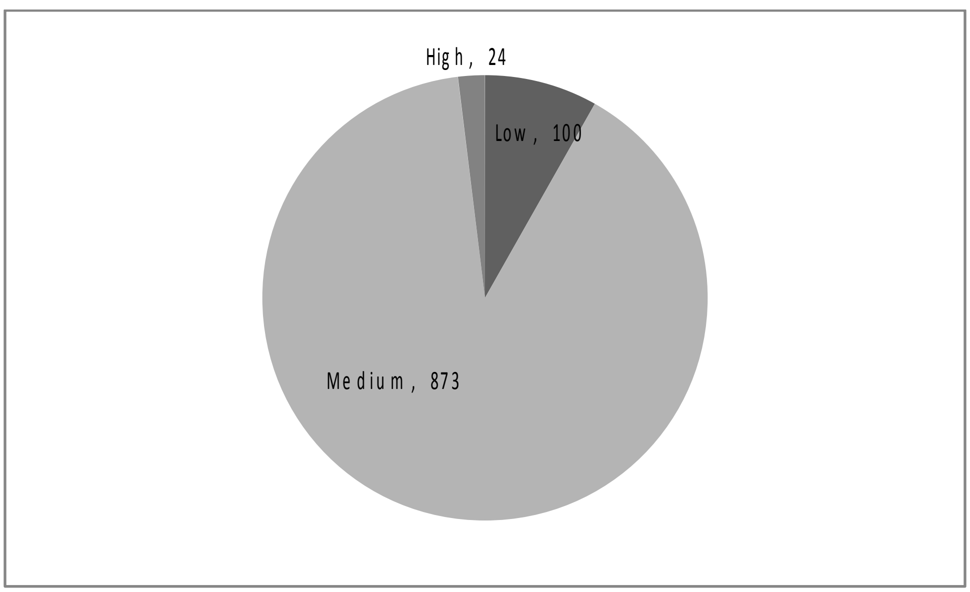


Figure 7. For band of 30 to 60 meters of all 52 lakes in High, Medium and Low NDVI value category. These counts are represented in count of the maximum value for each pixel. Where the Low value has a count of 100, the medium has a count of 873 and the high has a count of 24.

90 meters from edge

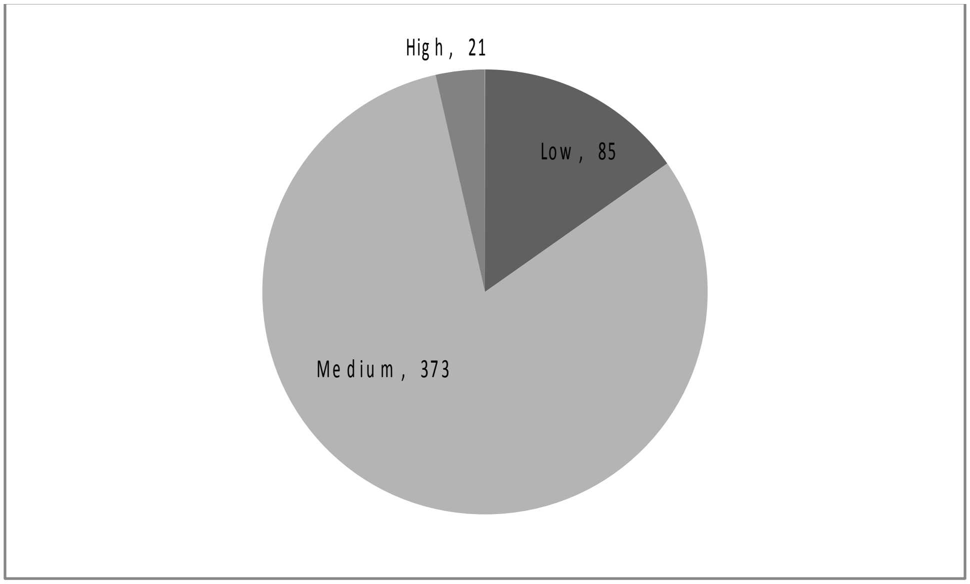
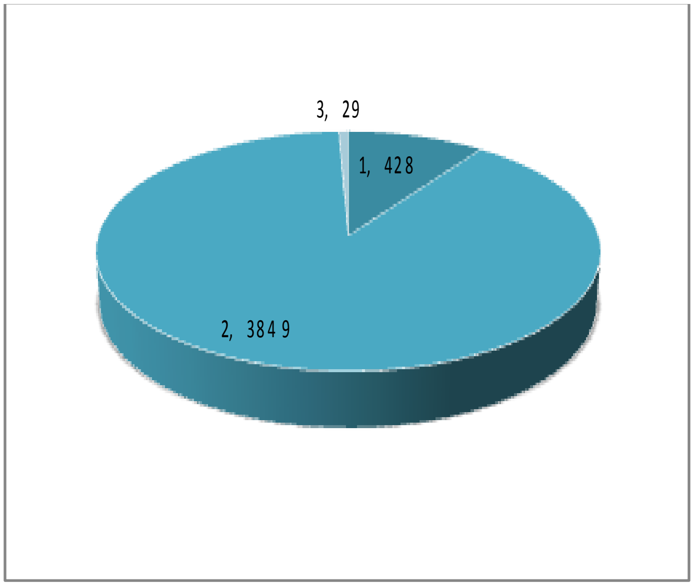


Figure.8 For 60 -90 meters of all 52 lakes in High, Medium and Low NDVI value category. These counts are represented in count of the maximum value for each pixel. Where the Low value has a count of 85, the medium has a count of 373 and the high has a count of 21.

When comparing the entire lake basins for wet years vs dry years, using cell statistics on the Landsat imagery that correspond with being above the average or below the average, the dry years have a much larger overall count of the maximum value of vegetation while the wet years have a greater amount of low value vegetation. Overall, the amount of vegetation is much greater in the dry years represented in figure.10 when compared to the wet years displayed in figure.9. When specifically looking at the maximum value the dry years have 143 cells compared to only 29 cells in the wet images dates.

Wet:



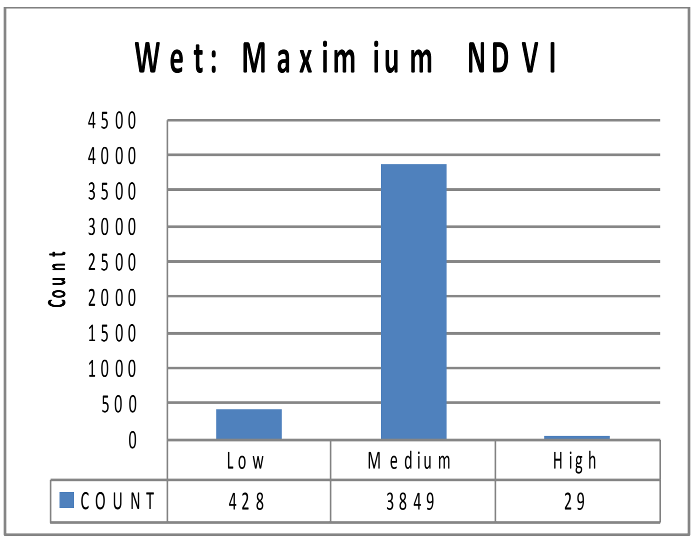
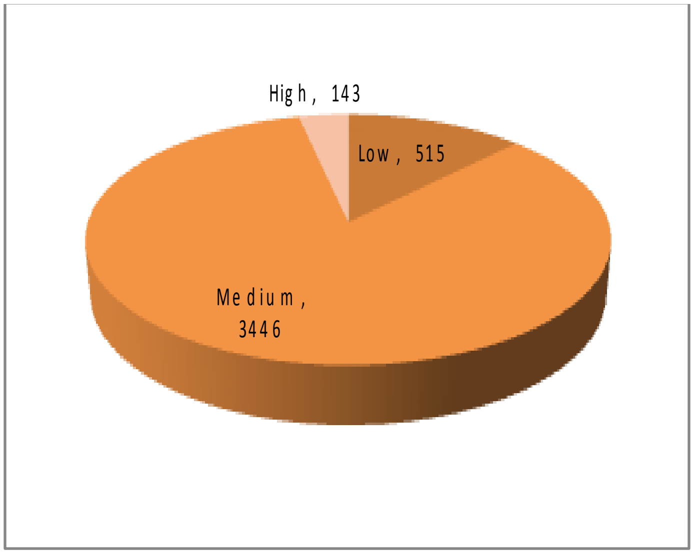


Figure 9 Analyzed using ArcGIS cell statistics, low, medium and high NDV categories were calculated based on the Landsat images that were greater than the average for precipitation, these are the counts for the three categories in the wet dates.

Dry:



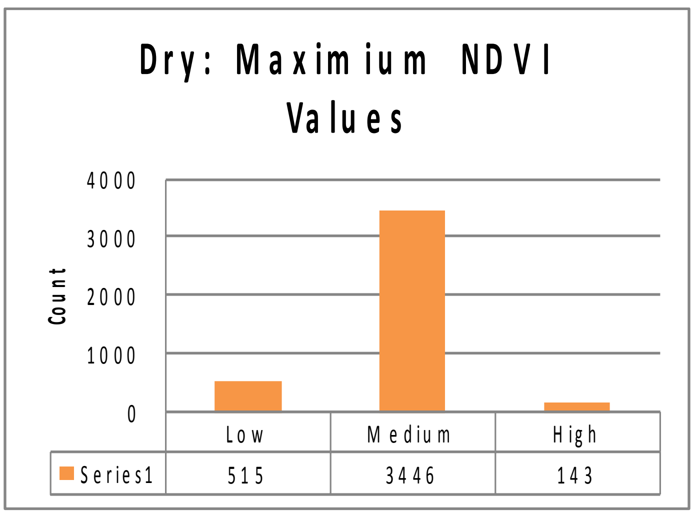


Figure 10. Analyzed using ArcGIS cell statistics, low, medium and high NDV categories were calculated based on the Landsat images that were less than the average for precipitation, these are the counts for the three categories in the dry dates.

The wet verses dry comparison for 0-30 meters, 30-60 meters and 60-90 meters are presented in figures 16 through 19. Also shown, are the results of the zonal means of the max values for the entire lake basin and the three 30 meter band regions. The vertical axis of the graph displays the NDVI Value and the horizontal axis represents the 52 individual lakes. The higher vegetation (3, highest value NDVI) has a greater amount in the below mean temperatures at 135 as compared to 37 for the above mean temperatures. Additionally, the cool temperature of the maximum NDVI is also a larger percentage when compared to all the NDVI.

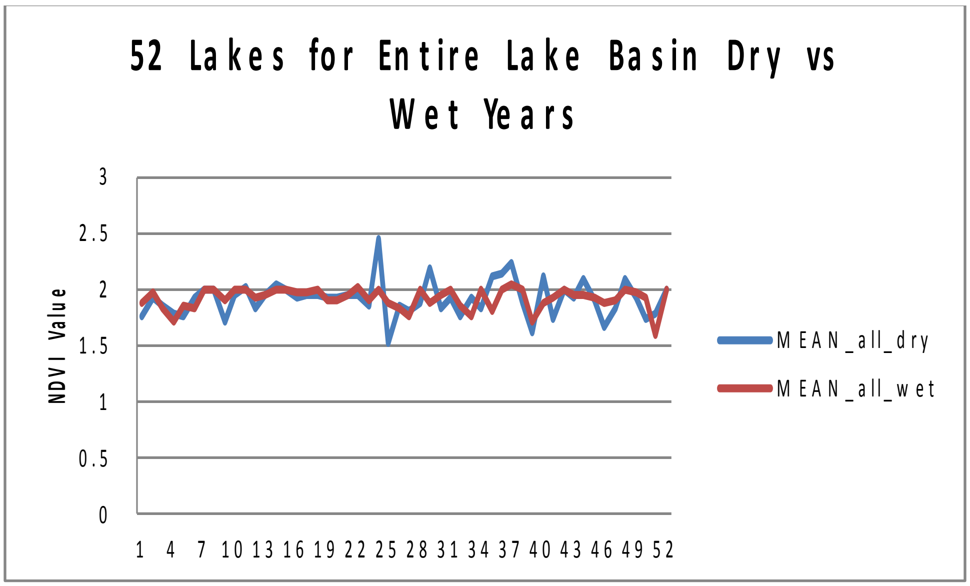


Figure. 11 The mean NDVI comparing the wet to dry years for all fifty-two lakes.

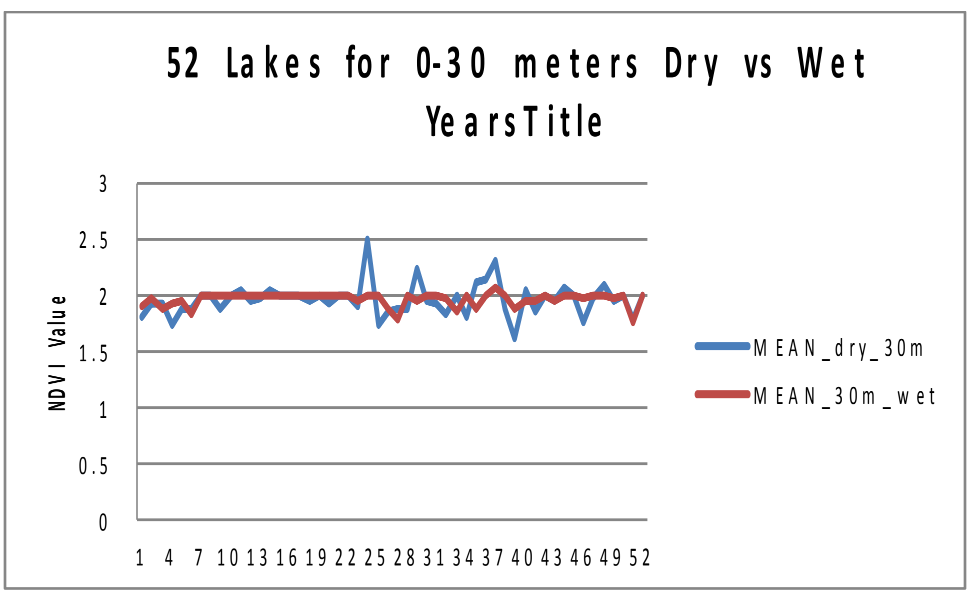


Figure 12. The mean NDVI comparing the wet to dry years for the region of 52 lake, from lake perimeter to 30 meters inside.

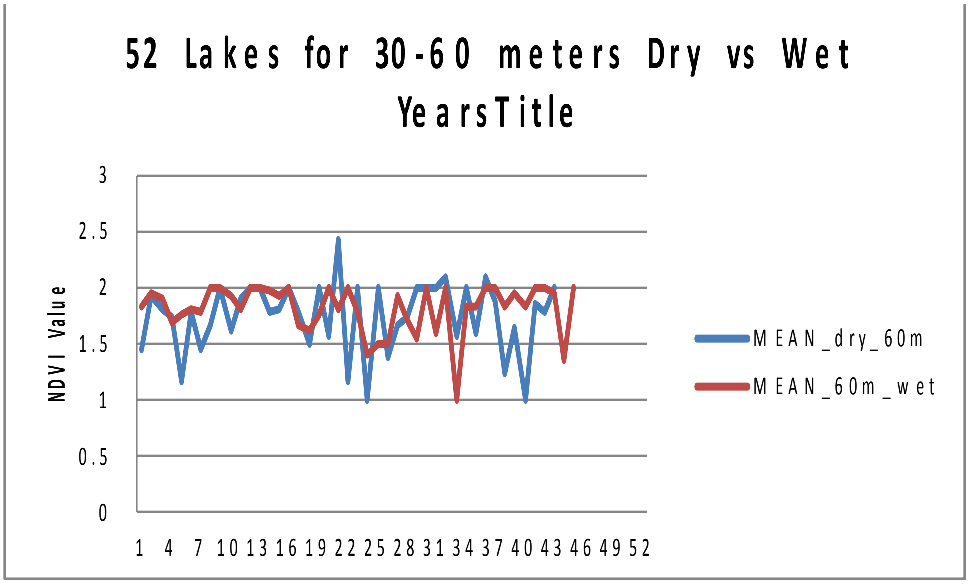


Figure 13. The mean NDVI comparing the wet to dry years for the 30 meter to 60 meters in from the former lake edge.

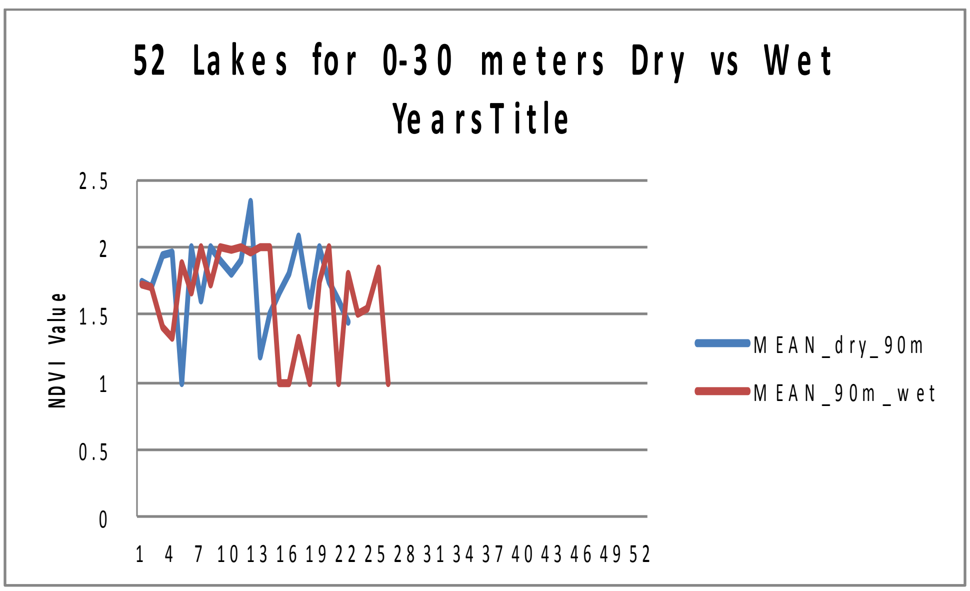


Figure 14. The mean NDVI comparing the wet to dry years for the 60 meter to 90 meters in from the former lake edge.

Cool max cell value:

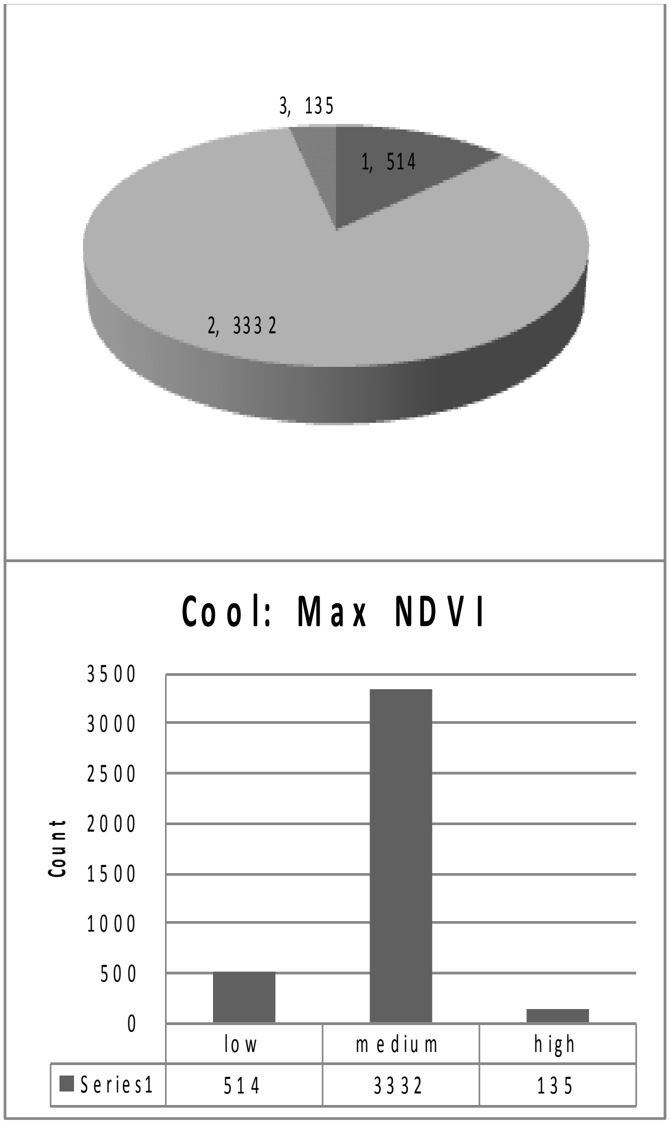
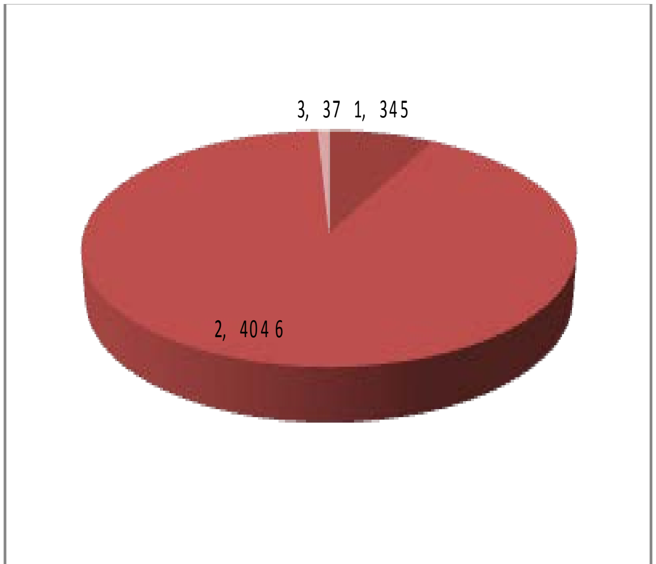


Figure 15. Analyzed using ArcGIS cell statistics, low, medium and high NDV categories were calculated based on the Landsat images that were less than the average for temperature, and these are the counts for the three categories in the cool dates.

Hot max cell value:



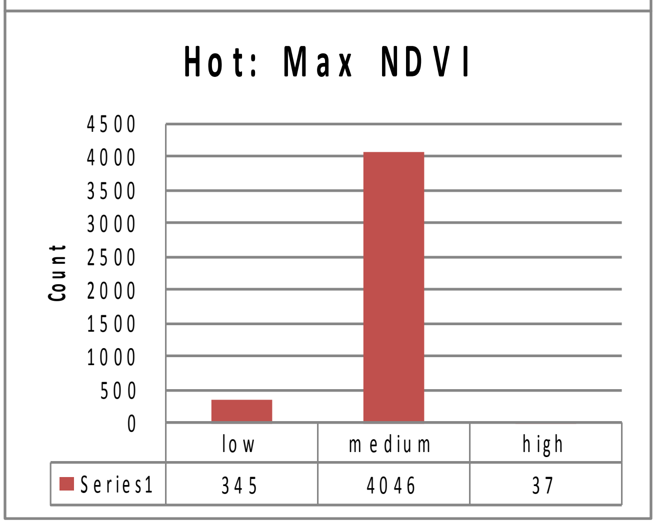


Figure 16. Analyzed using ArcGIS cell statistics, low, medium and high NDV categories were calculated based on the Landsat images that were greater than the average for temperature, these are the counts for the three categories in the hot dates.

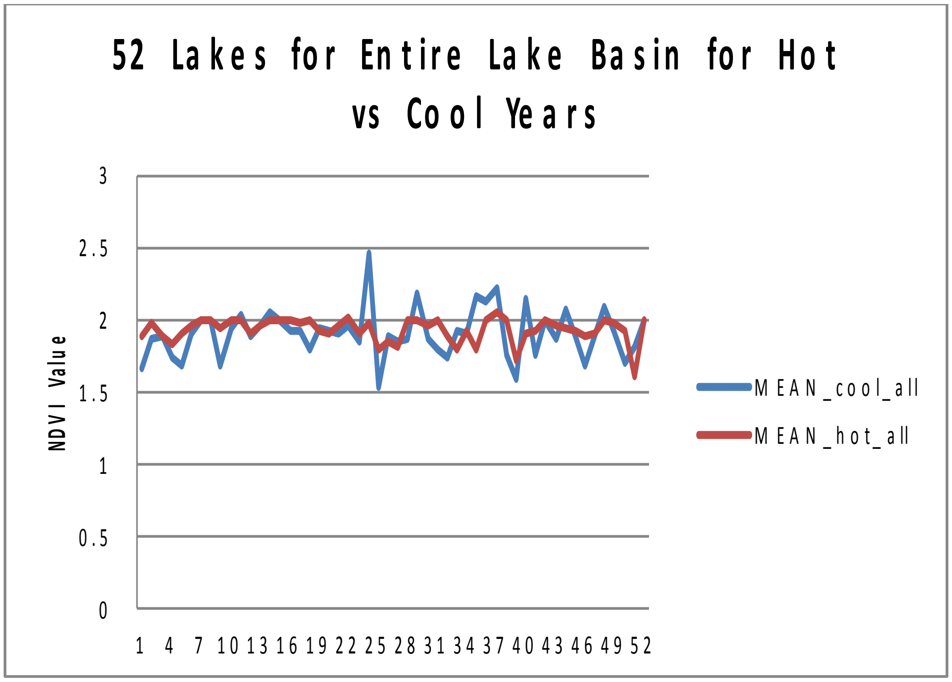


Figure 17. The mean NDVI comparing the hot to cool years for all fifty-two lakes.

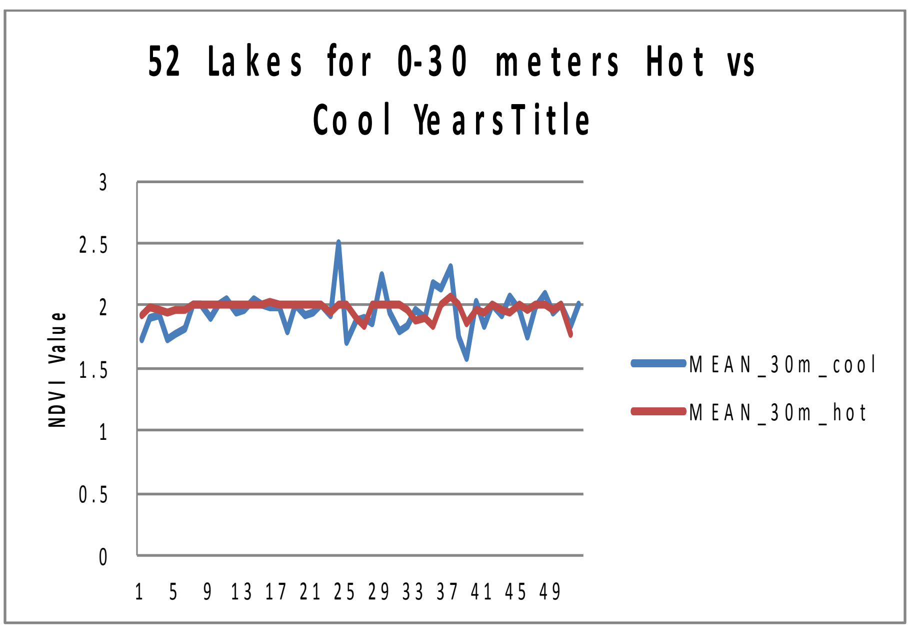


Figure 18. The mean NDVI comparing the hot to cool years for the region of 52 lake, from lake perimeter to 30 meters inside.

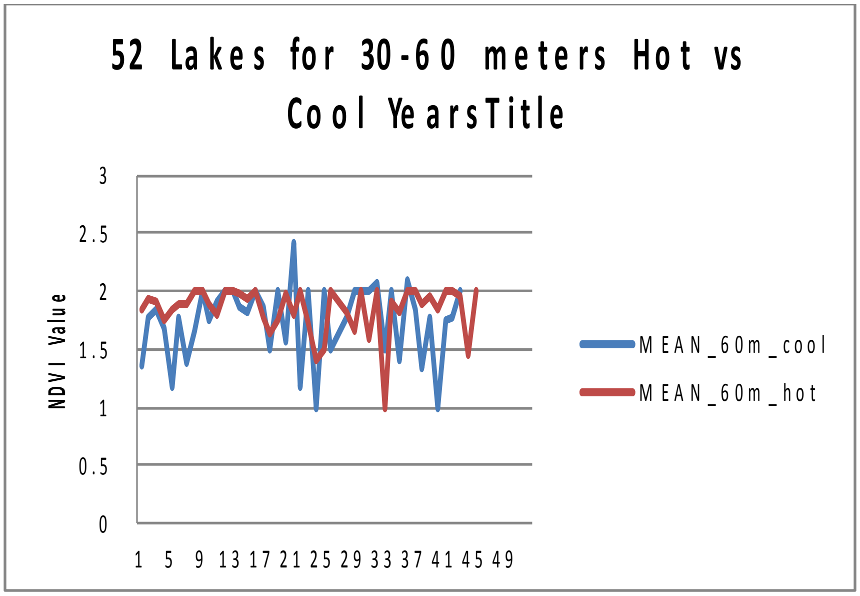


Figure 19. The mean NDVI comparing the hot to cool years for the region of 52 lake, from 30 meters to 60 meters inside.

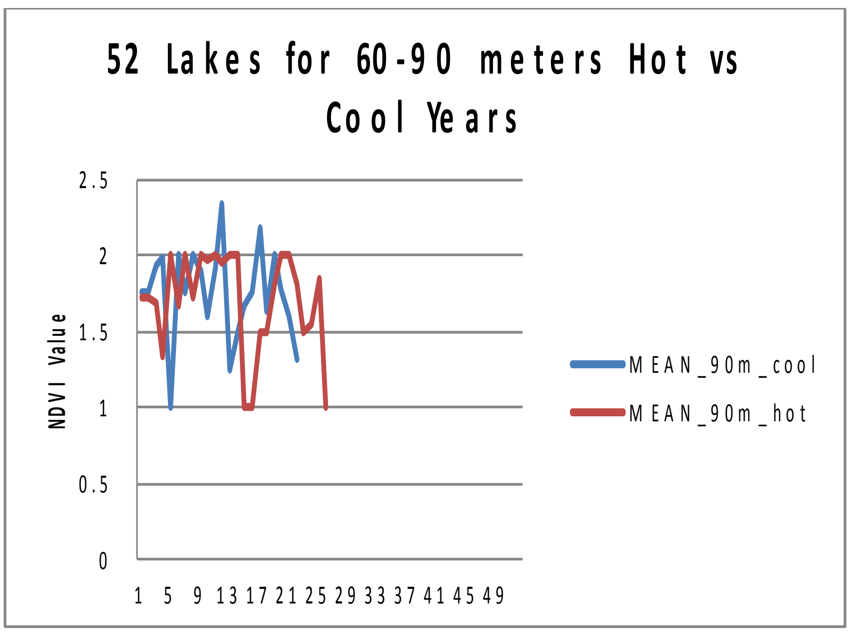
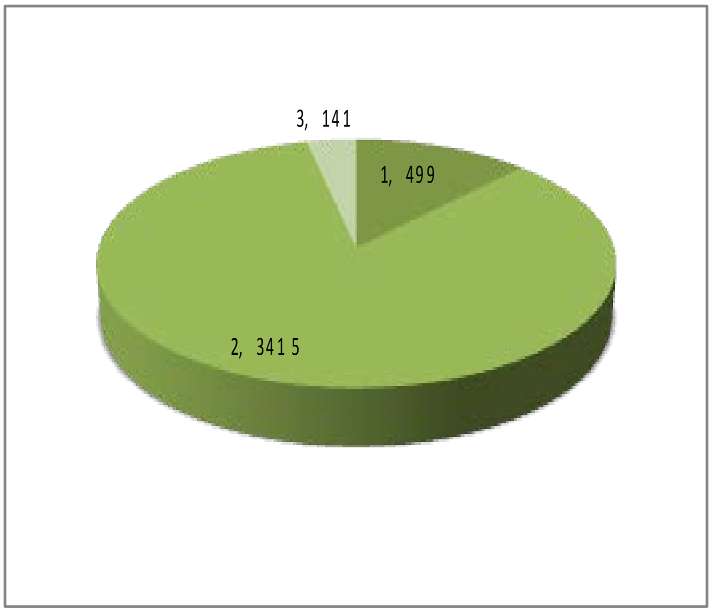


Figure 20. The mean NDVI comparing the hot to cool years for the region of 52 lake, from 60 meters to 90 meters inside.

For the late and early categories there is more vegetation in the high NDVI value in the late season, which may be a result of leaves on trees becoming more abundant. It is easy to infer that there is more of the high NDVI value counts in the late season compared to the early season, however the early season does have higher NDVI value counts for the medium and low NDVI values.

Late:



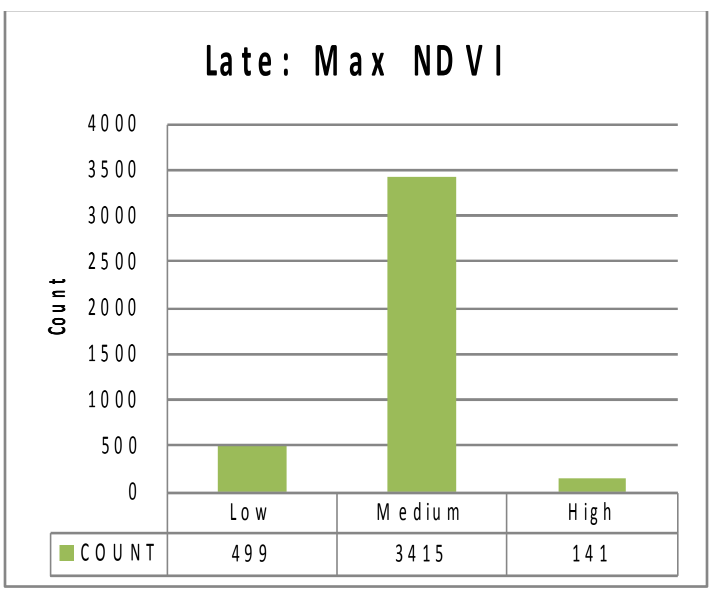
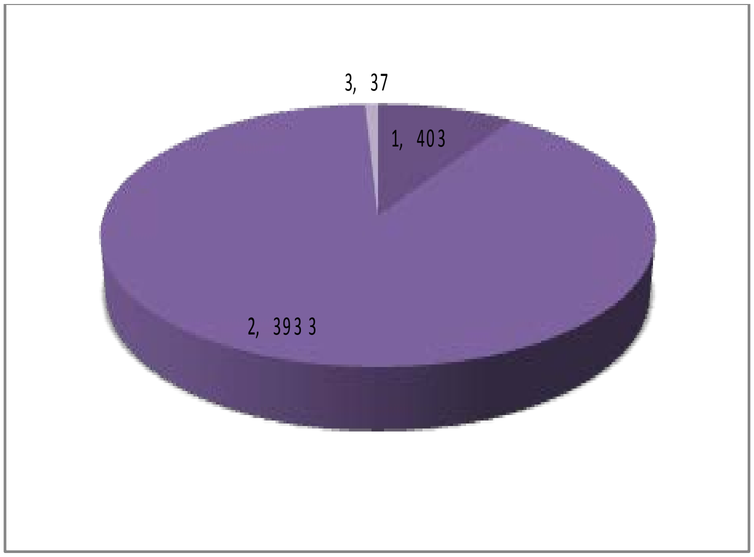


Figure 21. Analyzed using ArcGIS cell statistics, low, medium and high NDV categories were calculated based on the Landsat images that were greater than the mean for the defined growing season, and these are the counts for the three categories in the late dates.

Early:



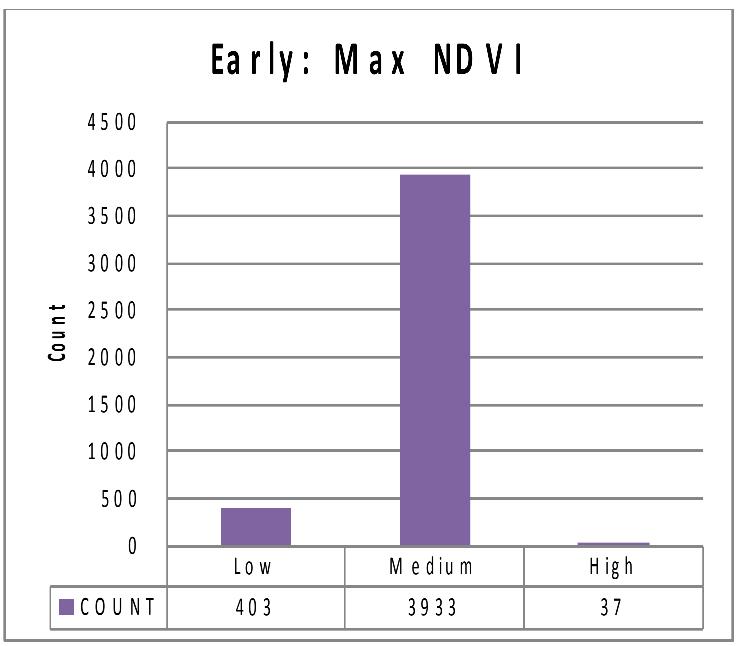


Figure 22. Analyzed using ArcGIS cell statistics, low, medium and high NDV categories were calculated based on the Landsat images that were less than the mean for the defined growing season, and these are the counts for the three categories in the early dates.

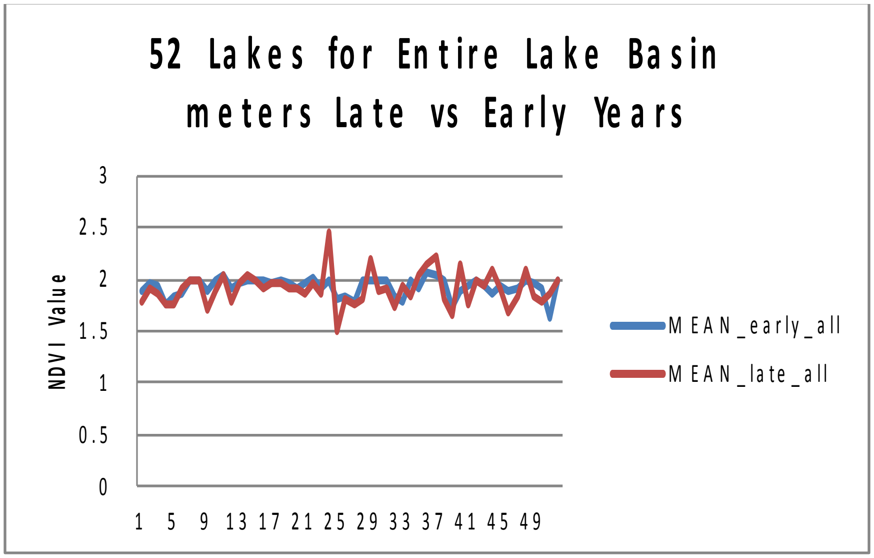


Figure 23. The mean NDVI comparing the early to late years for all fifty-two lakes for the entire lake basin.

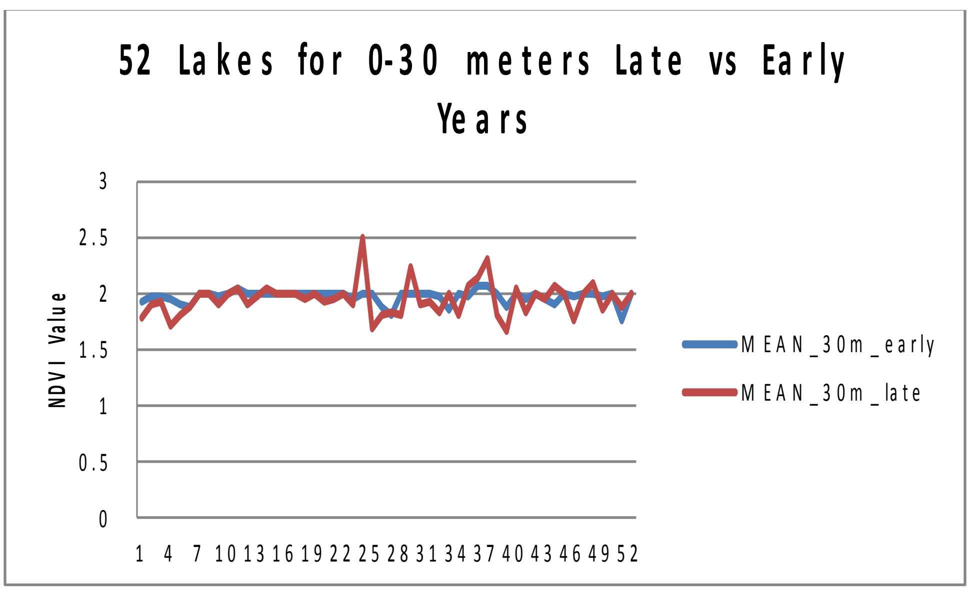


Figure 24. The mean NDVI comparing the early to late years for the region of 52 lake, from lake perimeter to 30 meters inside.

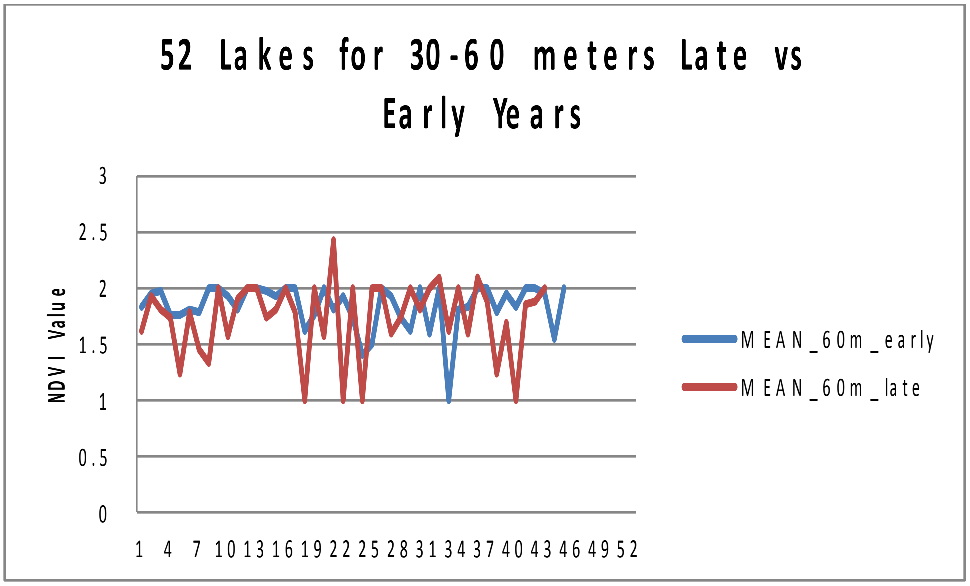


Figure 25. The mean NDVI comparing the early to late years for the region of 52 lakes, from 30 to 60 meters inside the lakes.

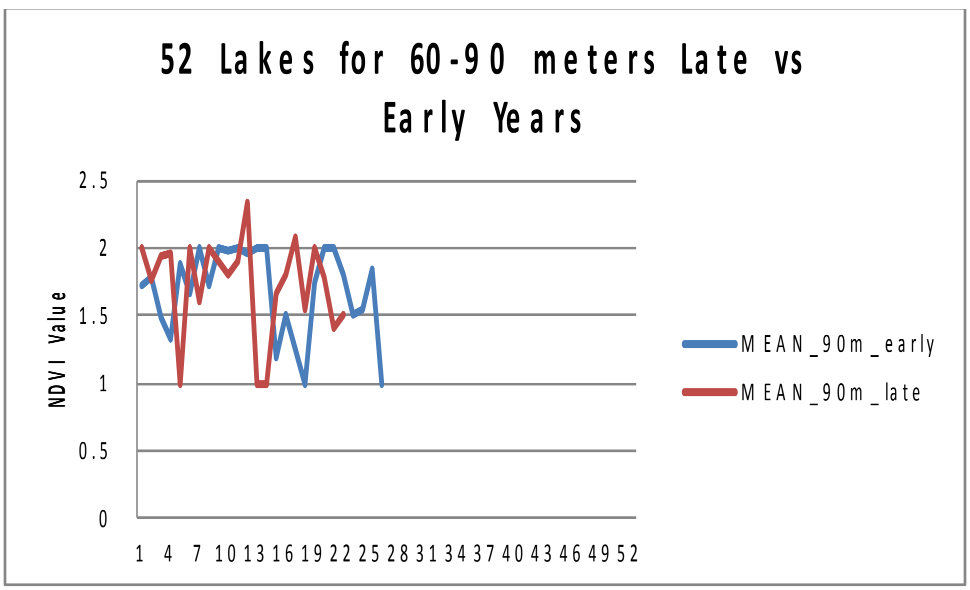


Figure 26. The mean NDVI comparing the early to late years for the region of lakes from 60 to 90 meters inside.4

Additionally, the attached animation shows a simple visualization of what the graphs and charts demonstrate and numerically represent. The animation verifies how maximum NDVI (dark green) has a stronger presence in the central regions of the lakes. There is a greater ratio amount of the maximum vegetation between the 60-90 meter buffered band which is the area closer to the center of the lake. However, there are more aspects that could be explored to determine what is taking place as lakes are taken over by plants over time such as a finer resolution, greater frequency of capture dates and exploring the phenomena further.

Discussion

This project adds value to the field of natural resources in that it is a new approach for using long-term Landsat to look at vegetation dynamics specifically for shrinking lakes. This project also advocates for using more temporal visualization in natural resource applications. Not only will this project add significance by looking at what is happening to boreal forest in Alaska, but there is value in knowing more about how the landscape is affected by climate change. This project provides an example of how to collect a baseline of information on what is taking place and adds to the body of knowledge of lake area succession. Additionally, this project is important because determining how rates of vegetation succession of disappearing lakes can help with climate models and forecasting the future of the climate variables, such as CO2, and temperate and extent of where vegetation and water will be available as the planet changes.

Generally this type of analysis, using time enable data/animations, is also valuable for conservation biologists and land use planners. This analysis can play a vital role in understanding the nature of environmental systems and can be used by interested member in a variety of ways.

Areas for Further Research

A finer scale resolution to identify individual plants as lakes undergo succession to plants would be very valuable addition to this analysis. The Landsat satellite imagery was used because it started in the 1980s, had medium resolution at 30 meters, included band 3 and band 4 for calculating NDVI and it was free to access. However, using a finer resolution imagery, even though it cannot go back as far as Landsat imagery, would allow for more precise regions to emerge as to what is taking place in the lake basins the why the higher NDVI maximum vegetation values are showing up in the 60-90 meter zone rather than closer to the former lake edge. In addition to using a finer scale satellite imagery to examine the spatial distribution of the vegetation, it would be valuable to examine inter-seasonal and intra-seasonal variability with the growing season at a finer scale resolution. For example, there is a lot of cloud cover in the high latitudes of interior Alaska and the Landsat Satellite only has nadir image capturing capabilities and numerous images were not able to be used. In the future, it would be constructive to use more dates at a finer scale. Even though a finer scale would not be able to go as far back in history as the Landsat satellite, it would help confirm the validity of the above results and if they remain true at a finer scale and with greater amount of dates within a growing season and between years.

Similar methods could be used to approach a region within a comparable ecosystem, and additionally, spatially assessing vegetation change to lake loss would be a valuable exercise for any type of ecosystem. Furthermore, integrating historical temporal data from bird migrations or other temporal variables for research of land cover and land change would be significant for spatial and temporal research. Lastly, different morphological shapes of lakes could be analyzed to see if there are differences between general shapes of lake bed morphology and how the succession happens from water to vegetation.

The Yukon Flats is a vital area for in terms of cultural geography and physical geography, from local subsistence to habitat for numerous wildlife species. How lands are managed is vital for the future protection of the management of natural resources. Using Geographic Information Systems/Science and incorporating components such as temporality and animation as well as various spatial statistics can allow for a greater understanding of a region of patterns and processes that are taking place in light of extremely complex systems. Land-use managers, conservations, scientists and researchers involved with understanding natural resources would benefit from the increased use of building temporality into data systems for making decisions about land management. Moreover, for this specific case analysis using a combination of spatial statistics and animations gave insight into the vegetation dynamics for lakes that are shrinking.

Appendix

The attached animation file helped with visualizing and analyzing the lakes and the vegetation change that is taking place to see emerging trends or relationships present that are not as easy to discern with other methods.

(Animation videos—double click the .wmv file below to open visualization)

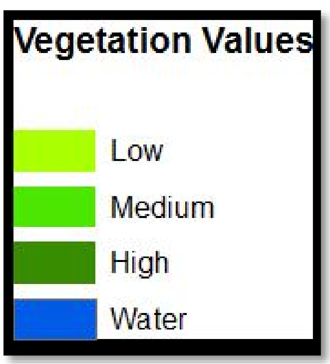


Figure 27. Depicts the Legend for the animation of the vegetation change of the NDVI for categories of low, medium and high.

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