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Use of GIS Spatial Analysis, Remote Sensing, and Unmanned Aerial Systems in Determining the Susceptibility to Wildfires in Barber County, Kansas

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USE OF GIS SPATIAL ANALYSIS, REMOTE SENSING, AND UNMANNED AERIAL SYSTEMS IN DETERMINING THE SUSCEPTIBILITY TO WILDFIRES IN BARBER COUNTY, KANSAS

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by

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ABSTRACT

Wildfires are becoming more frequent each year not only in the United States, but throughout the world. Barber County, Kansas experienced a devastating wildfire in March 2016, and continues to be at risk of wildfires during the fire season months. This study involved creating a functional GIS Database with layers corresponding to communication, transportation, and infrastructure throughout the county. This will allow responders and officials to have one unified reference space, which will facilitate communication and navigation. Within the ArcGIS environment, route maps can be created to show potential routes and quickest drive time to the scene of the emergency. Another aspect of this project was to identify areas with the potential for large fire outbreaks. In order to monitor fire hazardous areas, Landsat imagery was utilized to identify potential outbreak areas using the Normalized Differential Vegetation Index. Using this imagery allows officials to track areas that are at risk of overgrowth and fuel build up. Imagery taken from an Unmanned Aerial System (UAS) was used to provide a different perspective of the fire front. Having the vantage point being taken above the fire allows for responders to see exactly where the fire is currently active. The UAS also provided a more time efficient way of observing grassland conditions of the study area, Township 34 South, Range 13 West. While the focus of this project is in Barber County, Kansas, the techniques utilized can be transferred and set up for other counties across the United States.

ACKNOWLEDGEMENTS

I would like to say a huge thank you to my advisor, Dr. Tom Schafer. Without your advice and guidance, I would not have pursued my masters. You were one of my first professors at Fort Hays and a major reason I continued down the geography path. I cannot thank you enough for pushing me and helping me through my time at Fort Hays, especially the two years of grad school.

Another huge thank you goes to Dr. Richard Lisichenko. You provided so much insight through my years at Fort Hays. I had no idea that taking my first GIS class with you would lead to me make a career out of it. Thank you for teaching me and guiding me through the world of GIS. To Dr. Mitch Greer, thank you for being a part of my committee and sharing your knowledge of grassland and fire behavior.

A special thank you to the Donovan family for granting me access to their land in order to capture imagery needed for me research. To the Becker family, thank you for allowing me to join you on the day of your controlled burn. I could not have completed this research without the help of your families, thank you!

To my closest friends, there is absolutely no way I could have made it through life without you. You all have been some of my biggest supporters and always there to cheer me on every step of the way. I have truly been so blessed with your friendships and know you are always a phone call away anytime I need anything, ever.

Finally, the biggest thank you of all, to my parents, Mike and Amy. You two have always supported me in every decision I have ever had to make. You have always encouraged me to follow my own path and spread my wings and fly. I could not have made it this far without you standing behind me every step of the way. And to my brother, Kyler, I could not have made it through this last year without you here in Hays by my side. I am so grateful we were able to share some last memories at Hays. Thank you for being here and supporting me.

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INTRODUCTION

This research seeks to discover if Geographic Information Systems (GIS) and Unmanned Aerial Systems (UAS) technology can be used to create a preparedness informational infrastructure for fire prone Barber County, Kansas. The objectives of this study are to: 1) create a functioning GIS Data base with layers to correspond to communication and transportation infrastructure of the county 2) examine and analyze the grassland area through remote sensing techniques for determining the amount of cured grassland for potential fire fuel and 3) determine how Unmanned Aerial Systems (UAS) can be used in preparation, combating, mitigating, and recovering from a wildfire. Wildfires are becoming more common not only in the United States, but all over the world. Each year more acres are burned and the severity of fire risk increases throughout the world (Charnley et al. 2015). This research is especially important for smaller communities that lack technology and resources putting them even more at risk during the spring and summer months where the fire risk is extremely high. Barber County, Kansas (Figure 1) is one of those rural counties that not only have a high risk each year, but has also recently experienced the effects from a wildfire.

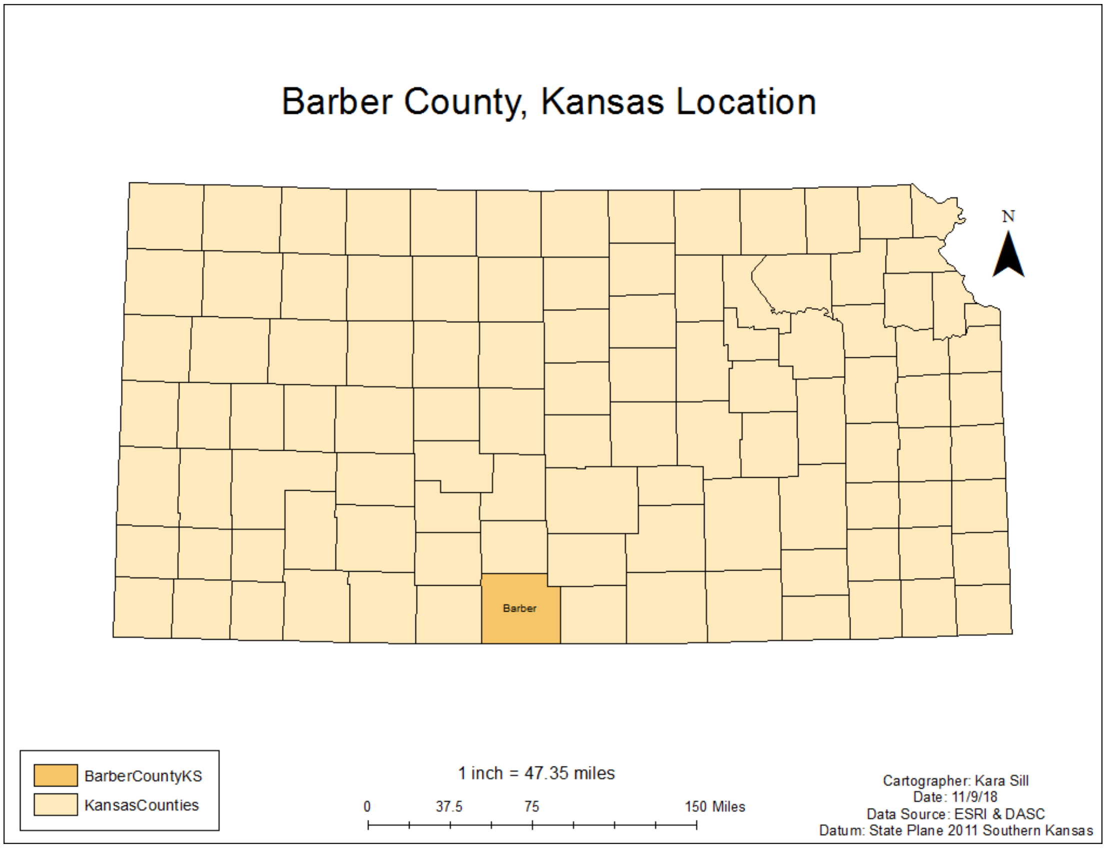

Figure 1: Barber County, Kansas. This map shows the location of the county the study area is located in south central Kansas.

Figure 2: Aerial View. This image shows the satellite aerial view of Barber County, Kansas. **Earthstar Geographics 2020.**

BACKGROUND

Barber County, Kansas was founded on February 26, 1867 and is located in South Central Kansas with an area of 1,136.21 square miles (Barber County, Kansas 2015) According to the 2010 U.S. Census it is home to 4,861 people (Barber County, Kansas 2015). The county has almost doubled in size since 1880 with an initial population of 2,661. Barber County is made up of eighteen different townships and seven incorporated cities, Medicine Lodge being the most populated with 2,334 people (Kansas Historical Society 2018). The county is home to the Gypsum Hills, which consist of beautiful scenery such as red dirt, canyons, and gypsum deposits. Gypsum is a sedimentary rock formed during the Permian Period around 250 million years ago. During this time, the land was covered by a seaway that stretched from northern Canada to the Gulf of Mexico (Kuhn 2007). Once the seaway dried, it exposed hills and canyons found in this region that were created when the sea once covered the area. The iron oxide left in the sediment gives the dirt its red color (Kuhn 2007). Barber County has one of the largest gypsum mines in the United States (Gypsum Mining 2018). Agriculture is another important sector in the economy of Barber County, as well as small town businesses keeping the towns alive.

In 2016, the Anderson Creek Wildfire became known as the largest wildfire in Kansas history, burning more than 397,420 acres in Oklahoma and Kansas (Gabbert 2016) - (Figure 3). Barber County, Kansas was greatly impacted by this fire, costing close to $1.5 million from Federal Emergency Management Agency (FEMA) resources

(Bickel 2017). For two weeks, firefighters worked to contain this massive fire fueled by windy weather and dry conditions. When dealing with these extreme conditions, wildfires are incredibly hard to contain, and fire behavior is unpredictable. To add to these difficulties, in an area such as Barber County, getting control becomes even more difficult due to topography. Barber County is home to the Gypsum Hills and with those hills comes cedar trees, gouges, rough terrain, deep canyons, and roads with no set township system, such as not following the standard mile by mile cross sections. Once the fire goes down through the canyons and ignites the cedar trees, it burns hot and fast (Engholm 2016). There is no way of getting down into the canyons to put the fire out, which allows the fire to spread quickly. Due to the topography in the Gypsum Hills, the firefighters could not get ahead of the fire. Many of the county roads in the western part of Barber County go on for miles before coming to an intersection. This made it difficult to get ahead of the fire, which allowed it to intensify. The unique terrain also made it difficult to determine how it was going to spread throughout the canyons systems and how it would behave with different slopes and wind drafts.

Throughout the hills, cell service and radio tower communication are not guaranteed. This caused another issue when fighting this fire. As the fire advanced, the radio towers often were in its path causing responders to lose communication with other team members (Engholm 2016). Without communication, there was no way of letting responders know what was happening on the front lines or where the fire seemed to be spreading. This caused those fighting the fire to rely on what they could see ahead of them, which was not much considering the hills and canyons, creating very hazardous conditions. After calling for help from several surrounding communities and fire departments, the National Guard brought in Blackhawk Helicopters to help put out the hot spots (Engholm 2016).

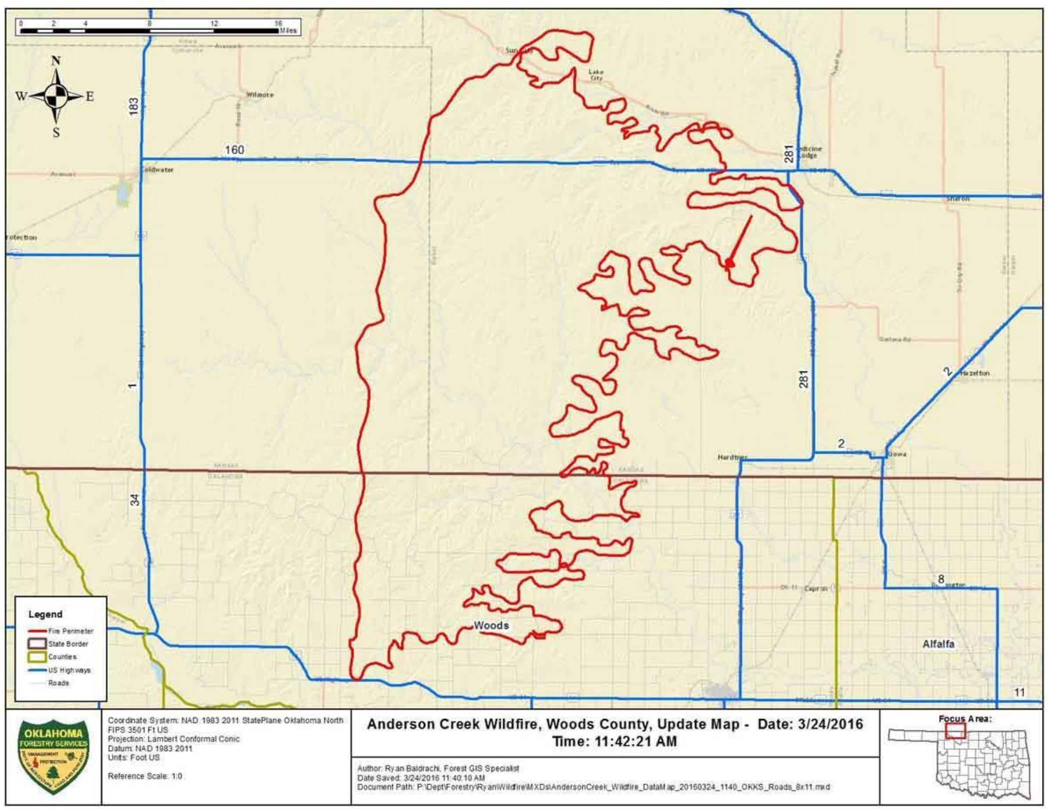

Figure 3: Anderson Creek Wildfire Burn Scar. This image shows the burn scar from the Anderson Creek Wildfire in 2016. The fire originated in Woods County, Oklahoma and spread into Comanche County, Kansas and Barber County, Kansas. The majority of acreage burned was in Barber County, Kansas. **Oklahoma Forestry Services. 2016.**

LITERATURE REVIEW

Grassland Curing

Curing, or grassland senescing, can be defined as drying grass often caused by seasonal drought. Grassland goes through a cycle that transfers the above ground nutrient rich biomass to the below ground roots and as that biomass dries, it becomes cured. The level of curing that occurs is based on a percentage from zero to one hundred (Nichols, D., et. al. 2014). The more cured the grassland is, the higher the chance for a severe fire to occur due to fuels that are more likely to ignite and allow the fire to spread faster. A fire that originates in grassland that is 40 percent cured is going to burn at a lower intensity, less hot and not as fast moving, compared to a fire burning in 100 percent cured grassland (Garvey and Millie. 2001).

Grassland curing can be measured directly by having an expert examine the area visually and assess to what level the grassland is cured. Remote sensing imagery can be used as well, by looking at a broad area and assessing the photographs and other imagery to decipher what level the grassland is cured (Kidnie et al. 2015). Curing occurs as a process that is most clearly seen through the visual aspect of the change in color. Curing is also a very important aspect of predicting seasonal fire danger risks and understanding fire behavior (Kidnie et al. 2016).

Remote Sensing and Grassland Curing

A study showed that a small area can be examined by using Landsat Thematic Mapper in order to discover grassland curing levels (Xulin, Price, and Stiles 2000). The imagery can be used to monitor vegetation and based on the color of the grassland, the curing level can be determined. The Grassland Fire Danger Index (GDFI) is a method often used to help determine the potential risk of fire occurrence in a given area by accessing the curing level and weather conditions. DOC or degree of curing is based on a scale of 0-100 percent curing, zero being the greenest grass while 100 is driest grass. The higher the DOC the greater the chance for a severe fire to occur (Wasin et al. 2018). Newnham et al. (2011) assessed grassland curing by predicting fuel load. Using the Relative Greenness approach, along with the Normalized Differential Vegetation Index (NDVI) Newnham et al. (2011) monitored a specific area over time in order to predict a more accurate degree of curing.

GIS and Predictor Variables

Geographic Information Systems (GIS) is a computer software that manages and analyzes data through relationships with spatial patterns. GIS can be used to make maps that help people understand the world around them (What is GIS? 2020). Maps can be beneficial in many ways. For this study, a map showing areas of potential high risk fire area could be made using GIS.

An aspect of grassland fires that are becoming more of an issue and often overlooked is the impact of humans. Zhang et al. (2010) used spatial analysis and logistic regression to assess the probability of humans increasing the risk of fire outbreaks. A probability based model indicated the closer to human infrastructure such as villages, railroads, and dirt roads, there was an increased fire risk. Maps produced by these findings can help fire managers monitor the higher risk areas. Creating fire risk maps can help emergency managers prepare and take preventative measures so that an extreme wildfire does not occur. Ariapour and Shariff (2014) utilized Landsat ETM+ data for imagery while using an Analytical Hierarchical Process to weigh different environmental factors and their contribution to fire risk to create fire risk maps. Adab, Kanniah, and Solaimani (2011) created a Hybrid Fire Index using different variables for creating low and high risk zones which were then transferred into high risk fire maps. Having updated maps are beneficial when responding to emergencies and communication for officials and responders.

Use of Unmanned Aerial Systems (UASs)

The use of Unmanned Aerial Systems (UASs) is currently increasing in regards to inspections for real estate, natural disasters, and law enforcement has used for finding missing persons or vehicles. Ollero, Martinez-de-Dios, and Merino (2006) discuss how UAS can aid in fire management. UASs can be used in fire management practices by observing vegetation growth and creating fire risk maps. If a fire was to occur, the use of

UASs could then monitor the fire front and georeference the location of the front and other spot fires that occur. Hot spot recognition and mapping of the burn scar can be done post fire by having the UAS collect imagery.

Other fire management techniques using UASs include enhancing the visual of the fire through smoke and night monitoring. Twindwell, et al. (2016) discuss how the use of UAS can improve communication in areas where cell and radio towers may be limited due to being in remote locations. Having real time data from the UAS and using radio relays can help increase response time. Yuan, Zhang, and Liu (2015) state UAS help lower the cost of management and response practices while also keeping personnel safe while detecting and monitoring the fires. Mapping the fire front under a controlled burn using UAS was conducted by (Marinez-de-dios et al. 2011). This showed how monitoring the fire front can be consistent in tracking how the fire is moving.

METHODS

For this project, the Township 34 South, Range 13 West, Quadrants 8, 9, 10, and 11 were chosen as the area of study (Figure 4). This section was part of the severely burned areas of the Anderson Creek Wildfire and are major dead zones when it comes to communication.

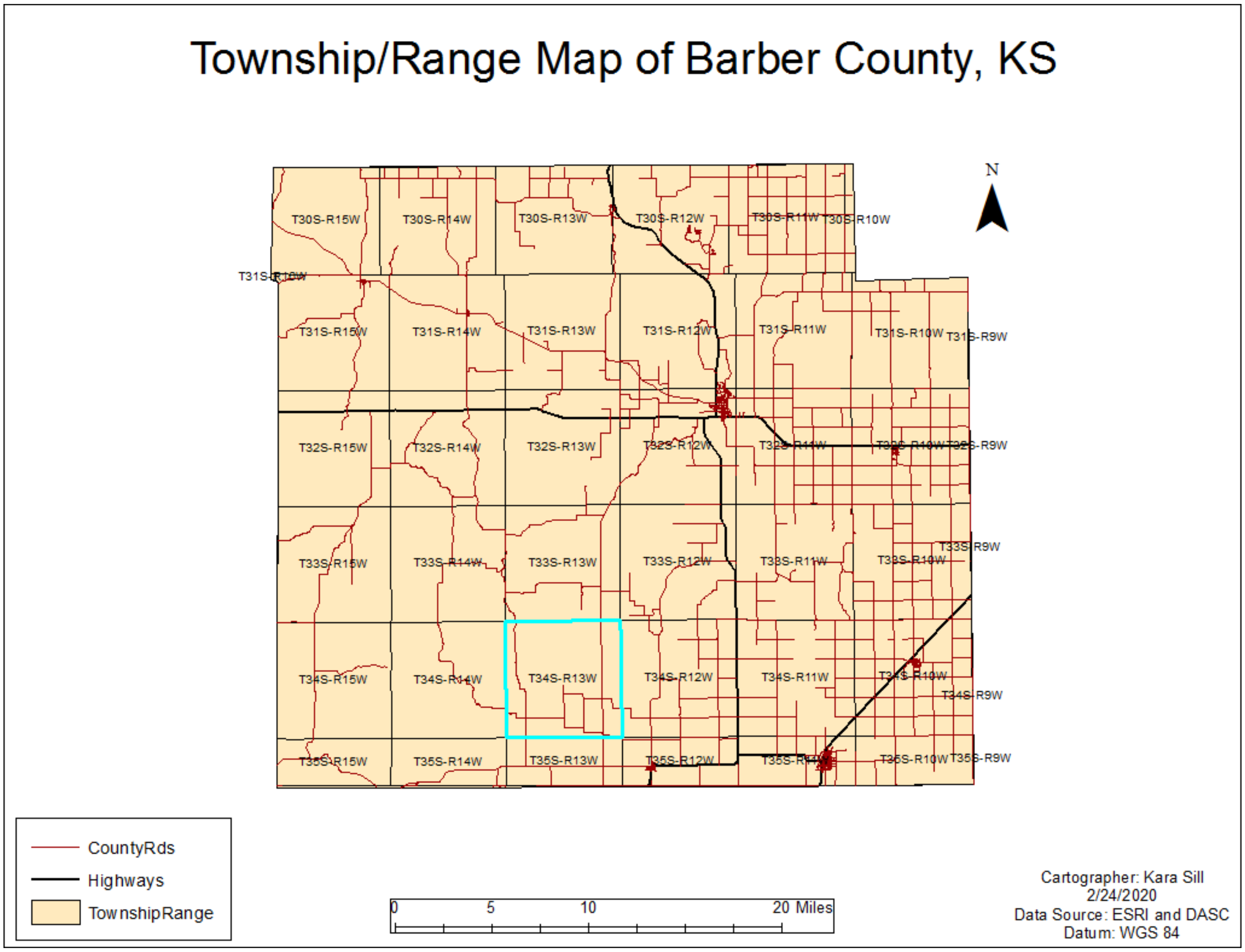

Figure 4: Barber County, Kansas Township/Range Map. The study area chosen for this project was a township and range section in Barber County, Kansas. This section was chosen because it was an area that burned severely during the

Anderson Creek Wildfire. This area is also major dead zone for radio and cell reception which caused a loss of communication during the fire.

A database was created in ArcMap, which includes the layers of the state Kansas, Barber County, state highways (2012), county roads (2012), cell towers (2017), fire stations (2013), and radio towers (2017). The data was collected and downloaded for each layer from the State of Kansas GIS: Data Access and Support Center (DASC) (Kansas DASC 2020). Once the database layers were in place, a simulation response route utilizing the Network Analyst tool in ArcMap was created to demonstrate a potential route to an area of emergency. This was done by creating a new Network Dataset in ArcMap.

The Normalized Differential Vegetation Index (NDVI) of the grassland in Barber County was also determined throughout this project to show areas of vegetation density based on reflectivity which could help determine cured grassland. Remotely Sensed data derived from Landsat was used to produce the NDVI. Landsat 8 data was downloaded from February 27, 2016 to March 13, 2016; March 1, 2017 to March 16, 2017; July 1, 2016 to July 30, 2016; and July 1, 2017 to July 30 2017. The first dataset being February 27 through March 13, 2016 was the time frame right before the fire went through Barber County in March of 2016. The second dataset being March 1 through March 16, 2017 was the time frame during the same season and time of year the fire had gone through. This set was used to compare the difference between pre-fire in 2016 and post-fire in

2017. The July datasets were used to compare the summer seasons. July 2016 being the summer after the fire and July 2017 being the summer one year post fire, but one year later. Bands 4 and 5, the red and near infrared reflectivity bands, from Landsat were added into the ArcMap environment. Using the raster calculator within the Spatial Analyst toolbox, the NDVI was determined by using the equation NDVI = (IRC-R)/(IRC+R). IRC represents band 5, which is the reflectivity in the near infrared, while R represent band 4, which is the reflectivity in the red spectrum. This produces a rastered image scaling areas from negative one to one, with higher vegetation density, or more reflectivity, being scaled closer to or at one (GeoGeek 2016). Next, using the overlay tool in the Spatial Analyst Toolbox, a weighted overlay of the NDVI images were combined to show the difference between 2016 and 2017. The NDVI image produced from March to April of 2016 was combined with the image produced from March to April of2017. Then, the July 2016 image was combined with the July 2017 image. Both these images were combined to show the change in vegetation before and after the fire.

A DJI Phantom 4 Pro Drone was used to capture images of a controlled burn to show a different perspective of the fire front. On August 5, 2019, before flight safety checks were preformed ensuring the drone would be flying in the legal air space and appropriate weather conditions. Using the Pix4DCapture® app, the images of the controlled burn came from burning off wheat stubble. The free flight mission was selected in order to capture images for every 15 feet vertically and every 21 feet horizontally the drone flew. Images were also captured manually by the pilot controlling the drone. As the fire spread over the field, the drone's camera was positioned in different angles to capture several perspectives of the fire line. The drone, app, and the same parameters were then used on September 6, 2019 to capture imagery from the study area, Latitude 37; 5; 53.281 and Longitude 98; 44; 28.648, to provide images of fuel build up and curing conditions from parts of the grassland that was burned in the fire of 2016 and then a different section burned again in a fire that went through in 2017.

Creating a GIS database including the infrastructure and communication layers will allow officials and responders one spatial environment to work in to help cut down on response time by using a quickest route tool within Network Analyst. Using NDVI maps can help identify areas of high vegetation density, which would allow officials and landowners to locate areas of potential high fuel load and use mitigation techniques to avoid a fire outbreak. The use of the overlay map allows for change between years to be detected. In this case, it was able to determine where the land cover change occurred once the fire had gone through. The use of an UAS allows for a different visual of the fire head to be protected. Having a view from in the air, allows for the fire head to be monitored, even through thick smoke. Another use of the UAS is to capture imagery from the air at a large scale to cut down on time when surveying the grassland. The UAS images show the change in the color of the grassland between the seasons, while also displaying the topography of the area to provide insight of what lies ahead and what the responders may be up against when fighting a fire.

RESULTS

Having an infrastructure communication map allows emergency responders, managers, and other officials to have one environment with all the tools and details they need to utilize for communication and transportation during an emergency. Figure 5 shows an example of the map involving the infrastructure in Barber County, Kansas.

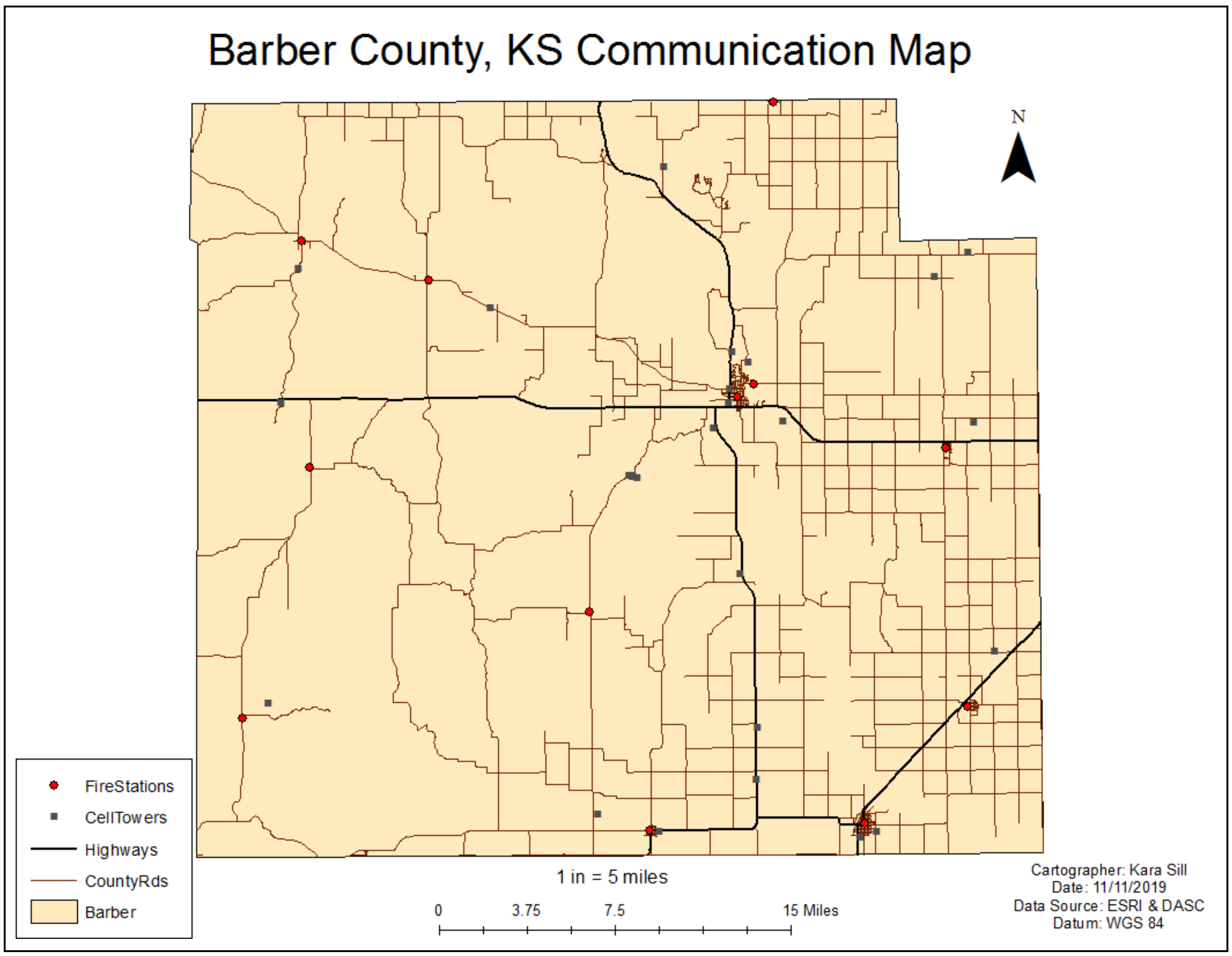

Figure 5: Barber County, Kansas Communication Map. This map represents a functional GIS database with layers corresponding to infrastructure and communication. It allows officials to view data in one environment and use layers needed in certain emergencies.

Using the communication map, the Network Analyst tool was utilized to create a quickest route simulation. Figure 6 represents a possible route to the study area. The route begins in the town of Medicine Lodge and goes out to an area that is located west of town, in the hills, and an area of low reception. It shows the location to the nearest road, not the exact area of emergency due to lack of roads.

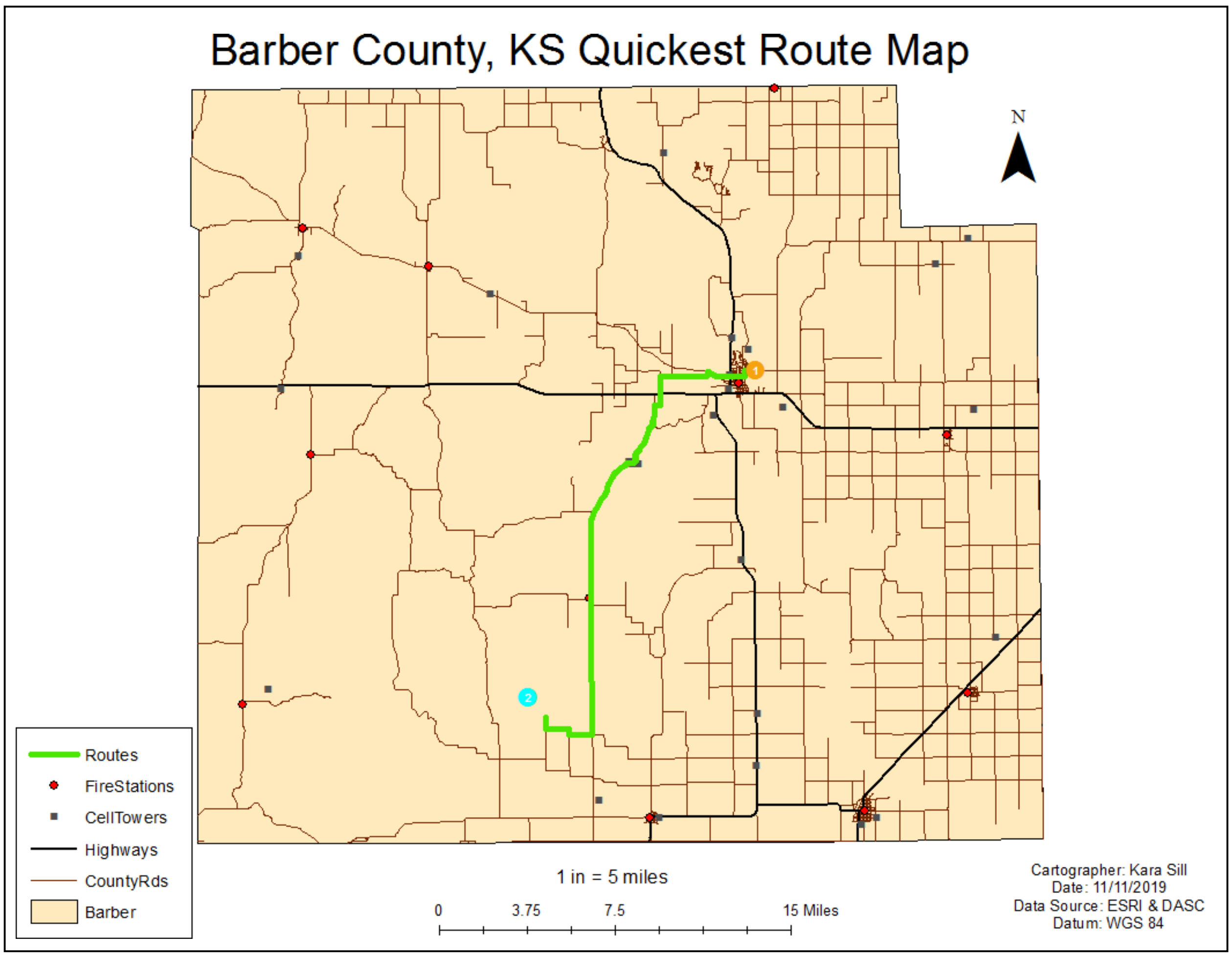

Figure 6: Barber County, Kansas Quickest Route Map. This map is an example of a simulation route that can be created in the ArcMap environment. Having access to this tool can increase response time to the area of emergency by knowing the quickest route to the area.

Using the Spatial Analyst tool, the raster calculator in ArcMap was used to determine the NDVI of the study area which was derived from Landsat 8 Data, Path 29, Row 34, bands 4 and 5 from the Earth explorer website. The equations “Float("LC08_L1TP_029034_20160227_20170224_01_T1_B5.TIF" - "LC08_L1TP_029034_20160227_20170224_01_T1_B4.TIF") / Float("LC08_L1TP_029034_20160227_20170224_01_T1_B5.TIF" + "LC08_L1TP_029034_20160227_20170224_01_T1_B4.TIF")”

“Float("LC08_L1TP_029034_20170301_20170316_01_T1_B5.TIF" - "LC08_L1TP_029034_20170301_20170316_01_T1_B4.TIF") /Float("LC08_L1TP_029034_20170301_20170316_01_T1_B5.TIF" + "LC08_L1TP_029034_20170301_20170316_01_T1_B4.TIF")”

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“Float("LC08_L1TP_029034_20170707_20170716_01_T1_B5.TIF" - "LC08_L1TP_029034_20170707_20170716_01_T1_B4.TIF") / Float("LC08_L1TP_029034_20170707_20170716_01_T1_B5.TIF" + "LC08_L1TP_029034_20170707_20170716_01_T1_B4.TIF")” were used to create the NDVI for each image shown. The images are based on a scale of negative one to one with higher vegetation areas being closer to one, or darker green in the image. The NDVI's are shown for the months of February 2016 (Figure 7), before the fire came through, March 2017 (Figure 8), a year after the fire came through, July 2016 (Figure 9), the summer after the fire came through, and July 2017 (Figure 10), the summer a year after the fire came through.

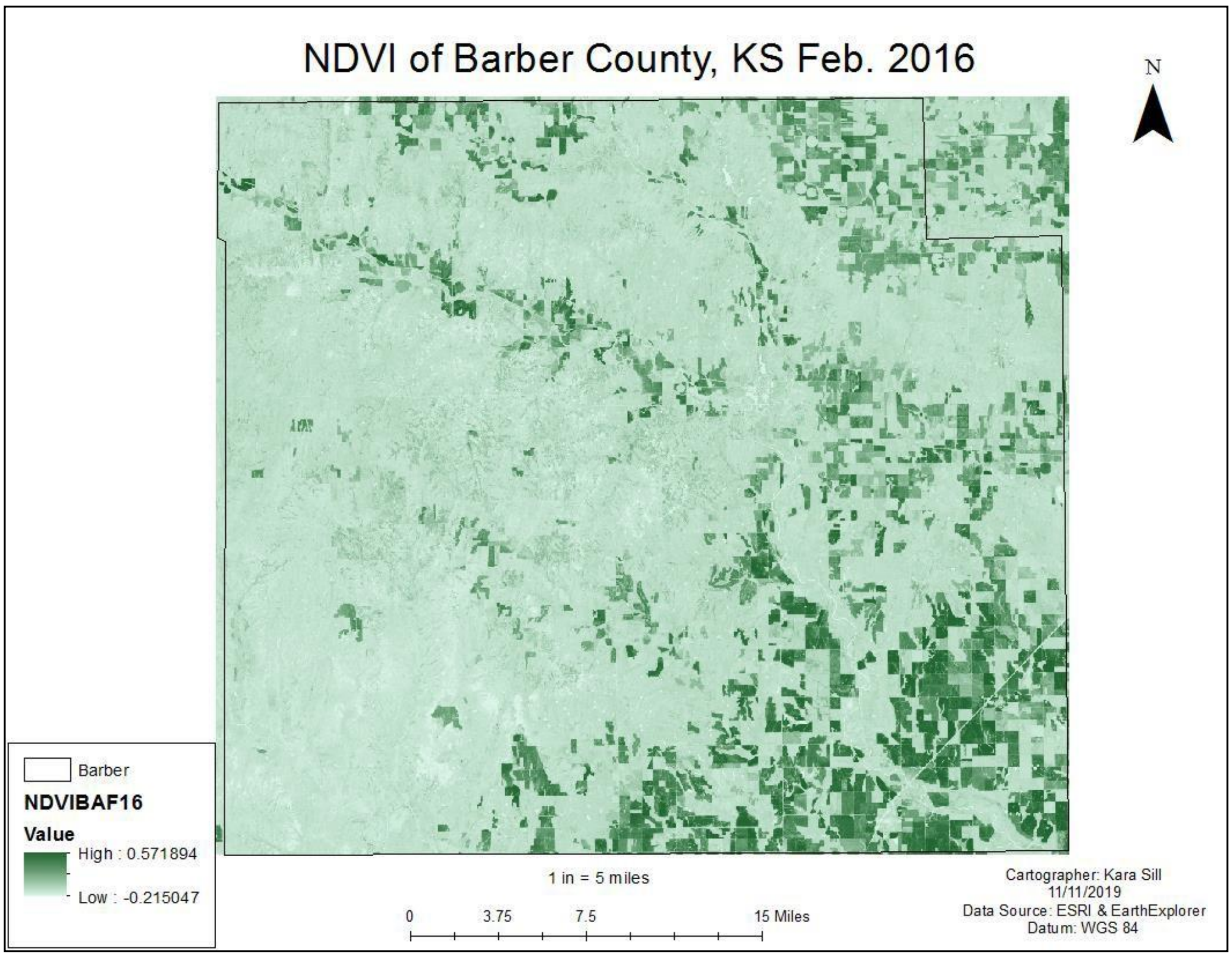

Figure 7: NDVI Map Spring 2016. This map shows the Normalized Differential Vegetation Index of the study area in Barber County, Kansas in the month of February 2016, the month before the fire went through. With vegetation density ranging for -1 to 1, the highest vegetation being closer to 1, or darker green in color as represented on this map.

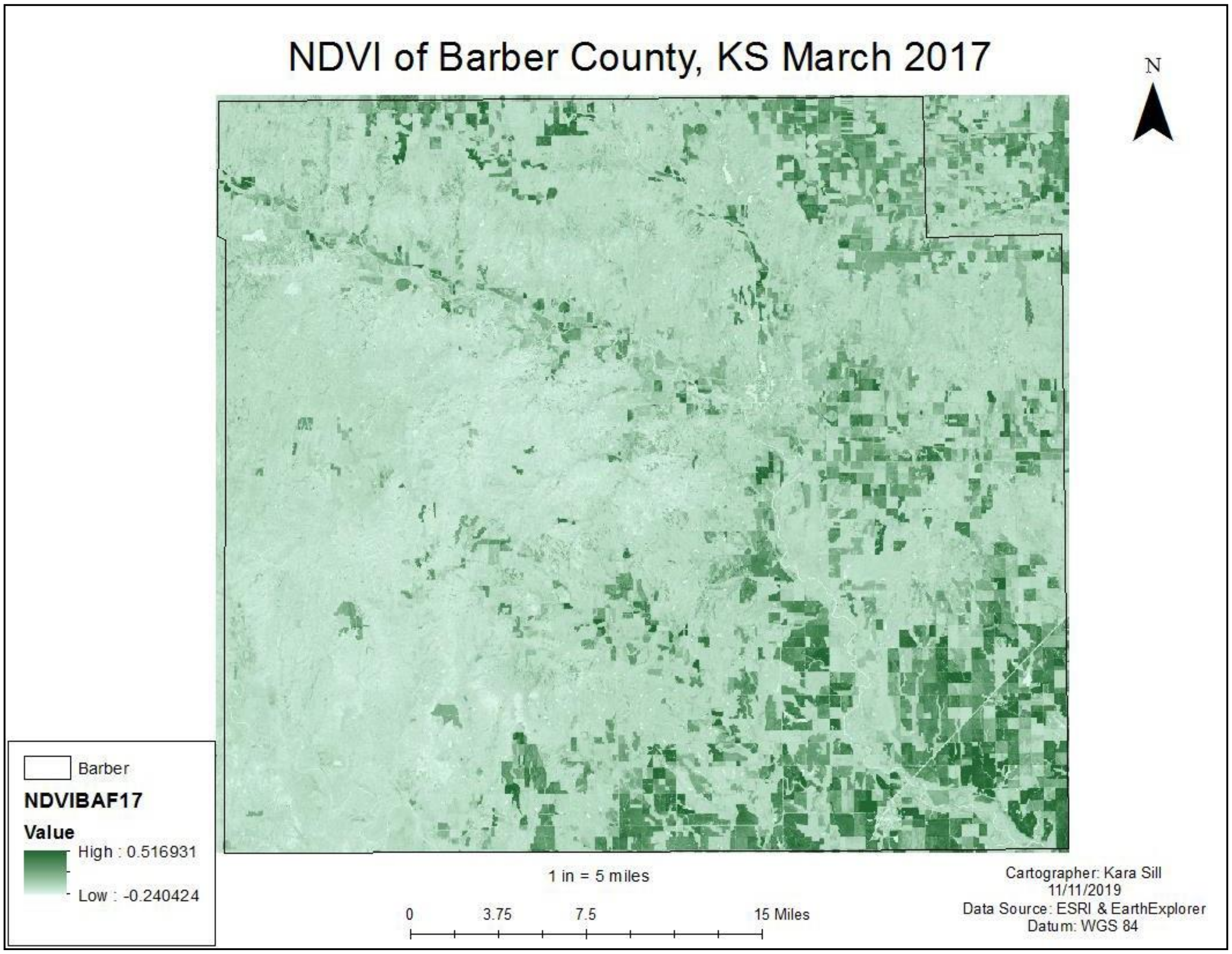

Figure 8: NDVI Map Spring 2017. This map shows the Normalized Differential Vegetation Index of the study area in Barber County, Kansas in the month of March 2017, a year after the fire went through. With vegetation density ranging for -1 to 1, the highest vegetation being closer to 1, or darker green in color as represented on this map.

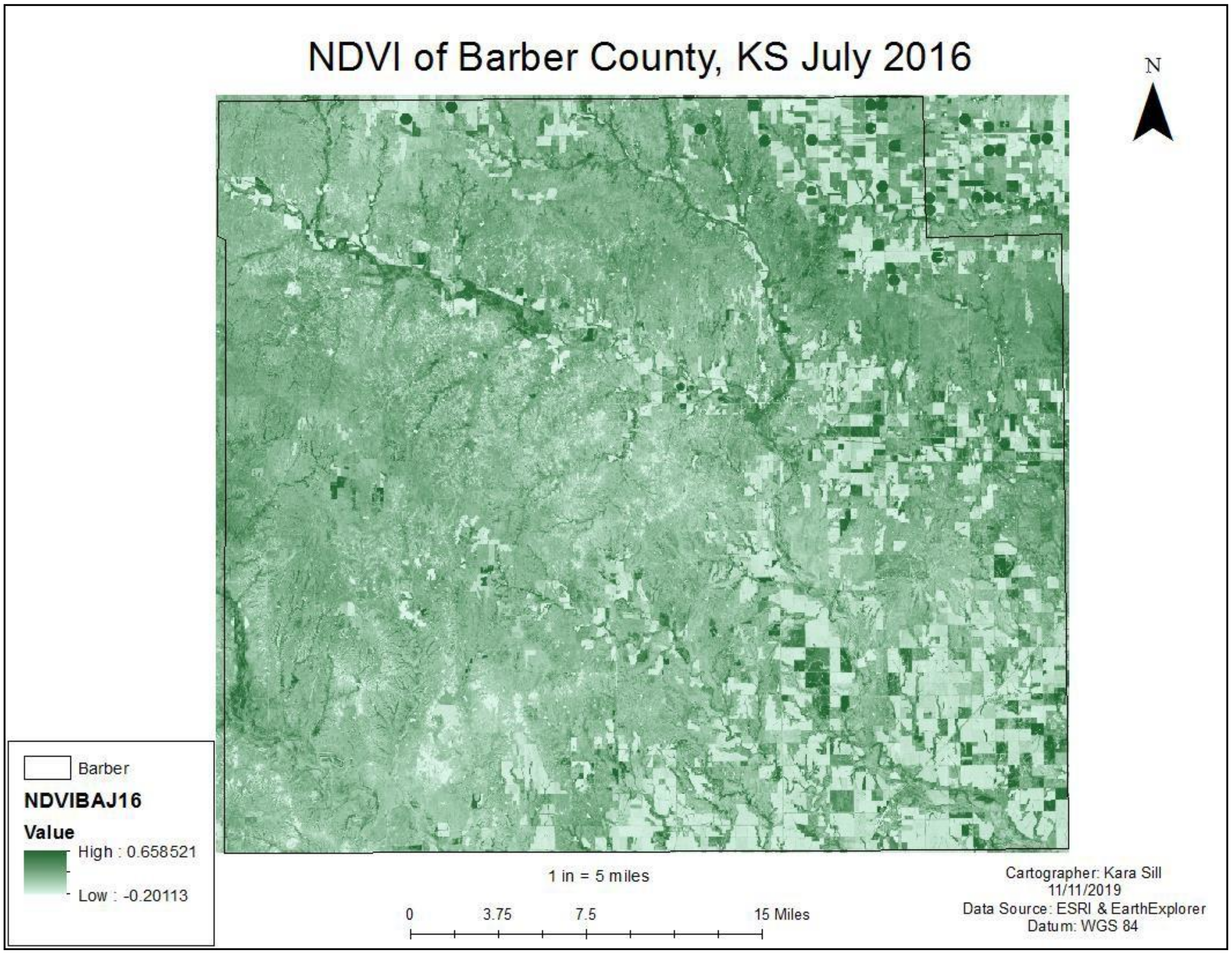

Figure 9: NDVI Map Summer 2016. This map shows the Normalized Differential Vegetation Index of the study area in Barber County, Kansas in the month of July 2016, the summer after the fire went through. With vegetation density ranging for -1 to 1, the highest vegetation being closer to 1, or darker green in color as represented on this map.

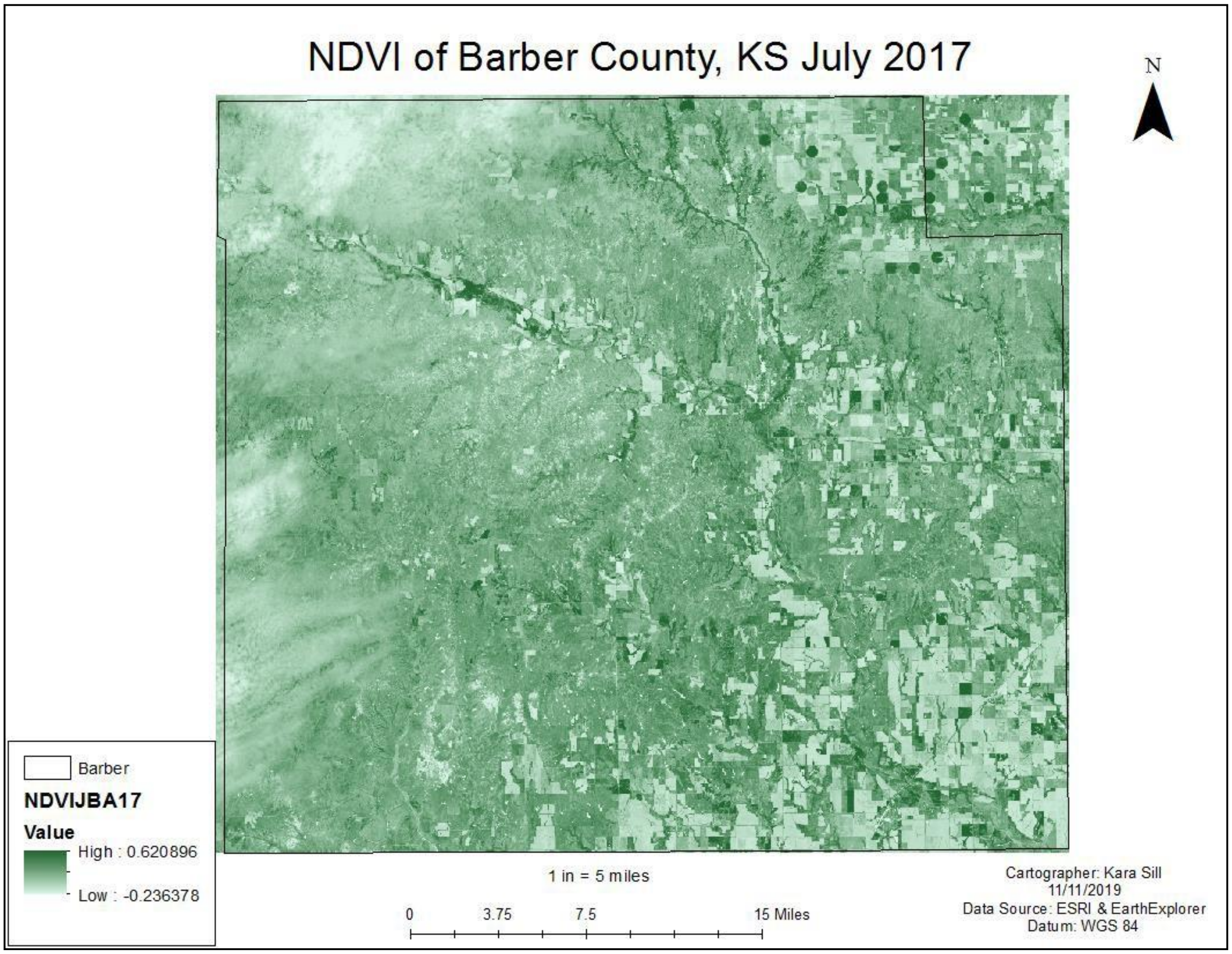

Figure 10: NDVI Map Summer 2017. This map shows the Normalized Differential Vegetation Index of the study area in Barber County, Kansas in the month of July 2017, the summer a year after the fire went through. With vegetation density ranging for -1 to 1, the highest vegetation being closer to 1, or darker green in color as represented on this map.

Overlay maps for each season were created by combining the rastered images from February 2016 and March 2017 for the spring comparison and July 2016 and July 2017 for the summer comparison. Figures 11 and 12 show the overlay comparison.

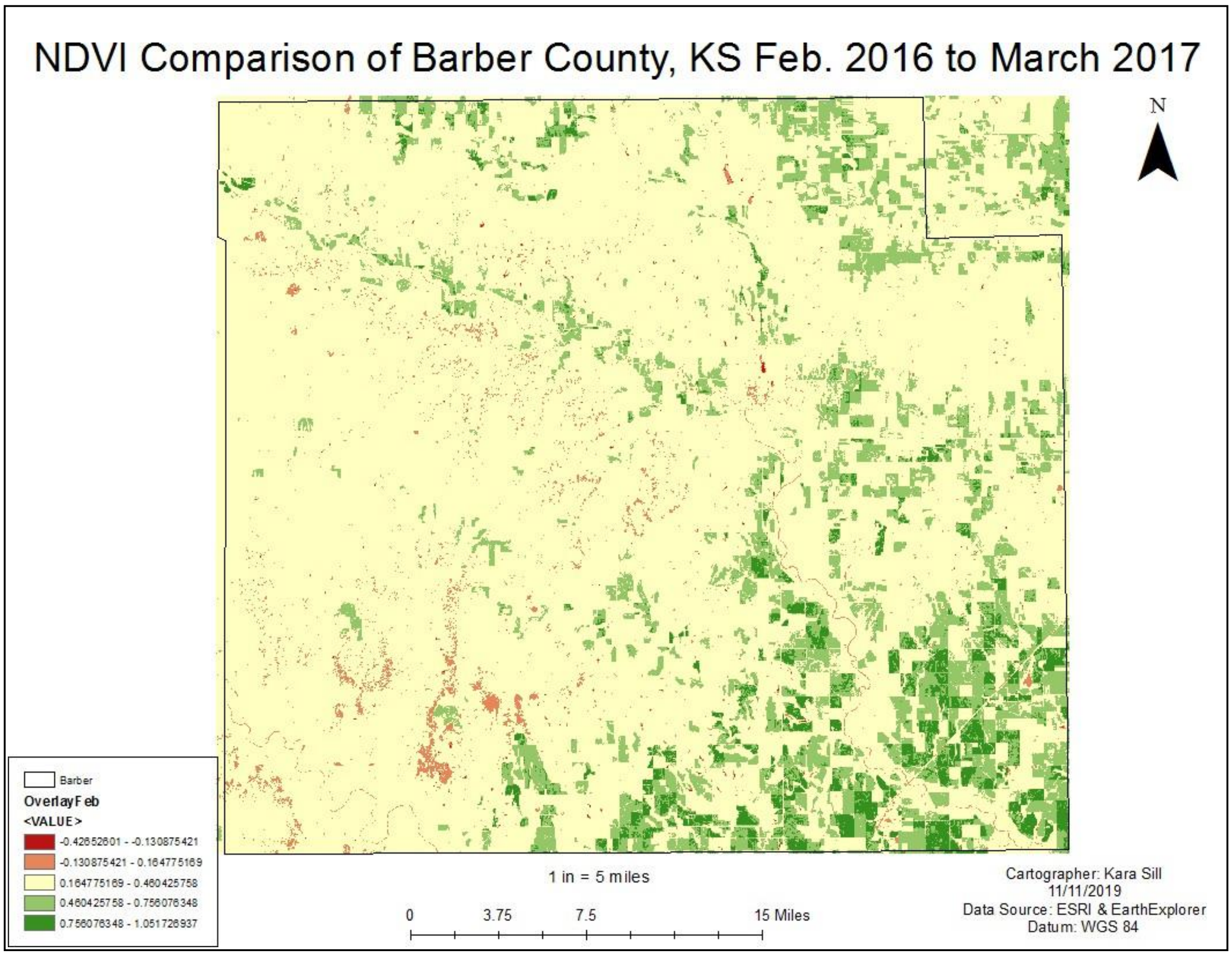

Figure 11: Spring Overlay Map. This map overlays the Normalized Differential Vegetation Index of the study area in Barber County, Kansas to compare the change in vegetation between the months of February 2016 and March 2017. The areas in red show the greatest change between the two years. The red areas also relate to where the fire went through in March of 2016.

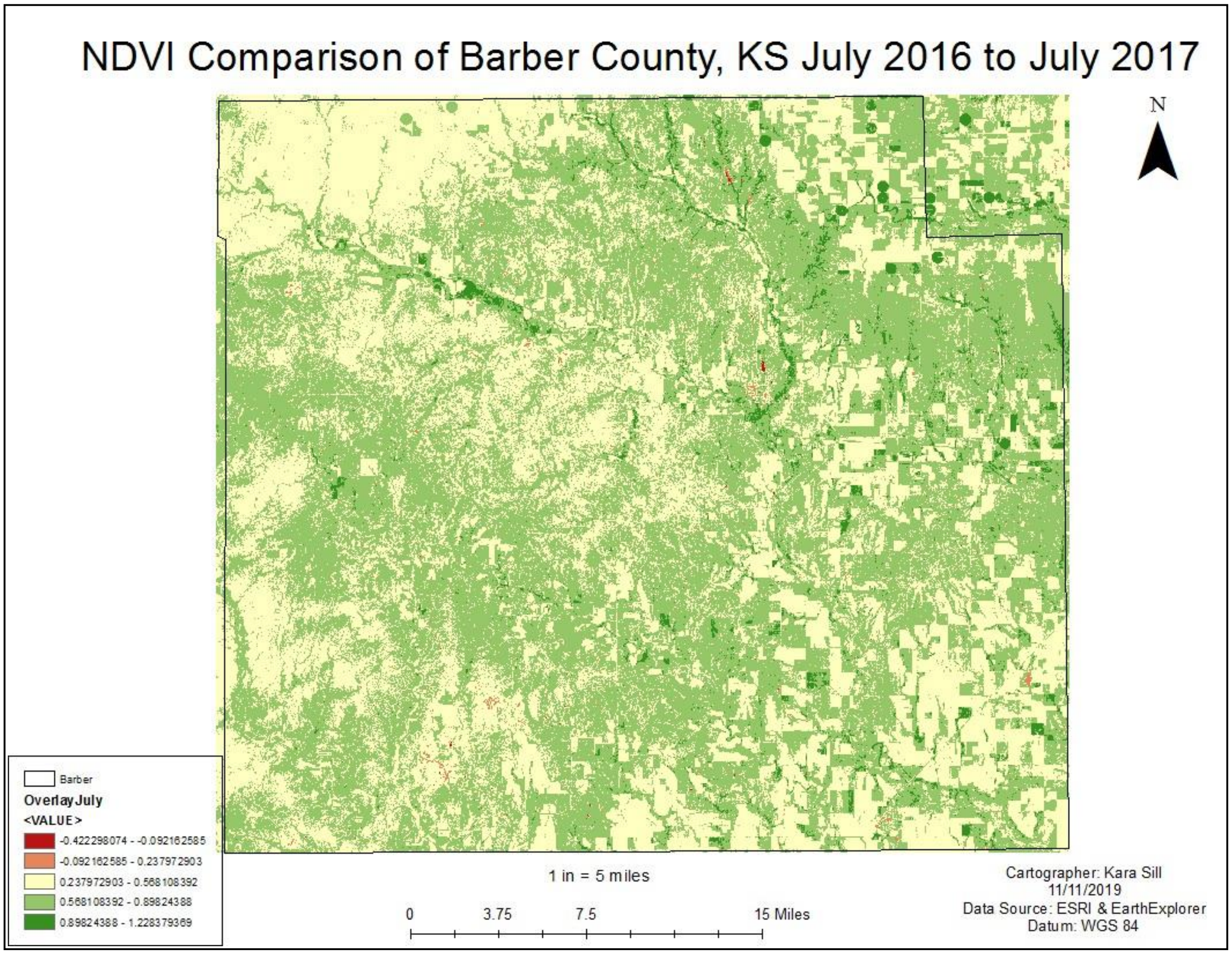

Figure 12: Summer Overlay Map. This map overlays the Normalized Differential Vegetation Index of the study area in Barber County, Kansas to compare the change in vegetation between the months of July 2016 and July 2017. There was not much difference in vegetation change between the summer months.

The overlay maps take the NDVI maps and compare the differences shown between the two. Figure 11 takes the NDVI from February of 2016 and the NDVI from March of 2017, overlays the two by combining them and showing areas of change. Areas in red show the greatest change while areas in green show little change. Looking at Figure 11, it shows there were major areas of change, the red areas, in the western part of the county, which is where the wildfire in March of 2016 went through. Figure 11 shows there was change in land cover, especially where the fire had gone through. Figure 12 Takes the NDVI from July 2016 and the NDVI from July 2017, and overlays them to show the areas of change. During the summer months, the grass has grown and is alive and green, making it hard to detect change within the areas. Figure 12 has very little red showing, indicating there is not much change in land cover during the summer.

UAS imagery was captured to show different perspectives of a controlled burn. The images show the progression of the fire from ignition of the back burn, to the ignition of the flank fires and then head fire to all fires coming together, the head fire through the smoke, and the burned area after the fire had extinguish itself.

Figure 13: Start of Control Burn. This image shows the ignition of the controlled burn taken from the drone.

Figure 14: Head of Fire. This image shows the head fire front and clear direction that it is moving.

Figure 15: Spot Fire and Fire Line Merging. This image shows the fire heads merging together while also catching the spot fire moving as well.

Figure 16: Fire Lines. This image shows the fire lines even through the smoke it is putting off.

Figure 17: End of Burn. This image show the burned area as the fire dies off.

Finally, the UAS was utilized to capture the appearance of the grass and topology of the area during two different season. The figures 18 and 19 are showing the vegetation at the end of summer in early September. These images indicate how green and alive the grass appears during this time period in the season. Figures 20 and 21 show the vegetation during the end of winter into early spring in March of 2020. The same area is pictured, but appears much different as the grass has died during the winter months.

Figure 18: Green Vegetation. The study area during September of 2019 as the grass level is still alive and green.

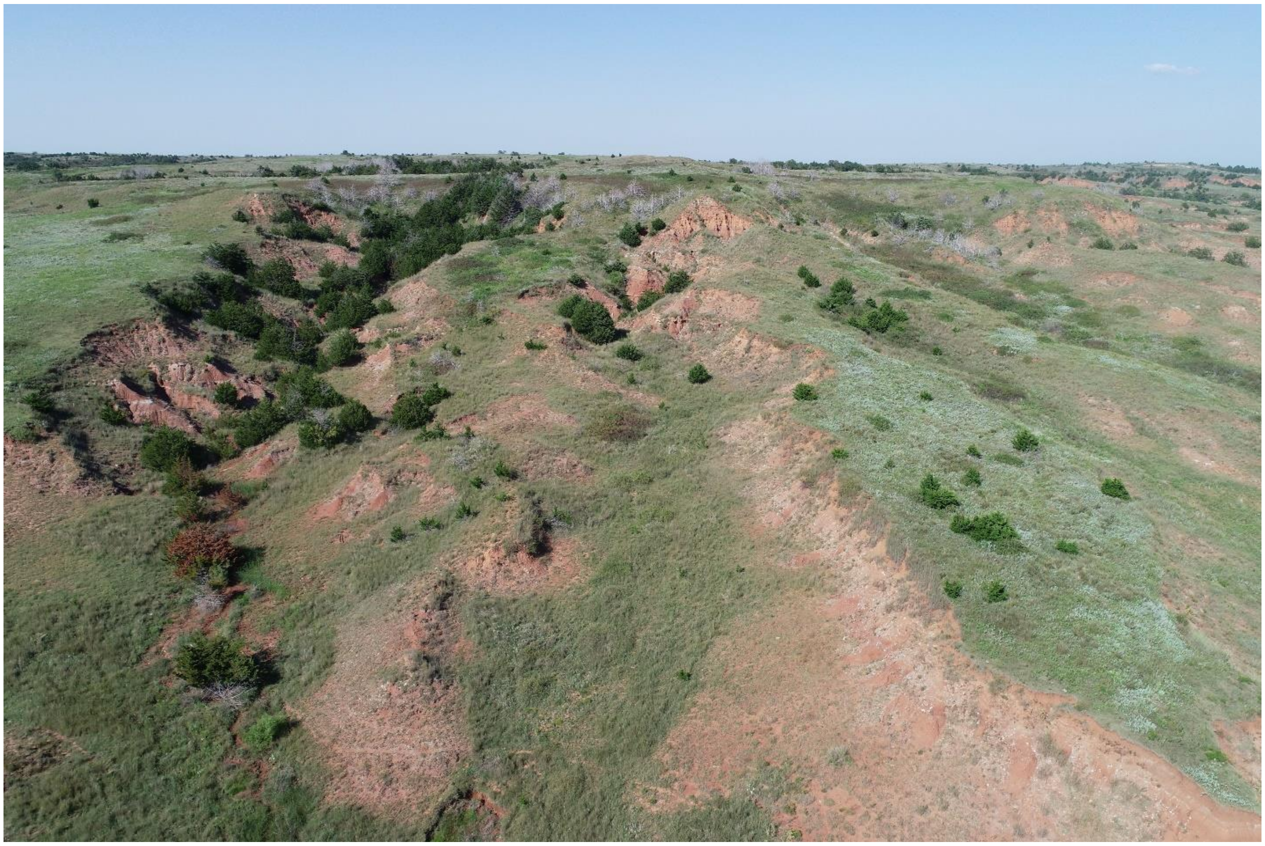

Figure 19: Green Vegetation and Topography. The study area during September of 2019 as the grass level is still alive and green while also showing the rough terrain.

Figure 20 Dried Vegetation. The study area during March 2020 as the grass has senesced.

Figure 21: Dried Vegetation and Topography. The study area during March 2020 as the grass has senesced and showing the topographic landscape.

Being able to use an UAS to capture imagery as seen in Figures 18, 19, 20, and 21, allows for a large area of land to be observed and seen from a different perspective. This imagery shows the topographic features of the areas while also showing how much of a change there is to the appearance of the grassland between the months of September and March. Using a UAS to capture the grasslands appearance during different seasons, not only saves time of viewing the area by foot, but gives insight to the fuel build up in the area. By knowing exactly what features and fuel lies within the area, mitigation efforts can be made to help reduce the risk of fire.

DISCUSSION AND CONCLUSIONS

This study aimed to create a reliable database useable for all emergency responders, managers and officials. Barber County Emergency Manager, Mike Loreg, passed along information that GIS was not used to its full capability during the Anderson Creek Wildfire of 2016. They did not have a mapping infrastructure set up to help communication flow more smoothly. The county has access to GIS tools, but nothing has been implemented to allow efficient use of it during emergencies. By creating the communication map, the county can have one spatial environment to look at and see all their state highways and county roads, cell towers, radio towers, and locations of fire stations throughout the county. This will allow them to pinpoint areas of emergency and respond quicker and more efficiently. Having all this information in one place, saves time during an emergency. Responders will not have to search and wait for this information to be passed along to them. This information is digital and they will not have to deal with finding the right paper map. This not only cuts down on time, but space as well, and allows more area to be searched in further detail.

Another issue during the wildfire was the limited access to roads west of Medicine Lodge. Due to the canyons and gorges, roads may go on for miles before coming to a cross section. Using ArcMap and the Network Analyst tool allows for the quickest routes to be mapped. Once Barber County has a database of the roads, they can locate the area of emergency and determine the fastest route from nearest station in the county. As shown in Figure 5, the quickest route begins in the town of Medicine Lodge and ends in the middle of land away from the road. The City Fire Department and Barber County Rural Fire Station One are located in Medicine Lodge. It also shows the route taking a county road, which then turns into a dirt road. The roads might still limit the responders, but having the information from the communication map will help them cut down on response time by knowing what type of topography lies ahead of them and what type of vehicles can make it into the area. This way they can know whose land they will have to enter and if they will face inaccessible land due to the topography.

Analyzing the land and assessing how susceptible the grass is to wildfire through remote sensing techniques in order to prepare for the next wildfire was done by calculating the NDVI of the study area to show the greenness level of the vegetation. The calculation for this study was derived from the Landsat images during the month of February 2016, March 2017, July 2016 and July 2017. This shows the greenness level during the month prior to the fire, February 2016, and then again one year later for March of 2017. Maps were also made to show the NDVI of the study area in the months of July 2016, the summer after the fire, and July 2017, the summer a year after the fire. The month of July had to be used instead of an earlier month due to the Landsat images having too much cloud cover to assess the land. Since the NDVI measures greenness level of the grass, the February and March calculations do not show a high level of greenness, except for the crop land in the area. The low reflectivity shown in the spring NDVI relates to the cured grassland, which puts the grass at a fire risk. The July calculations, however, show more areas of darker green indicating a higher greenness level. Which when compared to the spring months, when the grass is senesced, the greenness reflectivity would be much lower than the summer months when the grass is actually green and actively growing. Next, an overlay comparison of the seasons was created to determine if the area of fire damage was recognizable through the NDVI. The first overlay for the spring NDVI of February 2016 to March 2017 showed a significant change in the landscape, proving that the NDVI and overlay analysis picked up where the fire had gone through and changed the vegetation in that area. This area had large amount of fire fuel built up over the years, including red wood cedar trees that have invaded the area. The difference between the 2016 and 2017 spring maps show how the use of fire can change the landscape. Using prescribed burns, would allow a controlled environment for this natural process of clearing the area to take place, and help avoid a wildfire. The July 2016 and July 2017 NDVI comparison overlay did not show much change between the two years. This observation is because the vegetation had grown back in by this time and the difference was not as noticeable. Fire is beneficial in the natural process of grass growth. When the wildfire went through, it allowed for the overgrowth to be burned off, creating better opportunity for native grasses to grow back as healthier vegetation and also removed much of the detrimental eastern red cedars. The greenness shown in the NDVI maps represents that. Using these methods can help monitor fuel load and indicate where prescribe burns should be conducted for many of these areas and help prevent major fire outbreaks from occurring.

An Unmanned Aerial System was used in order to capture imagery of a controlled burn to show how having a perspective from the air can help monitor the head of the fire line. The images taken from the UAS show the initial ignition of the controlled burn, a clear visual of the head of the fire, fire head merging together as well as a spot fire. The UAS also captured the fire head even through thick smoke, and was still able to monitor the direction it was moving. These images were taken of a controlled burn to allow for a controlled and safe environment. This shows how beneficial the use of an UAS during a wildfire outbreak could be by having a visual from above to see the direction the fire head is moving. After the burn had finished, the UAS was able to capture imagery of the burned area. This could be useful for going back in after a fire had gone through and determining the burn scar and damage done.

Another application of the UAS was to capture the greenness level and topography of the study area. Images were taken in September of 2019 and then again in March of 2020 to compare the greenness level of the seasons. In September, the grassland is green and alive. Come March, the grassland has cured and turned brown. The images show the comparison of how the grass transitions from the fall into the winter months as it dies. Come spring, before the grass begins to green back up, it is still very fry and very fire prone. The images help show how high risk the grass is to burning during the spring months as fire season approaches. The images also capture the topography in the area, hills and canyons that the fire would have gone through. From ground level, it would be very difficult to see how the fire was moving, especially once it went down into the draws, but having an UAS in the air could show the responders exactly where the fire front is and how it is moving through the grassland.

By creating a database for Barber County, this allows responders and officials to have one spatial environment to locate infrastructure within the county and determine network analysis responses in regards to an emergency. The analysis of using NDVI to show areas of different reflectively levels, provides insight where potential over growth has occurred, or where areas of cured grassland can be found, and can be reduced through mitigation efforts, such as controlled burning. This project used the overlay comparison to determine if fire damage was visible between the years of 2016 and 2017, this aspect can show where the changes between the years, or seasons have occurred. An UAS can be beneficial in multiple ways during a fire outbreak. First, having a UAS in the air during a fire can show different visuals for how the fire head is moving that would be hard to detect from ground level. It is able to detect the fire head through smoke to help keep a visual. In the area of Barber County, it would allow for the responders to see the topography they are up against and be able to determine how it is moving through the canyons and hills in the area. Secondly, after the fire has gone through, the UAS can be used to fly over the damaged area, and get footage of exactly where the fire had gone, and determine exactly what was damaged. Lastly, the UAS can be used to monitor areas in the county for vegetation growth. This project took images during the month of September, where the grass was still green, and compared them to the same area during the month of March where the grass was dead from the winter and at high risk for fire.

Being able to assess the land using a UAS can cut down on time when determining which areas are at risk, while also giving a large visual of the land being analyzed.

This research is solely based on Barber County, Kansas. However, if funds and resources are made available, it could be utilized for any county. As the population throughout the United States grows and as humans encroach into grassier and more forested areas, the risk of these disastrous fires occurring increases. Instead of waiting until the unthinkable happens and using resources to fight the fire or disaster, funds could be used towards preventative techniques and measures. But knowledge of what topography and infrastructure lies within the county must be known. This research has successfully put together a basic infrastructure system and laid out the details of how counties could use mitigation efforts to help prepare and respond to an emergency such as a wildfire.

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