4-29-2013

# Using Geographic Information Systems to Select Suitable Columbian Sharp-Tailed Grouse Habitat in Northern Idaho

Jennifer Grew
*University of Denver*



DOI
https://doi.org/10.56902/ETDCRP.2013.11

# Using Geographic Information Systems to Select Suitable Columbian Sharp-Tailed Grouse Habitat in Northern Idaho


## Abstract

The Columbian sharp-tailed grouse was once the most abundant game bird in the Inland Northwest area. The main reason for their loss was the conversion of their habitat into agricultural lands and timber forests. Several variables were incorporated into a weighted sum tool in ArcGIS using public raster layers for each of three seasons. The results layers were analyzed using the same tool to find the most suitable habitat. Six locations in the county had 50% or better suitability. One location showed 80% or better. The grouse historic range appears to coincide with Palouse prairielands in Benewah County. Further research should be conducted to fine tune the weights of the variables and more refined data layers would yield better results.



## Document Type

Masters Capstone Project

## Degree Name

M.S. in Geographic Information Science

## Department

Geography

## Keywords

Columbian sharp-tailed grouse, Conversion of habitat, Agricultural lands, Timber forests, ArcGIS

## Subject Categories

Geographic Information Sciences | Geography | Physical and Environmental Geography | Social and Behavioral Sciences

# Using Geographic Information Systems to Select Suitable Columbian Sharp-Tailed Grouse Habitat in Northern Idaho

Jennifer Grew

University of Denver Department of Geography

Capstone Project

for

Master of Science in Geographic Information Science

April 29, 2013

## ABSTRACT

The Columbian sharp-tailed grouse was once the most abundant game bird in the Inland Northwest area. The main reason for their loss was the conversion of their habitat into agricultural lands and timber forests. Several variables were incorporated into a weighted sum tool in ArcGIS using public raster layers for each of three seasons. The results layers were analyzed using the same tool to find the most suitable habitat. Six locations in the county had 50% or better suitability. One location showed 80% or better. The grouse historic range appears to coincide with Palouse prairielands in Benewah County. Further research should be conducted to fine tune the weights of the variables and more refined data layers would yield better results.

## TABLE OF CONTENTS

**INTRODUCTION**

The Columbian sharp-tailed grouse was once the most abundant game bird in the Inland Northwest area (Stinson and Schroeder, 2010). Their range once covered as far north as Southern British Columbia down south through Northeastern California and east to the states of Colorado and Utah. (Figure 1)

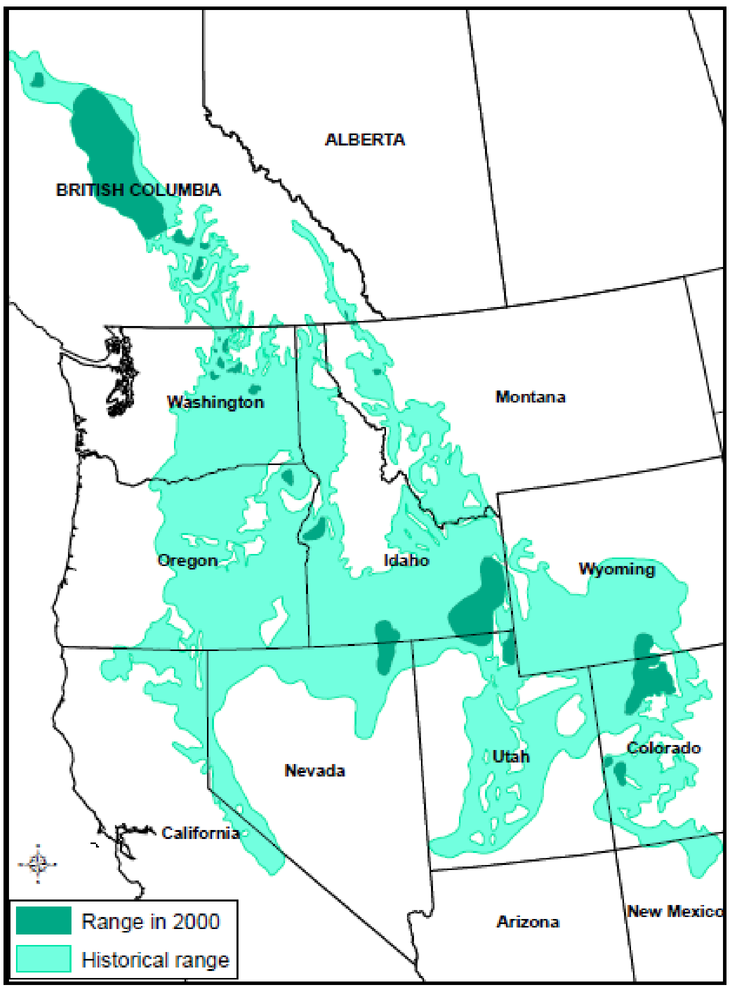



Figure 1. Historical and current range of the Columbian sharp-tailed grouse.

The main reason for the loss of this subspecies of grouse has been the conversion of their habitat into agricultural lands and cattle rangelands (Green, 2002) (Giesen, Connelly, 1993). By the 1920's most of the Columbian sharp-tailed grouse were gone. The hunting season for them was closed from 1933-1953. The season was re-opened from 1954-1987. When numbers still fell despite a shorter hunting season, it was closed again. (Stinson and Schroeder, 2010)

114 leks that were studied from 1960-2006 show 82 or 71.9% abandonment rates. 33(40.2%) of those leks are on land now vacated by the grouse and 49 leks that were abandoned are within areas that they still live in, but are thought to be empty due to low population. As a result, sharp-tailed grouse were added to the state of Washington Threatened species list in 1998.

The Columbian sharp-tailed grouse historic range used to include lands within the Coeur d'Alene Tribe Reservation though now "…sharp-tailed grouse are not present at detectable levels on the Reservation" (Vitale et al. 2002). This species is considered environmentally and culturally significant to the Coeur d'Alene tribe and there are currently management plans and habitat suitability model projects in progress to bring the sharp-tailed grouse back to the Tribe.

Historically, "…the tribe was forced to convert prime riparian habitat into agricultural lands to supply sustenance for their changed needs." (Green, 2002) The aboriginal territory of the Coeur d'Alene Tribe encompassed approximately five million acres originally. By the turn of the 20$^{th}$ century, it had been reduced by the federal government to just 345,000 acres. (Figure 2)(Coeur d'Alene Tribe, 2011) "Wildlife habitats within the portion of the Hangman Creek Watershed that lies within the Coeur d'Alene Indian Reservation have been degraded from a century of land management practices that include widespread conversion of native habitats to agricultural production and intensive silvicultural practices." (Green, 2002)

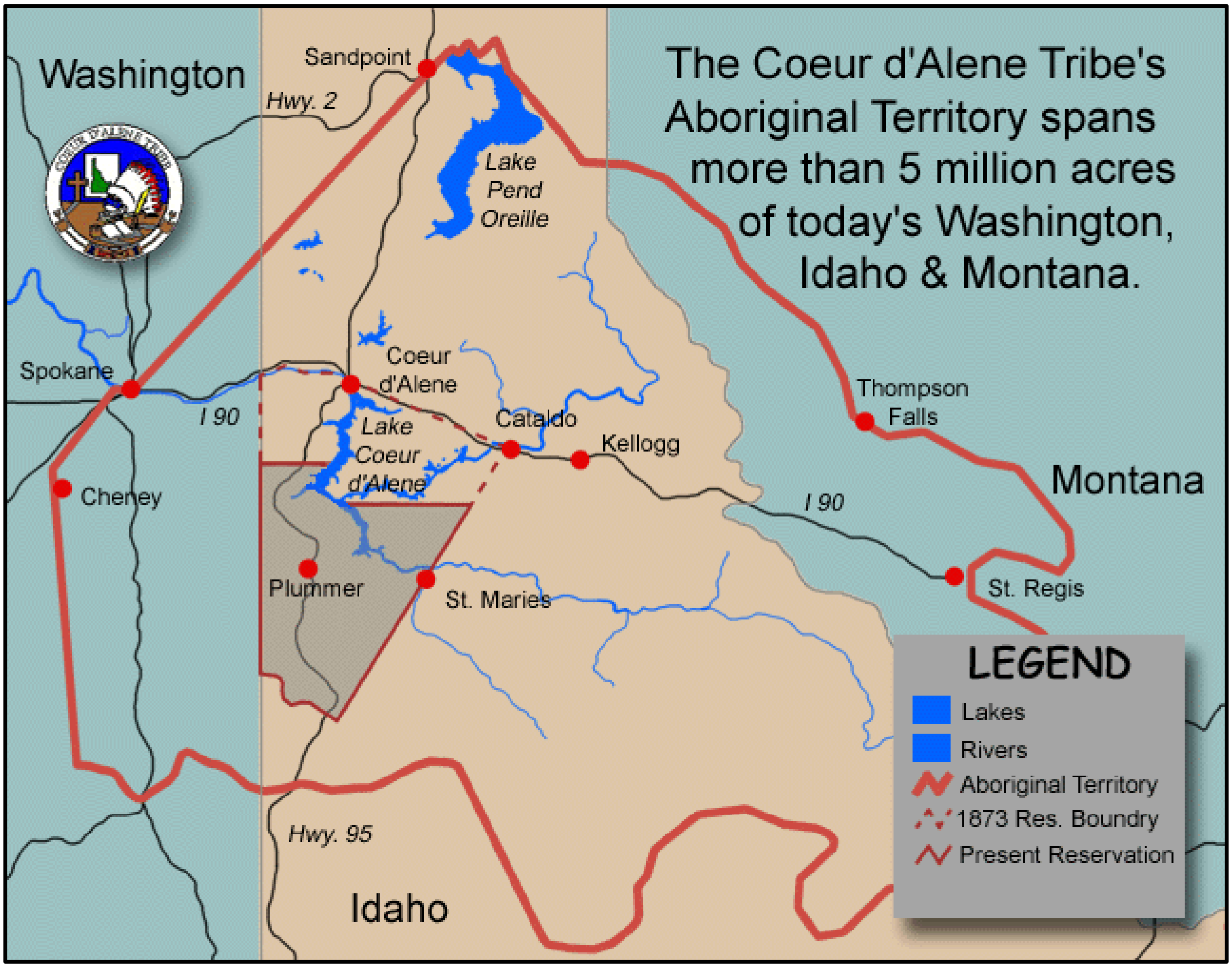



Figure 2: A map of the coeur d'Alene Tribe Reservation boundary over time. (http://www.cdatribensn.gov/LakeMngmt/lakeimgs/mapsm.gif)

The Coeur d'Alene tribe is currently overseeing a restoration effort of several watersheds on the reservation including Hangman Creek Watershed by restoring landscapes instead of catering to any one species. They believe that "By focusing restoration efforts at a macrohabitat level, restoration efforts target all native species inhabiting that area. This approach marks a paradigm shift that emphasizes ecological based restoration rather than species-specific restoration" (Vitale et al. 2002).

Other tribal entities, most notable the Colville Confederated Tribes are in the process or have already relocated sharp-tailed grouse to their historic ranges. In Washington State, the majority of the 712 bird breeding population is located on the Colville reservation (Stinson and Schroeder, 2010).

Tribal reservations offer a unique opportunity for habitat restoration and species reintroduction since large areas of land are still available to work with by local tribal entities. The Coeur d'Alene Tribe Natural Resources Department has been developing a habitat suitability model to use on the reservation leveraging Geographic Information systems (GIS) technology to map out areas that would best suit sharp-tailed grouse nesting habits. With these areas Identified, the next phase of habitat selection can commence before reintroduction is attempted.

**THESIS STATEMENT**

Columbian Sharp-tailed Grouse require different multi-successional habitats throughout the year that will support their life cycle habits. Vegetation is a main contributing factor to their habitat selection and retention. GIS can be used to select likely areas for relocation of Sharp-tailed grouse; however, micro climate level mitigation is required to maximize the chances of establishing a viable population.

## LITERATURE REVIEW

Sharp-tailed grouse belong to the order (Galliforms) and family (Phasianidae) or pheasant like birds. They belong to the sub family Tetraoninae (grouse) originally described as Tetrao Phasianellus in 1758 by Linnaeus but later put into the monotypic genus Pedioecetes. Still later, they were synonymized to Tympanuchus after taxonomists recognized their similarities with prairie chickens. (Stinson and Schroeder, 2010)

The sharp-tailed grouse shares a common forest dwelling ancestor with sage grouse, ptarmigan, and prairie chickens. Their closest genetic relatives are prairie chickens. The two species probably separated during the late Pleistocene. They lack the longer neck of the prairie chicken but share similarly long central tail feathers. Sharp-tailed grouse males also have similar air sacks as the male prairie chicken with a notable difference in color. Sharp-tailed grouse males have pink to violet air sacks while prairie chicken males exhibit yellow to orange air sacks. (Figure 3)(Stinson and Schroeder, 2010)

(Figure 3): Sharp-tailed grouse to the left, Greater Prairie Chicken to the right. Note the differences in the air sacs and tails.

Inter-breeding between sharp-tailed grouse, Sage Grouse, and Prairie Chickens has been recorded but is rare. It has been debated whether or not this is occurring more frequently with the supposed cause being depleted populations in both species. (Cameron et al., 2001) (Stinson and Schroeder, 2010)

While sharp-tailed grouse are generally thought of as one species, there are in fact seven known sub species that have been recorded.

- **Northern Sharp-tailed grouse** are found in Manitoba, northern Ontario, and central Quebec.
- **Northwestern Sharp-tailed grouse** are residents of the Mackenzie River to the Great Slave Lake in the Northwest Territories, Canada.
- **Alaska Sharp-tailed grouse** inhabit north-central Alaska eastwards to the southern Yukon, northern British Columbia, and northern Alberta.

- **Columbian Sharp-tailed grouse** can be found in isolated pockets of native sagebrush and bunchgrass plains of Idaho, Washington, Wyoming, Colorado, Utah, and British Columbia.
- **Prairie Sharp-tailed grouse** lives in Saskatchewan, southeastern Manitoba, southwestern Ontario, and the Upper Peninsula of Michigan to northern Minnesota and northern Wisconsin.
- **Plains Sharp-tailed grouse** make their home in the northern Great Plains in southern Alberta and Saskatchewan, eastern Montana, North and South Dakota, Nebraska, and northeastern Wyoming.
- **New Mexico Sharp-tailed grouse** are extinct. (Hoffman and Thomas, 2007)

The subspecies that would best fit our plans of relocation is the Columbian sharp-tailed grouse. The Coeur d'Alene Tribe Reservation covers part of its historic range and contains many of the historic food supplies necessary for it to survive all year round. (Vitale et al. 2002) The historic range appears to coincide with Palouse prairielands of which the Coeur d'Alene Reservation had several thousand acres of before it was converted into agricultural lands. (Green, 2002)(Vitale et al., 2002)

There are currently several small populations of Columbian sharp-tailed grouse located in the state of Idaho. They are in the southern part of the state with one being in the south eastern Pocatello area and the other is to the west of the state north of Boise. (Figure 4) The population near

Figure4. Current Columbian sharp-tailed grouse distribution in Idaho (Marks and Marks, 1988).

Pocatello is one of only two populations of sharp-tailed grouse still legally hunted in the United States. This is a testament to its robustness and size. Examples will be taken from this population to aid the Coeur d'Alene tribe in its translocation efforts including selection of habitat size, vegetation, elevation, and slope.

Sharp-tailed grouse have many particular habitat needs. The most striking need is for several very different habitats for different seasons throughout the year. They are very difficult to translocation to an area once they have been extirpated because of the variety of habitats that must be present to keep them alive and procreating.

They are also notoriously difficult to plan translocations for because for every study that you find looking at what habitat is best for them, you find a different answer for different regions from different years. The following are different conclusions from several peer reviewed articles.

"Historically, the most important areas for sharp-tailed grouse were probably the Palouse, Wheatgrass/Fescue, Three-tip Sagebrush, and Big Sage/Fescue vegetation zones. The highest densities of sharp-tailed grouse were probably in the more mesic grassland and steppe types where annual precipitation averages at least 11 inches." (Stinson and Schroeder, 2010)

"Land area on which a sharp-tailed grouse population is to be managed should be comprised of at least 24ha of grassland and shrub within 1.6km (1.0mi) radius in order to attract breeding males." (Gylywoychuk, 1993)

"Maintenance of important habitat types like native shrub-steppe communities in advanced seral stages is especially important for conservation of Columbian sharp-tailed grouse habitat in the intermountain region. (Saab and Marks, 1992)

All of these conclusions may be correct for their particular area, but overall it appears that these birds require a separate set of habitat for the different seasons of the year starting with early successional habitat, through mid-successional grasses and shrubs to forested riparian habitat.

***Guideline 1: Space Use***

Sharp-tailed grouse begin the year by returning to the lek where they "…engage in ritualistic, communal breeding displays on relatively open areas within breeding habitat. These display areas are known as leks, or in the case of sharp-tailed grouse, dancing grounds." (Connelly, 2010) While studies vary, Giesen and Connelly, (1993) noted a study area of about 2000m. They concluded that the area extending out from a known lek to a minimum of 2,000m radius should be considered the breeding complex. This includes the lek, nesting areas and brood rearing areas. Sharp-tailed grouse will travel up to 2.6km in the winter time for their foraging needs as well. They will travel throughout an average roughly 2.0-4.6km areas throughout the year.

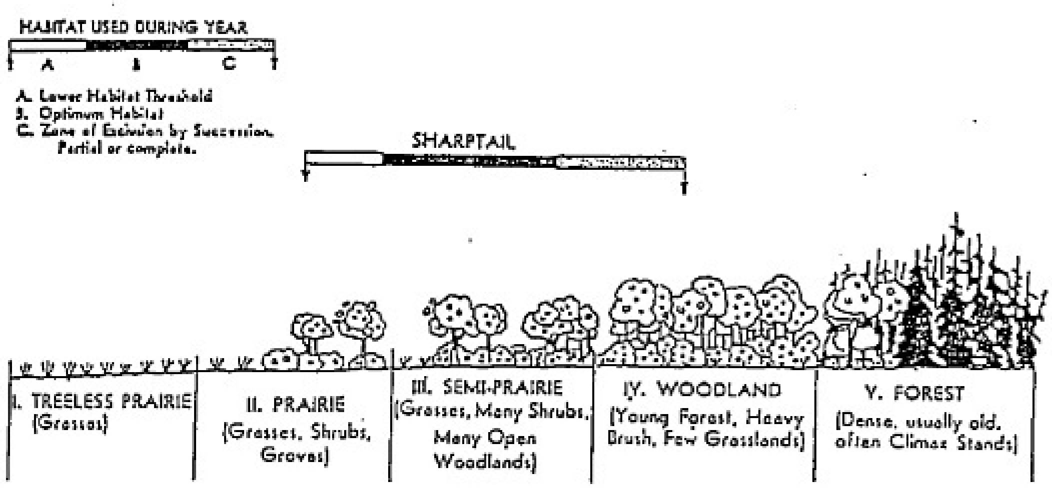



Figure 5. A schematic representation of prairie sharp-tailed grouse tolerance to different community types (Berg et al. 1987).

(Figure 5): shows an image referenced from (Gylywoychuk, 1993) who references (Berg et al. 1987) whose paper I could not attain. The image shows the ideal ranges of sharp-tailed grouse throughout three yearly preferences. It is worth noting here that conifers do not fall into any of the preferred ranges even though open woodlands do.

In all likelihood, the size of area will depend, at least in part, on productivity of the soil, vegetation communities involved, and topography. Meints et al. (1992) suggested that the minimum area necessary for successful reintroductions was 30 km2 (11.5 miles2) and that about 33% of this should be undisturbed grass/shrub habitat while the remainder can be composed of pasture, cropland and grazed uplands. (Connelly, 2010)

***Guideline 2: Spring Habitat***

Characteristics of Columbian sharp-tailed grouse leks often have been studied because they are important for mate selection and breeding, and typically are adjacent to nesting and brood-rearing areas. (Connelly, 1993) This is where first the males and then the females congregate starting in early April and climbing in attendance until early May when lekking reaches its peak. It then drops off and is finished by the end of May. (Gylywoychuk, 1993) The lek is host to the males dance for the right to mate with the females. There are several factors that make a good lek.

A lek is an open area usually found on a grassy knoll or ridge. It is sparsely vegetated and offers good visibility. “Visibility is one factor that could contribute to lek site abandonment.” (Gylywoychuk, 1993) They are usually located 0.8-4.0km apart from each other and usually have less than 1% slope with flat undulating topography.

The actual lek size usually is about 30-50m across but can be as large as 0.4ha in size. They are usually located on the highest land at least 183-270m from woody vegetation over 4ft tall. However, there must be taller vegetation around 400m away for females to perch in, and cover from predators within 500m to hide in. (Stinson and Schroeder, 2010) (Gylywoychuk, 1993)

Too little vegetation can be an obstacle as well. Marshal and Jenson (1937) reported that sharp-tailed grouse abandoned a large (25 male) lek site the year following a fire that removed most of the vegetation…" It was also found by Giesen and Connelly (1993) that Columbian sharp-tailed grouse are more adaptable when it comes to their lek. They will dance in areas that are far shrubbier than other sharp-tailed grouse populations and seem to require some shrub vegetation 20-30% visual obstruction to evade predators. There are even observations of some males displaying in the branches of shrubs on the lek.

It should be noted that in southeastern Idaho and Washington State, USDA Conservation Reserve Program (CRP) lands seem to be highly preferred by sharp-tailed grouse in early spring and summer, probably due to high levels of alfalfa in the seeding mixture. (Giesen and Connelly, 1993)(Edgley, 2001) (Stinson and Schroeder, 2010)

***Guideline 3: Summer and Fall Habitat***

Nest sites are dispersed in appropriate habitats adjacent to leks but do not appear to be concentrated in relation to distance from the lek, that is, females neither avoid nor attempt to nest close to leks (Connelly et al. 1998) In Idaho, Columbian sharp-tailed grouse broods generally remained within about 1 km (0.8 miles) of nest sites (Meints 1991). Roersma (2001) considers a 1:1:1 ratio of cover in shrubs, grasses, and forbs to be idea. Sharp-tailed grouse make their nests mostly out of residual vegetation. This includes shrubs, grasses, or forbs that died at the end of last year and were flattened down by the snow during winter. These tangled messes of dead vegetation make for perfect cover. Optimal nesting has residual grass at least 25cm high. Habitat where grass detritus is less than 15cm tall may still be suitable as long as there are many micro sites of grasses >25cm. (Meints et al. 1992) (McDonald, 1998)

Nests are usually found under shrub with overhead cover or within a few feet of it. The nests are located near sources of seeds, berries, buds, or catkins as the mother will not stray far from her nest to feed. They will choose areas with moderately open over-story but dense understory of dead grasses. (Gylywoychuk, 1993) They prefer areas dominated by Western snowberry and can tolerate areas that have had grazing activity as long as obstruction of visibility of the nest is maintained. (Kirby and Grosz, 1995) Shrub density for Columbian sharp-tailed grouse can be higher for nesting areas as well as for their leks. Shrub densities found in nesting areas of the

Columbian sharp-tailed grouse have been found at 11,000 shrubs per ha compared to 5,000 shrubs per ha for other subspecies. (Giesen and Connelly, 1993) In areas of agriculture where grouse nested in alfalfa or wheat stubble fields, their nest mortality was 53% and 82% respectively, but only 30% on rangeland. These agricultural mortalities are probably due to spring field burnings commonly practiced in several western states. (Giesen and Connelly, 1993) It is also noteworthy to say that many fields on the Coeur d'Alene tribe reservation receive this treatment in fall or spring and should be taken into consideration.

Once chicks hatch, they will stay close to the nesting site. At this life stage, shrubs, forbs, and insects dominate the grouse's diet. "Shrubs seem to be a far more important part of brood habitat than trees and this seems to be related to food availability. (Hammerstrom, 1963) Sharp-tailed grouse will consume mainly insects and forbs during the summer and will eat agricultural grasses if available, especially wheat. "Forbs support a more varied insect fauna than grasses and provide shade and water. (Berger 1989)

***Guideline 4: Winter Habitat***

They must have shelter and food in winter. One of the most critical times for sharp-tailed grouse survival is winter. This is where many habitat restoration projects run up on problems. In the fall and winter sharp-tailed grouse move to riparian areas where there is still green vegetation, berries, and shade. (Stinson and Schroeder, 2010) (Marks and Saab, 1988) (Evans and Donald, 1974)

For Columbian sharp-tailed grouse, critical wintering habitat is riparian deciduous shrubs and trees. These areas provide cover, berries, seeds, buds, and catkins for winter forage. Service berry, Chokecherry, water birch, roses, hawthorn, silver buffalo berry, snowberry, thistle, big sagebrush, cottonwood, and aspen area all good sources of winter forage for sharp-tailed grouse (Marks and Saab, 1988). The primary food sources noted in Marks and Saab (1988) and Evans and Donald (1974) were Silver buffalo berry, Hawthorn berry, and serviceberry. The grouse will eat these in large quantity all winter whether frozen, dried, or otherwise. While Hawthorn does not have high protein content, the amount of berries consumed by the sharp-tailed grouse allowed them to not only keep on weight, but even gain weight in some instances. (Evans and Donald, 1974)

***Guideline 5: Multiple Successions***

Multiple habitat succession stages should be made available. Gylywoychuk (2003) suggests that multiple succession stages should be present in order to maintain a healthy sharp-tailed grouse population. This agrees with other studies that require sharp-tailed grouse have early succession grasslands for leks, later stage grasslands and shrub for nesting, and riparian shrubby woody habitat for wintering in.

Disturbed areas on the reservation, such as grasslands, resulting from logging and mining could work as long as they have a clear area for leks and riparian habitat nearby for wintering in. (Gylywoychuk, 1993)

## DESIGN AND IMPLIMENTATION

### *Data Acquisition*

I acquired free data layers from several sources found online. Due to arising permissions issues that could have hampered efforts of this project, I removed any data I had licensed from the Coeur d'Alene Tribe in lieu of more publically available sources.

I acquired a 30 x 30m DEM, existing vegetation Type layer, existing vegetation height layer, and existing vegetation cover layer from the LandFire Data Access web mapping application. These four layers form the basis of the different analysis due to grouse selection of habitat relies almost entirely on the vegetation type available, slope, and elevation.

I acquired Soil survey layers from U.S Department of Agriculture's Natural Resources Conservation Service SoilMart site. The survey came in three different regional layers for Benewah County, and had to be merged. They interact directly with an access database and require some instruction to set up. The database generated a soils report of all hydric soils. According to (Hanowski, J. M. et al., 2000), grouse were observed in higher numbers at leks in or near peat bogs, and other hydric soiled areas.

Structure and roads layers were acquired from the Inside Idaho site run through the University of Idaho. Structures have a negative impact on grouse, and roads help the general public locate areas in the study area. There was no literature seen that directly noted road kills and being a major factor for grouse survivability.

***Data manipulation for the tool***

All raster data layers were standardized to 30 x 30m cell sizes and UTM NAD83 Zone 11N projection. Each layer was given a new field for each of the studies it would be added to for weight designations. These fields are short integer and named Lek, Nest, or Winter for each of the different studies. The overall results layers were weighted as 0-49% suitability was given a 0, 50% to 82% was given a 1, and 83%+ was given a 2. They were then run through the weighted sum tool again to see where the best overall area was with an overall final range of 0 to 6.

All layers were trimmed to the Benewah county border by using the Clip (Data Management) tool. The counties polygon layer was used as the input feature and the Use Input Features for Clipping Geometry (Optional) was selected.

***Spring tool***

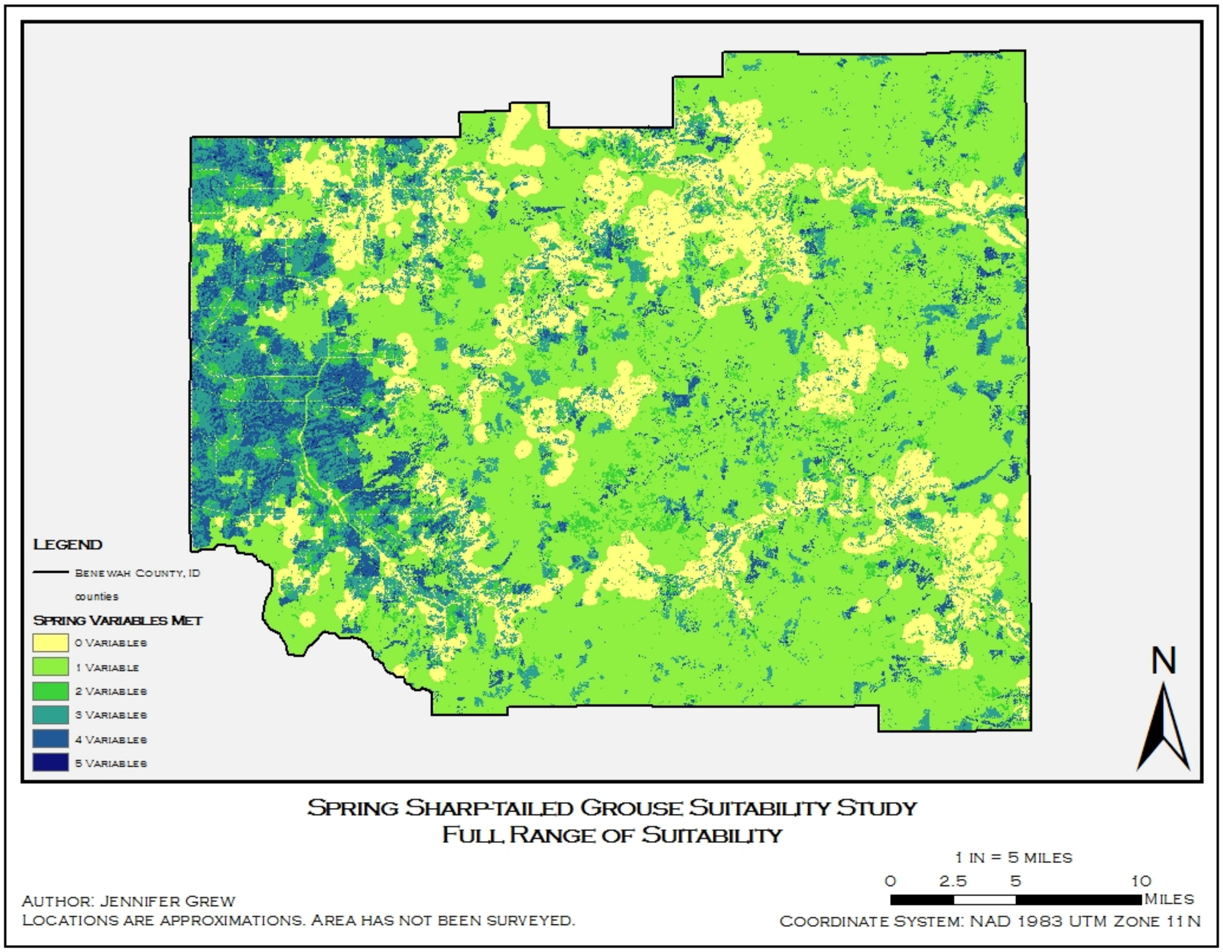
I incorporated the vegetation type, height, and cover, elevation, and slope layers together in the weighted sums tool in order to ascertain the proper locations that would serve as suitable lekking grounds. Gylywoychuk, (1993) suggests that lek sites smaller than 30-50m in diameter (47.12 – 74.50m$^2$) are not suitable, and that leks larger than 3-9ha (1ha = 10,000m$^2$) are prone to abandonment by the grouse and cost substantially more to build and maintain. Due to cell size of the DEM being 30x30m, the smallest resolution for analysis would be 900m$^2$ or 0.09ha. Therefore, the lek size was limited to 0.09 – 3ha. Sites that were larger were noted for future consideration of restoring surround areas to suitable nesting habitat.

The elevation layer was run through the slope tool with the percent rise option selected, and then run through the INT tool in order to divide it by 1.0% slope. All cells above 1.0% were given a designation of 0, and all cells below were given a designation of 1. In Manitoba, (Baydack, 1988) and (Berger, 1989) maintained that leks were generally elevated (less than 1% slope) with a flat to undulating surrounding topology. (Gylywoychuk, 1993)

This was accomplished by running the slope layer through the integer tool and then adding a new field that weighed slopes of 0-1% as a 1 and anything else as a 0. The raster was then converted to a polygon and back to a raster using the weight field to create a smaller more manageable layer. They vector layer also allowed for isolation of suitable locations by the above mentioned hectare limits. This was done using a new field called Hectares that I designated as a double data type to see the smaller decimals of 0.09ha up to 30000.00ha. Projections altered the number of decimal places;

therefore, the local UTM NAD83 Zone11N was used. Any hectare value outside of the above mentioned limit had its gridcode value changed to a 0 from 1. This filtered vector layer was then converted back to a raster for the weighted sum tool.

The vegetation layer was split between low early successional and all other vegetation types, with grasslands and forbs being designated as a 1, and all other land being designated as a 0. The vegetation height layer was separated out by grasslands and shrubs less than 0.5m high. These were given the designation of 1 while anything higher, or considered developed was given a 0. The vegetation cover layer was separated out as anything that was developed, forested, open water, snow/ice, or more than 20% shrub was designated as a 0. All grassland cover, and up to 20% shrub cover were designated as a 1. Structures were regarded as the only negative weight for all three analyses. The structures were buffered to 500m to account for grouse disliking being within range of people. The area around homes carries a weight of 0 while all other areas carry a weight of 1.



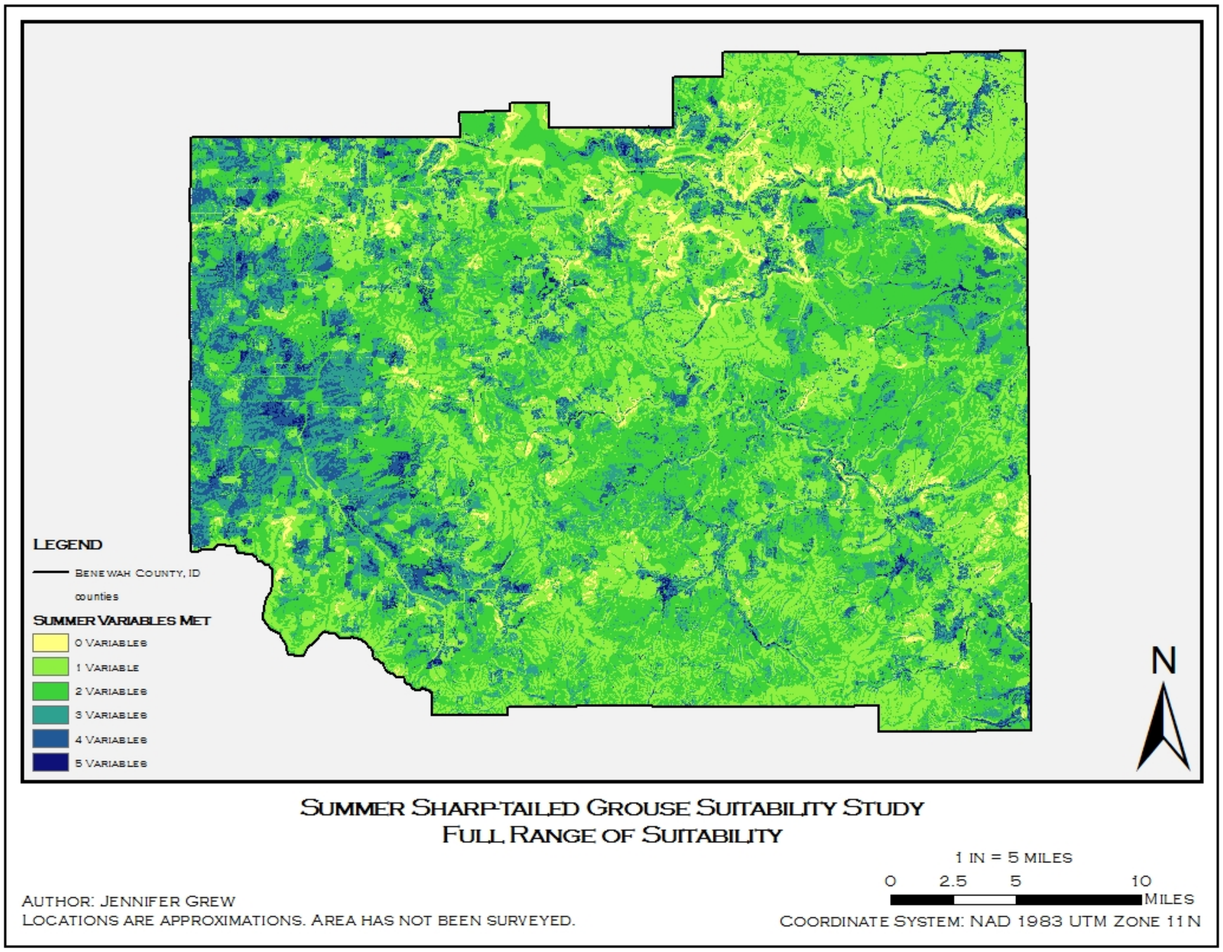

(Figure 6): Results of Spring Weighted Sum tool for the five above mentioned variables.

***Summer tool***

The elevation layer was run through the slope tool with the percent rise option selected, and then run through the INT tool in order to divide it by 30.0% slope. All cells above 30.0% were given a designation of 0, and all cells below were given a designation of 1. Marks and Marks (1988) concluded that >95% of sharptail home range use is on slopes <30%.

The vegetation layer was split between all grasslands, forbs, and shrub lands being designated as a 1, and all other land being designated as a 0. Croplands were included in this category because of their potential as nesting ground if burning can be restricted in these areas with plowing as an alternative. Apparently sharptails were able to nest successfully in stubble fields until burning became a common practice to eliminate heavy stubble which would clog up large gang plows pulled by caterpillars. (Yocom, 1952)

The vegetation height layer was separated out by grasslands greater than 0.5m high, and all shrub lands. These were given the designation of 1 while any lands were given a 0. The vegetation cover layer was separated out as all grassland cover, all shrub cover, and open deciduous forest were designated as a 1. Anything that was developed, closed canopy forested, open water, barren, or snow/ice, was designated as a 0. Structures were regarded as the only negative weight for all three analyses. The structures were buffered to 500m to account for grouse disliking being within range of people. The area around homes carries a weight of 0 while all other areas carry a weight of 1.



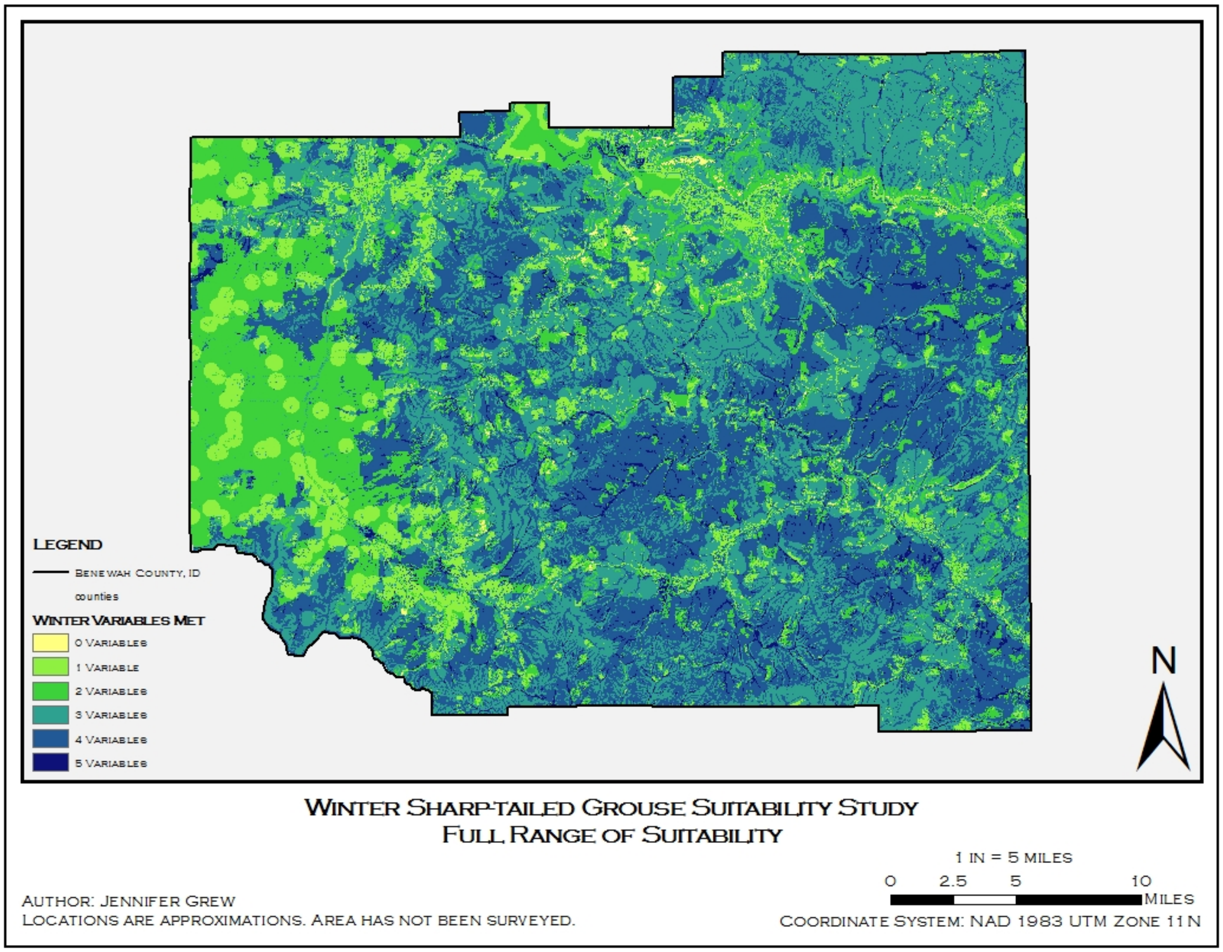

(Figure 7): Results of Summer Weighted Sum tool for the five above mentioned variables.

***Winter tool***

The elevation layer was run through the slope tool with the percent rise option selected, and then run through the INT tool in order to divide it by 30.0% slope. All cells above 30.0% were given a designation of 0, and all cells below were given a designation of 1. Marks and Marks (1988) concluded that >95% of sharptail home range use is on slopes <30%.

The vegetation layer was split between all grasslands, forbs, and shrub lands being designated as a 1, and all other land being designated as a 0. Croplands were included in this category because of their potential as nesting ground if burning can be restricted in these areas with plowing as an alternative. Apparently sharptails were able to nest successfully in stubble fields until burning became a common practice to eliminate heavy stubble which would clog up large gang plows pulled by caterpillars. (Yocom, 1952)

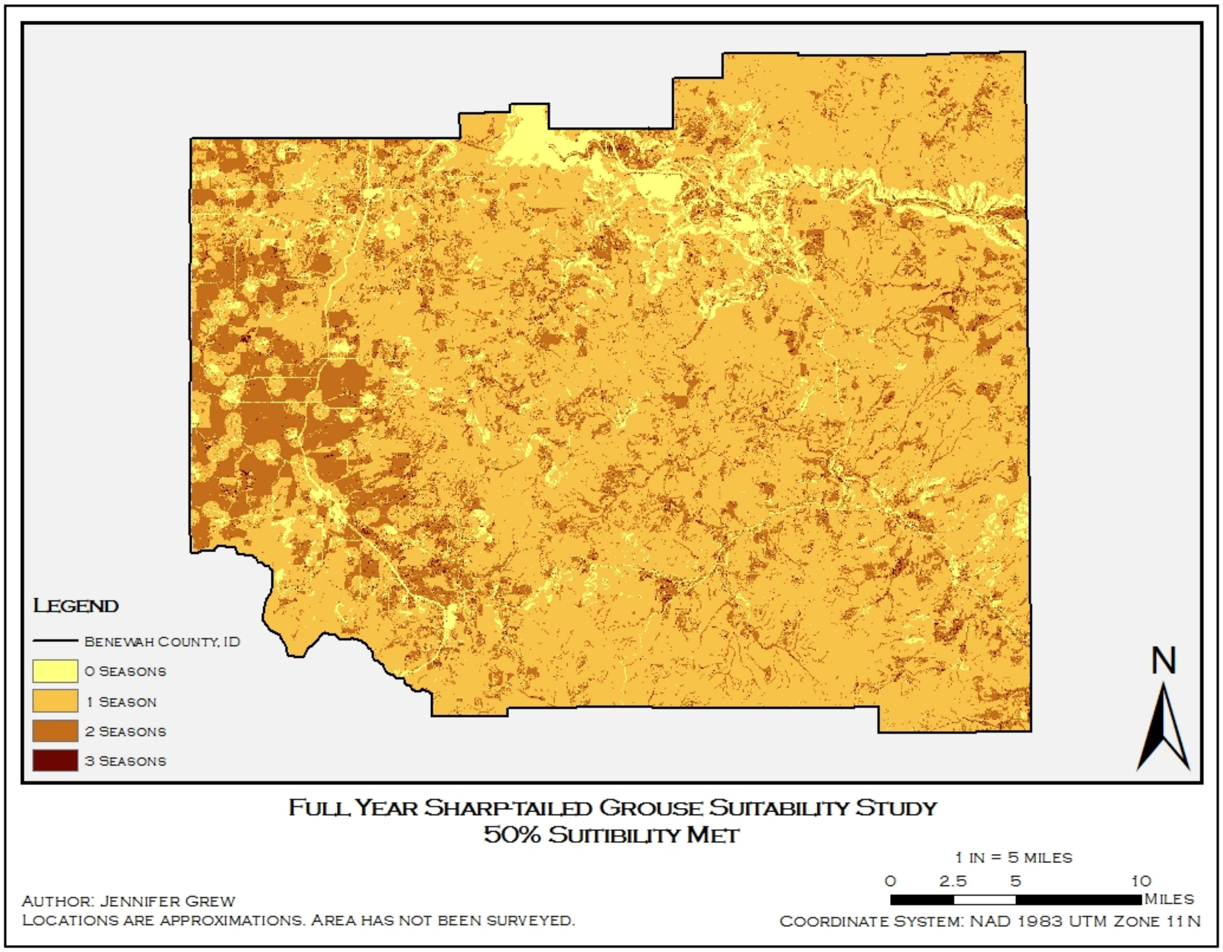
The vegetation height layer was separated out by grasslands greater than 1m high, all forest heights (evergreen versus deciduous was not available in the data set), and all shrub lands. These were given the designation of 1 while any other lands were given a 0. The vegetation cover layer was separated out as all shrub cover, and all forest cover (evergreen versus deciduous was not available in the data set) were designated as a 1. Anything that was developed, open water, barren, grassland, or snow/ice, was designated as a 0. Structures were regarded as the only negative weight for all three analyses. The structures were buffered to 500m to account for grouse disliking being within range of people. The area around homes carries a weight of 0 while all other areas carry a weight of 1.



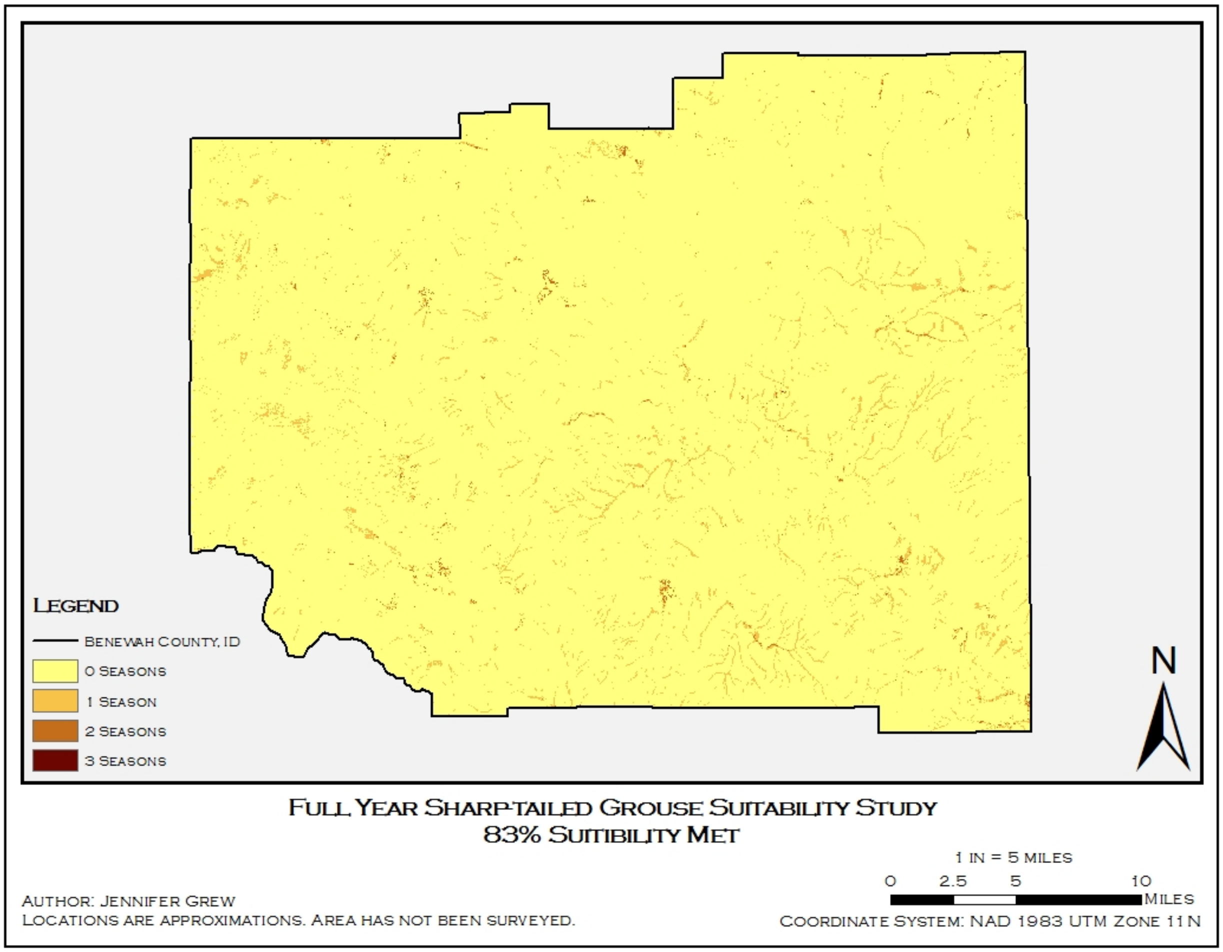

(Figure 8): Results of Winter Weighted Sum tool for the five above mentioned variables.

***Year tool***

The spring results layer, summer results layer, and winter results layer were given a weight field. 0-49% suitability (values 0-2) was weighed as 0, and 50% suitability and above (values 3-5) was weighed as 1. These three layers were then entered into the weighed sum tool via their weight field and the resulting layer had a potential suitability value of 0-3 for 50% suitability of all seasons (Figure 6). The same was done for 83% suitability of all seasons by giving perfect values of 5 from each season a weight of 1, and values 0-4 were given a weight of 0 (Figure 7).



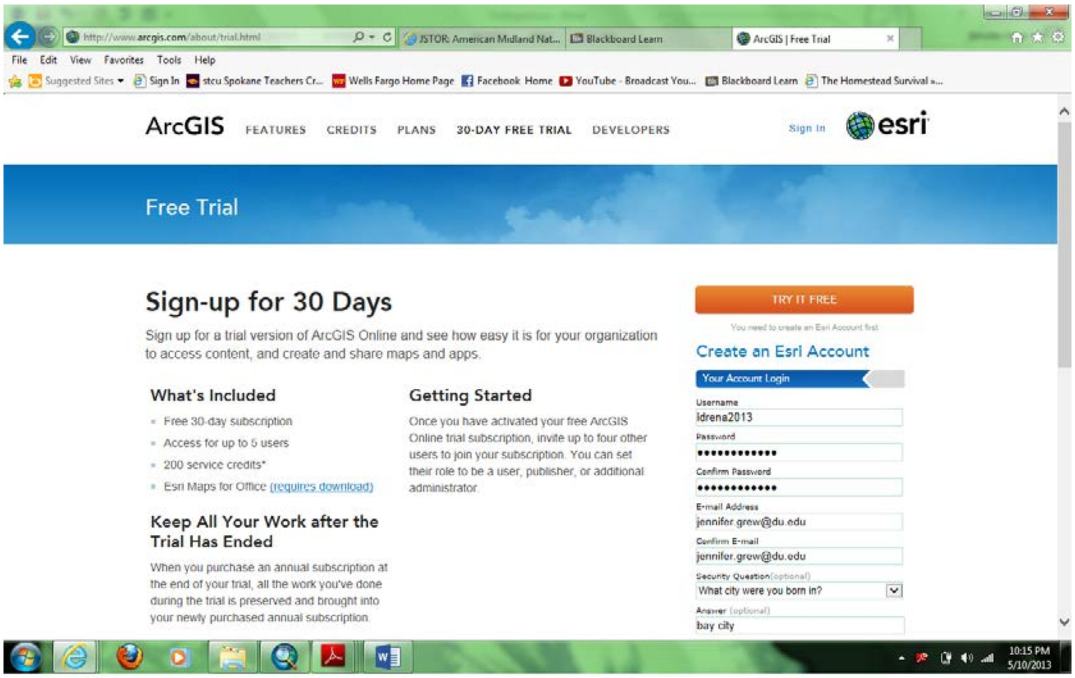

(Figure 9): Results of Year Weighted tool of top 50% of each season's results layer.



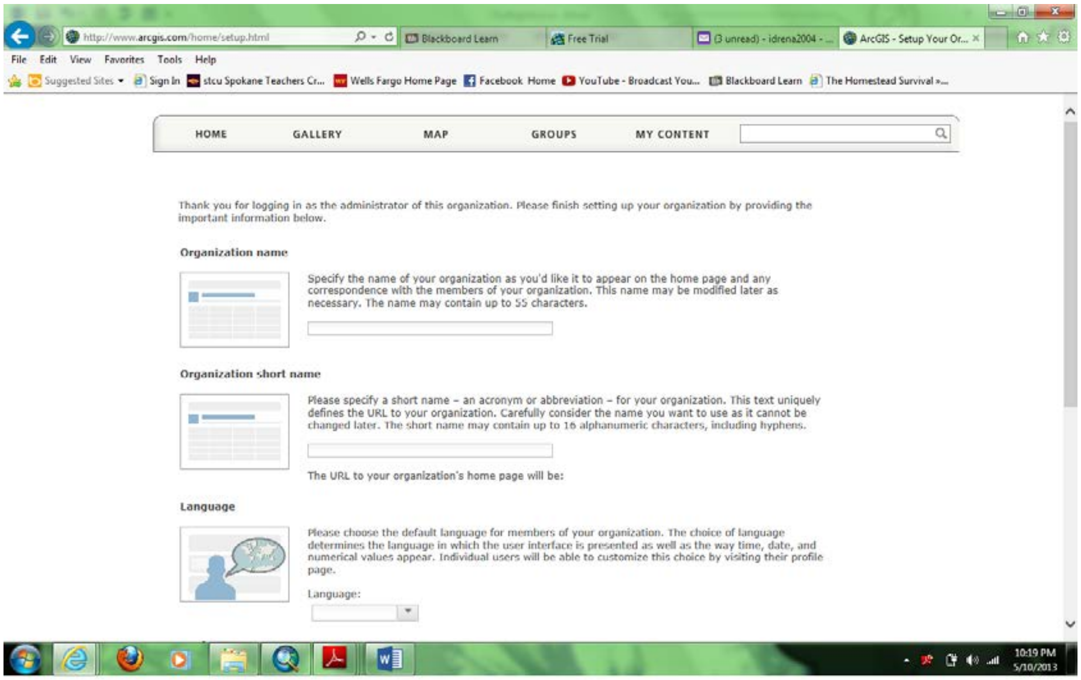

(Figure 10): Results of weighted tool of top 83% of each season's results layer.

### *ArcGIS Online for Organizations*

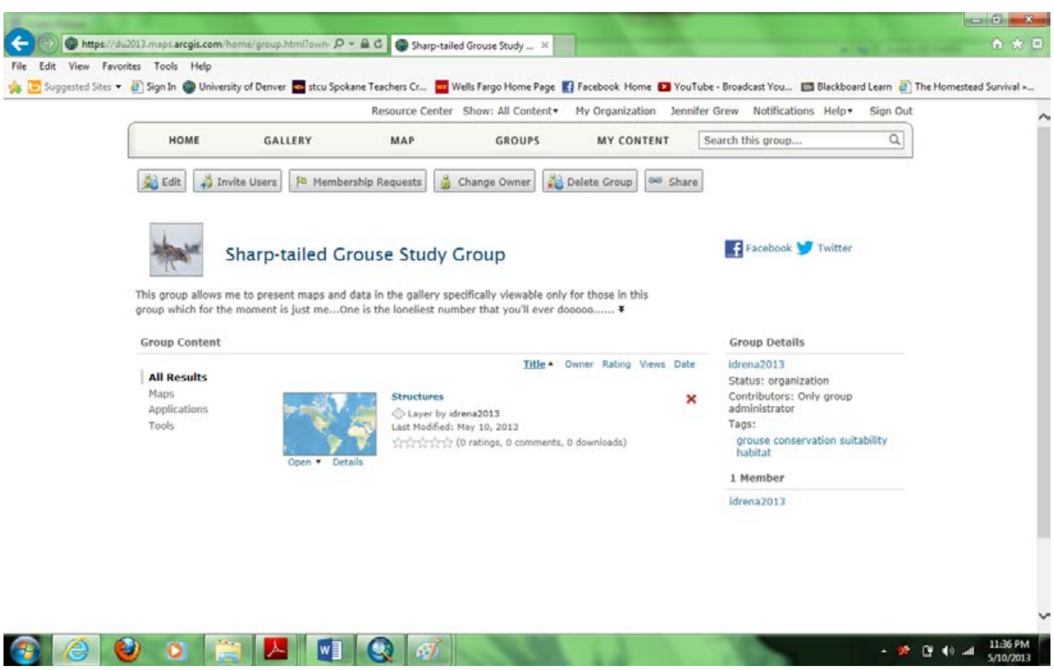
ArcGIS Online for Organizations is a tool that can be readily used when ArcGIS Server is not readily available financially or physically. I signed up for a free trial of their ArcGIS Online for Organizations. This version allows me to import a larger variety and size file into the cloud server space allotted for me, and it allows me to lock down my data to, from, and in the cloud server space with SSL securities.



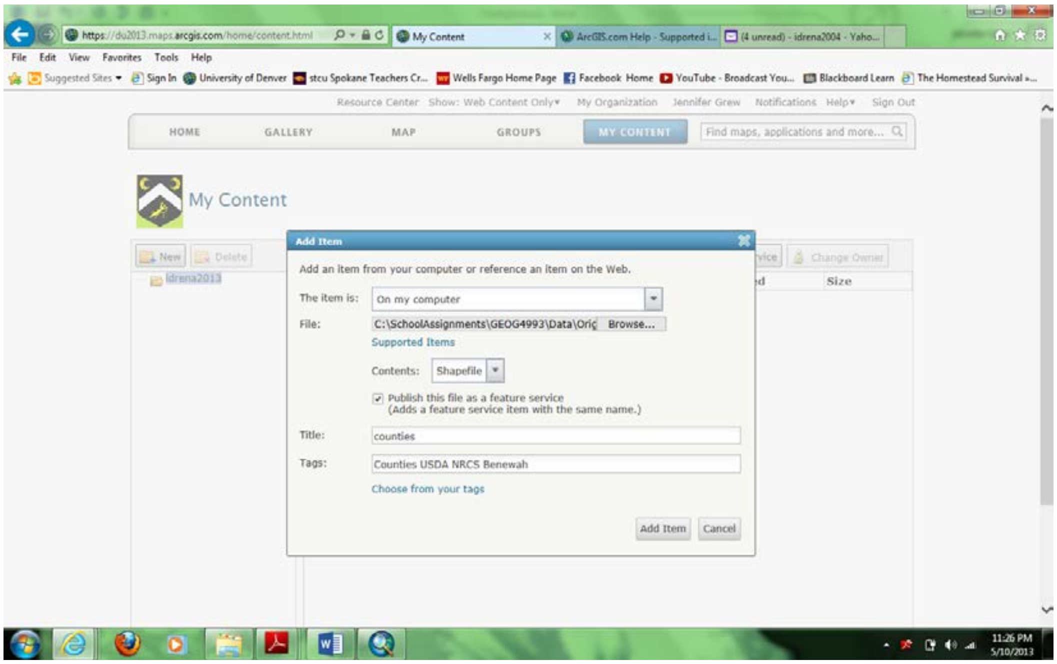

(Figure 11): Sign up - I first signed up for the free trial for 30 days by creating a new ESRI login. Even though I already have one, I am required to open a new one for the trial.



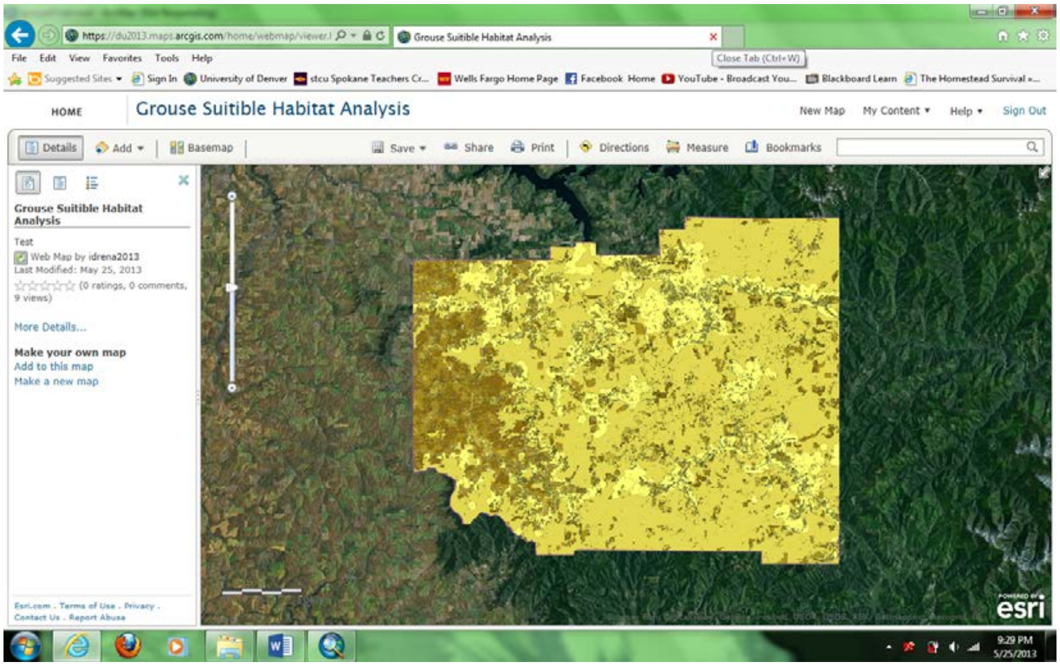

(Figure 12): Start-Up – The first screen allowed me to set the basic ArcGIS Online settings such as: University of Denver for the name of my organization, DU 2013 for the short name that is now in my URL identifying the site as uniquely mine.



(Figure 13): Inviting Users and Creating Groups – I created Sharp-tailed Grouse study group in order to allow only approved users to see these data layers and maps.




(Figure 14): Adding Data – I added data layers using zipped shapefiles, and feature services straight from ArcMap.




(Figure 11): Creating the Map – I created a basic ArcGIS Online map using zipped county lines and feature class created from the spring_results, summer_results, winter_results, and year_results feature layers.

## RESULTS

### *Spring results:*

Spring results were compiled into a final raster layer with values ranging from 0 (no suitable habitat) to 5 (completely suitable habitat). The raster layer for the county included 2,259,785 30x30m cells in total. 391,817 (17.34%)cells rated as a 0, 1,283,320 (56.79%)cells rated as a 1; 143,072 (6.33%)cells rated as a 2; 276,675 (12.24%)cells rated as a 3; 160,585 (7.11%)cells rated as a 4; and 4,316 (0.19%)cells rated as a 5.

***Summer results:***

Summer results were compiled into a final raster layer with values ranging from 0 (no suitable habitat) to 5 (completely suitable habitat). The raster layer for the county included 2,270,746 30x30m cells in total. 73,181 (3.22%)cells rated as a 0; 784,413 (34.54%)cells rated as a 1; 893,349 (39.34%)cells rated as a 2; 335,295 (14.77%)cells rated as a 3; 167,002 (7.35%)cells rated as a 4; and 17,506 (0.77%)cells rated as a 5.

***Winter results:***

Winter results were compiled into a final raster layer with values ranging from 0 (no suitable habitat) to 5 (completely suitable habitat). The raster layer for the county included 2,270,746 30x30m cells in total. 8,501 (0.37%)cells rated as a 0; 254,207 (11.19%)cells rated as a 1; 383,299 (16.88%)cells rated as a 2; 782,535 (34.45%)cells rated as a 3; 787,148 (34.66%)cells rated as a 4; and 55,524 (2.44%)cells rated as a 5.

***Year results:***

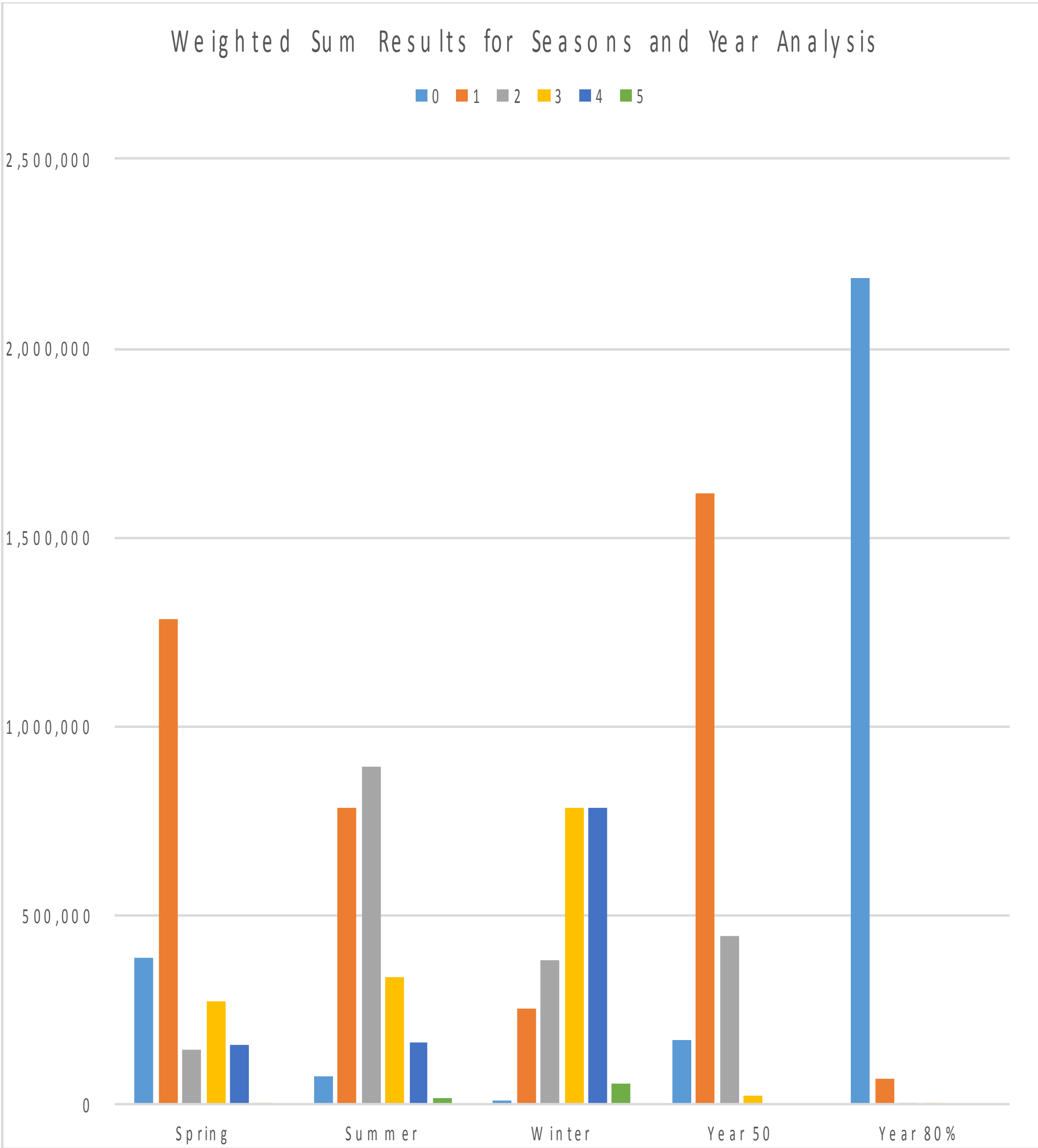
Spring, summer, and winter layers were run through the weighted sum tool to see where the best overall area was. Year results were compiled into a final raster layer with values ranging from 0 (no suitable habitat) to 3 (completely suitable habitat). The tool was run twice, once for 50% suitability for values 3-5 in each season's result layer, and once for 83% suitability for value 5 only.

*Year Results - 50% suitability:*

The raster layer for the county included 2,256,515 30x30m cells in total. 171,825 (7.61%) cells rated as a 0; 1,615,878 (71.61%) cells rated as a 1; 445,619 (19.75%) cells rated as a 2; 23,193 (1.03%) cells rated as a 3.

*Year Results - 80% suitability:*

The raster layer for the county included 2,256,522 30x30m cells in total. 2,184,828 (96.82%) cells rated as a 0; 66,158 (2.93%) cells rated as a 1; 5,518 (0.24%) cells rated as a 2; 18 (0.0008%) cells rated as a 3.




(Figure 12): A bar graph of resulting 30x30m raster cell counts after weighted sum tool analysis measuring number of suitability variables were met.

***Mapping application capabilities:***

ArcGIS Online ran without errors. I added zipped shapefiles, and several feature services to ArcGIS Online's mapping application. There was issue with creating a tile service layer. The cache would generate, but fail in the last stage of upload. This would have allowed for import of the raster as a cached tile layer rather than a feature layer created from a converted vector layer. KML layers were able to be generated by ArcMap, but were not allowed to be added to the mapping application. They would import into ArcGIS Online as a separate map that could not have other layers added to it.

## DISCUSSION

The spring layer was the limiting factor of the three seasons. It had the lowest number of perfect fit cells (5) and near perfect fit cells (4). The majority of cells that were considered to be suitable were also located in areas high in agriculture. While these areas physically are considered to be good habitat, there could be conflict with local farmers.

Six areas were identified as possible translocation areas at 50% suitability. Only one was potentially suitable at 80% suitability after mitigation is performed to bring the spring habitat up.

The six locations can be seen above in Figure 9 where the darkest portions of the data layer. Location 1 is approximately three miles west of highway 95 and two miles north of highway 60. Location 2 is 2.5 miles west of highway 95, and 4 miles south of highway 60. Location 3 is less than a mile south of Santa along highway 3 on the either side. Location 4 is 2 miles due south of Santa, and 2.5 miles west of highway three. Location 5 is found in the wetlands at the mouth of the St. Joe River. Location six is a narrow band that runs for 5 miles along highway 95 on the eastern side from DeSmet, to Sanders Road.

These areas that are defined as being 50% suitable are areas that have at least three favorable variables that lend to overall suitability. The three locations on or near highway 95 on the western half of the county would be considered most favorable due to this area being located in part of the historic Palouse prairie, and also in areas where there is more open ground overall. This is in comparison to the more heavily forested eastern half of the county. Three locations on the eastern side of the county appear to be clear cuts or opened areas surrounded by conifer forest and thus inherently isolated.

The only location that could be considered for the 80% suitability analysis is the same as location 6 above. Areas along highway 95 between DeSmet and Sanders Road had the highest concentration of all three seasons having all five suitability variables present. This area was very fragmented however at 80% suitability and should be considered for mitigation efforts to improve it. Nevertheless, Location 6 of the 50%

suitability analysis and the only location for the 80% suitability analysis appears to be the most suitable location in Benewah County for translocation of sharp-tailed grouse. This is followed closely by location1, location 2, and location 5. Location 5 may become more suitable due to its proximity to wetland habitat and publically owned lands along the St. Joe River.

All six locations were large enough to be considered suitable for sharp-tailed grouse relocation; however Hanowski, (2000) discusses the potential for microclimates leading to unsuitable conditions in grouse habitat that can and has led to abandonment of leks and nesting grounds. The microclimates of conifer stands or other tall cover vegetation in close proximity to leks can lead to abandonment. It is thought that while most studies focus on overall percentages of habitat, in the case of grouse habitat, vegetation location on the micro scale is equally if not more important for population retention at a site. Landscape management will have to play a large role in relocation efforts for the grouse.

Removal of taller vegetation will be key to ensuring the lekking areas are accepted. Several other mitigation practices can be employed. Gylywoychuk, (1993) remarks on how burning is one practice that while the most cost effective, should not be used in most cases for grouse habitat mitigation. Grouse will tend to abandon sites that have been burned unless the fire was used to clear an area previously inhabited by conifer stands.

These areas once cleared can become grouse habitat after a few years and careful planting of grasses, forbs, and shrubs favored by the grouse.

Mastication is another practice that can be employed to clear conifer stands and closed canopies for grouse habitat. Once masticated, debris should be left in place for nesting cover. In these areas, planting of grasses, forbs, and shrubs favored by the grouse is also recommended.

It was suggested by Hanowski, (2000), and Connelly, (2010) that pasture lands that are not overly grazed would also make ideal grouse habitat. In this case, communication with local ranchers could lead to other locations becoming more favorable for grouse habitat. Mitigation of waterways within the pastures such as planting of deciduous trees and shrubs for forage and cover by grouse would be ideal.

Agricultural lands which are present on or around the three most suitable areas would create even more suitable habitat for nesting especially if local farmers can be convinced to use practices other than burning to clear large stubble from their fields in the spring. As mentioned above in Methods, grouse can survive well in stubble fields as long as fire is not used to clear the stubble. Were farmers to agree to burning either later in the season after eggs have hatched, or leave some areas unburned, grouse could successfully nest in these areas within agricultural fields. Identification and efforts of preservation of CRP lands will also allow more areas to become suitable grouse habitat. Communication with owners of CRP lands will be crucial to maintaining these areas indefinitely, and expanding areas. This will be difficult in times when grain prices are high. Should this become the case, grouse populations located on CRP lands should be considered for relocation, or have lands adjacent mitigated to replace lands that will be lost to renewed agricultural practices.

While the winter layer looks like it has the most favorable habitat of all the seasons, this is mostly due to the vegetation height and vegetation cover layers having no distinction between coniferous and deciduous trees. Deciduous riparian tree and shrub vegetation is what was sought after in this study. In areas that are selected for grouse relocation, coniferous trees should be removed whenever possible and replaced by deciduous trees and shrubs. Species mentioned in literature review should be considered first as they are major food sources in the winter for grouse.

## FURTHER RESEARCH

*Future Ecological Research:*

More research should be conducted with Sharp-tailed Grouse professionals in order to come up with statistically backed weights for variables and even weights of values within attribute tables of those variables to create more accurate balance of grouse preferences of vegetation types, cover, and height during nesting and rearing times

Hydric soils should be added as another variable in future studies as Connelly, (2010) mentions that areas of wetland vegetation or areas with hydric soils are favored by grouse. The study that mentions this was conducted in Minnesota where wetlands may be the most common non-forested areas where grouse have open land to work with. Research should be done to ascertain whether the grouse actually prefer wetland habitat, or open canopy habitat that was only available in that area as wetlands.

A new vegetation cover layer and height layer should be located that distinguish between coniferous and deciduous so that a more accurate portrayal of winter habitat can be made. It is possible once this is done, it will be shown that winter habitat is actually the limiting season for habitat.

Connelly, (2010), Hanowski, (2000), Gylywoychuk, (1993), and several other authors detail how grouse appear to have an aversion to coniferous trees at any of their life stages. These birds will abandon a lek if these trees are beginning to grow into the area. A relocation of birds could end in failure if there are too many of the trees in a stand or scattered nearby. The grouse do not appear to have as strong of an aversion to deciduous trees and even seek them out in the winter for forage and cover. The inland northwest is not known for having a great deal of the deciduous trees that the grouse tolerate, but we do have a great deal of the coniferous trees that they appear to be adverse to. Much of the landscape management for these birds will be to hold back growth of coniferous trees from grouse habitat areas, and clear trees out of areas that will become grouse refuges.

A detailed data layer of coyotes and foxes in the area should be located to provide location of current territories of these predators. This could lower mammalian predation of the hens and chicks during rearing months. (Manzer, Hannon, 2008), (Conover et al., 2009) Suitable areas found to have high populations of these predators should either be managed to lower populations, or if this is not a viable option, the area should be disqualified as a relocation area due to high predator populations.

The structures layer records structures in general and not necessarily high traffic residences. Structures that are abandoned or are only used during certain times of the year may be disqualified as a negative weight for grouse habitat. Barns, sheds, and hunting cabins if identified could be removed and add more territory to all three seasons results layers.

It should be determined if there is a land use layer already available through the county or tribe that lists all of the fields in the county that are already used for regular grazing versus crop farming to optimize nest survivability. These pasture areas should be added as another variable in the analysis as a positive weight for habitat suitability. If possible, include usage as an attribute as high usages of pasture lands renders them uninhabitable for grouse. Only low to medium grazing with years of regrowth should be considered for a positive weight. (Yocom, 1952), (Hanowski, 2000), (Connelly, 2010) (Kirby et al., 1995)

A data layer specifying CRP lands would be beneficial to the study as well. This could either be added into the vegetation type layer, or serve as its own weight. If these areas appear near areas that are lacking spring or summer habitat would boost that area's suitability such that it may become a viable initial relocation point, or future relocation point to expand the range of grouse once they are established in the area.

This study was a wide range conceptual study of overall suitability for sharp-tailed grouse. Smaller more detail oriented studies of each season, or each variable could provide valuable information that could enhance this study. Large national datasets were not detailed enough for the area and used lower resolution imagery for determining vegetation type, height, and canopy cover. Local datasets with higher resolution would show more accurate representations of local vegetation. The same goes for slope, aspect, soils, and predation. The structures layer was a compilation of local layers and as such is already as detailed as finances will allow for the area.

**APPENDIX**

ArcGIS Online

While experimenting with ArcGIS Online for Organizations as an alternative to ArcGIS for Server and also as a web map viewer, I discovered several pros and cons to using it. A major drawback to this program that I found early on was that it appears only .wms, .gpx, and feature/tile layers can be displayed on ArcGIS Online's viewer. All other layers will load into the content section for storage, but cannot be added to the viewer web map. These layers can be added to a web mapping application or sent on to be consumed by JavaScript, Silverlight, or FlexViewer web mapping applications.

The SSL securities held well during testing and the ability to sign up users to view specific content only based on the group they are allowed into will help keep users like ground truthing field crews from altering the data by accident while still allowing them to view the map and add data to approved layers as they need to.

The content section of the site will allow significantly large files of several megabytes to be stored and consumed by applications; however, this does not necessarily mean that the mapping applications or viewers were able to handle that load. Feature layers with over 1000 records will not display more than 1000 records in ArcGIS Online viewer. Also, data layers with long draw times such as rasters converted to vector because they would not properly cache their tiles will take several minutes to display each time you change views.

The results layers were also too large to convert to kml layers within ArcGIS online. Even though these layers would have been view only, they would still have been useful to ground crews. The alternative to this issue is having tablets out in the field with Google Earth available. Security will not be as good, but results .kml overlays in Google Earth or a tablet's GPS program would allow crews to navigate to their sites without issue, and as the data is view only, no sensitive data would be exposed to the web.

*Future Technological Research:*

Future work could go into creating a geoprocess that would be added to a web Viewer such as FlexViewer or JavaScript that would allow non GIS users to add their own data layers to the map and conduct the weighted sum or weighted overlay tool themselves. They could add their own weights and immediately see areas that have high suitability.

This geoprocessing tool could be within a map that only has layers for sharp-tailed grouse that could have future detailed layers added to it by request. There is also the option that a volunteer data entry tool could be added as well so that crews that go out in the field can report in real time what kind of vegetation is actually in the area since vegetation types derived from satellite remote sensing can be and is fallible. The data entry can be composed of a point layer with a pre-fabricated report style window for them to fill in so that consistency is maintained in the database. Domains would be set up to select specific events, species, predator sightings, and grouse sightings after releases, etc.

It is possible the speed of the maps was caused entirely by the aging internet line system here in rural northern Idaho. In the future it could be advantageous to move all data, processing, web servers, and ArcGIS programs themselves to Amazon cloud servers. This would allow maximum speed of processing data layers, tools, maps, and mobile applications without having to wait on slow connections or slow local servers.

**REFERENCES**

Aldridge, Cameron L., Sara J. Oyler-McCance, and Mark R. Brigham. 2001. Occurrence of greater sage-grouse x sharp-tailed grouse hybrids in alberta. The Condor 103 (3): 657-60.

Ammann, G. A. 1959. Sharp-tailed grouse predation by goshawk. The Journal of Wildlife Management 23 (1): 110-1.

Artmann, Joseph W. 1971. Capturing sharp-tailed grouse hens by using taped chick distress calls. The Journal of Wildlife Management 35 (3): 557-9.

Berg, W. E., Dickey, D., Watt, P., Telander, P., and Davis, G. 1987. Sharp-tailed Grouse: A Draft Management Plan. Minnesota Department of Natural Resources. St. Paul. 17pp.

Berger, Matthew. 2002. Sharp-tailed grouse restoration; Colville tribes restore habitat for sharp tailed grouse. Portland, OR: Bonneville Power Administration, 2001-030-00.

Berger, R.P. 1989. Sharp-tailed grouse habitat revitalization in the Interlake region of Manitoba. Natural Resource Institution, 138pp

Boyd, Chad et al. 2011. Looking toward a brighter future for lekking grouse. Rangelands 33 (6): 2-11.

Coates, Peter S. 2001. Movement, survivorship, and reproductive behavior of Columbian sharp-tailed grouse translocated to Nevada. Masters of Sciences Biology. University of Nevada Reno.

Coates, Peter S., San J. Stiver, and David J. Delehantyy. 2006. Using sharp-tailed grouse movement patterns to guide release-site selection. Wildlife Society Bulletin 34 (5): 1376-82.

Coates, Peter S., and David J. Delehanty. 2006. Effect of capture date on nest-attempt rate of translocated sharp-tailed grouse tympanuchus phasianellus. Wildlife Biology 12 (3): 277-83.

Cochran, W.G. and G.M. Cox. 1957. Experimental Designs. John Wiley & Sons Inc. New York. 611pp

Connelly, J. W. 2010. Habitat Needs and Protection for Columbian Sharp-tailed Grouse in Washington with Emphasis on Okanogan County.

Connelly, J. W., M. W. Gratson, and K. P. Reese. 1998. Sharp-tailed grouse (Tympanuchus phasianellus). In The Birds of North America, No. 354 (A. Poole and F. Gill eds.). The Birds of North America, Inc., Philadelphia, PA.

Conover, Michael R., and Jennifer S. Borgo. 2009. Do sharp-tailed grouse select loafing sites to avoid visual or olfactory predators? The Journal of Wildlife Management 73 (2): 242-7.

Drummer, Thomas D., R. Gregory Coraceiii, and Stephen J. Sjogren. 2011. Sharp-tailed grouse lek attendance and fidelity in upper Michigan. Journal of Wildlife Management 75 (2): 311-8.

Edgley, Eric F. 2001. Use of geographic information systems to model potential Columbian sharp-tailed grouse Nesting/Brooding rearing habitat. Master of Science in Geography. Utah State University.

Evans, Keith E., and Donald R. Dietz. 1974. Nutritional energetics of sharp-tailed grouse during winter. The Journal of Wildlife Management 38 (4): 622-9.

Flake, L. D., J. W. Connelly, T.R. Kirschenmann, and A.J. Lindbloom. 2010. The grouse of South Dakota. South Dakota Department of Game, Fish and Parks, Pierre. In press.

Fortems, Cam. 2003. Sharp-tailed grouse business:[final edition]. Kamloops Daily News, Apr. 15, 2003, sec B.

Giesen, Kenneth M., and John W. Connelly. 1993. Guidelines for management of Columbian sharp-tailed grouse habitats. Wildlife Society Bulletin 21 (3): 325-33.

Goddard, Alicia D. 2003. Reproductive success and habitat selection of sharp-tailed Grouse (tympanuchus phasianellus) in the Peace River region, northeast British Columbia. Master of Science in Natural Resources and Environmental Studies (Biology)., University of British Columbia.

Goddard, Alicia D., and Russell D. Dawson. 2009. Seasonal changes in habitat features influencing nest survival of sharp-tailed grouse in northeastern British Columbia, Canada. Ecoscience 16 (4): 476-82.

Goddard, Alicia D., and Russell D. Dawson. 2009. Factors influencing the survival of neonate sharp-tailed grouse tympanuchus phasianellus. Wildlife Biology 15 (1): 60-7.

Green, Gerald. 2002. Hangman restoration project. Plummer, ID: Coeur d'Alene Tribe, 2001-03300.

Gylywoychuk, D. T. 1993. Habitat Evaluation and Management Guidelines for Sharp-tailed Grouse Leks in the Narcisse Wildlife Management Area. Master of Natural Resources Management. University of Manitoba.

Hamerstrom, Jr, F. N. 1963. Sharp-tailed grouse Brood Habitat in Wisconsin's Northern Pine Barrens. The Journal of Wildlife Management 27: 793-802.

Hamerstrom, Jr, F. N., and Millard Truax. 1938. Traps for pinnated and sharp-tailed grouse. Bird-Banding 9 (4): 177-83.

Hanowski, J. M., Christian, D. P., Niemi, G. J. 2000. Landscape requirements of prairie sharp-tailed grouse Tympanuchus phasianellus campestris in Minnesota, USA. Wildlife Biology 6: 257-263.

Hanson, Harold C. 1953. Muskeg as sharp-tailed grouse habitat. The Wilson Bulletin 65 (4): 235-41.

Hays, David W., Michelle J. Tirhi, and Derek W. Stinson. 1998. Washington state status report for the sharp-tailed grouse. Olympia, Wash.: Washington Dept. of Fish and Wildlife.

Hoffman, R.W.; Thomas, A.E. 2007. Columbian Sharp-tailed Grouse (Tympanuchus phasianellus columbianus): a technical conservation assessment. USDA Forest Service, Rocky Mountain Region. 132 pp.

Holling, C. (1992): Cross-scale morphology, geometry, and dynamics of ecosystems. Ecological monographs. 62: 447-502.

Integrating landscape and metapopulation modeling approaches: Viability of the sharp-tailed grouse in a dynamic landscape. 2004. Conservation Biology 18 (2): 526-37.

Kirby, Donald R., and Kevin L. Grosz. 1995. Cattle grazing and sharp-tailed grouse nesting success. Rangelands 17 (4): 124-6.

Landers, Rich. 2001. GROUSE WOES GO BEYOND TURKEYS. Spokesman Review, Oct. 20, 2001, sec B.

Manzer, Douglas L., and Susan J. Hannon. 2008. Survival of sharp-tailed grouse tympanuchus phasianellus chicks and hens in a fragmented prairie landscape. Wildlife Biology 14 (1): 16-25.

Marks, Jeffrey S., and Victoria Saab Marks. 1987. Habitat selection by Columbians sharp-tailed grouse in west-central Idaho. U.S. Department of the Interior, Bureau of Land Management, Boise District, Id. 115pp.

Marks, Jeffrey S., and Victoria Saab Marks. 1988. Winter habitat use by Columbian sharp-tailed grouse in western Idaho. The Journal of Wildlife Management 52 (4): 743-6.

Marks, Raissa. 2007. Sharp-tailed grouse (tympanuchus phasianellus). Fish and Wildlife Habitat Management Leaflet.

Marshal, W.H. and M.S. Jensen. 1937. Winter and spring studies of the sharp-tailed grouse in Utah. The Journal of Wildlife Management 1: 87-99.

McDonald, M. W. 1998. Ecology of Columbian sharp-tailed grouse in eastern Washington. M. S. Thesis. University of Idaho, Moscow. 125 pp.

McEwen, Lowell C., and Robert L. Brown. 1966. Acute toxicity of dieldrin and malathion to wild sharp-tailed grouse. The Journal of Wildlife Management 30 (3): 604-11.

Meints, D. R.; Connelly, J. W.; Reese, K. P.; Sands, A. R. and Hemker, T. P. 1992. Habitat suitability index procedures for Columbian sharp-tailed grouse. Forest, Wildlife and Range Experiment Station Bulletin 55: 27 pp.

Morse, Lauren. 2009. Scampering in the city: Examining the long-term ecological and social viability of black-tailed prairie dogs (cynomys ludovicianus) in Denver, Colorado. M. S. Thesis. University of Denver, 125pp.

Moss, Robert, Ilse Storch, and Martin Muller. 2010. Trends in grouse research. Wildlife Biology 16 (1): 1-11.

Noppadol Paothong. Dance of Columbian sharp-tailed grouse on snow. in Save the Last Dance [database online]. 2011Available from http://www.savethelastdancebook.com/2011/05/dance-of-columbian-sharp-tailed-grouse-on-snow/ (accessed 03/08/2012).

Quick guide to ESRI ArcGIS Online for Organizations. 2012. 129110 ESRI.5C3/12ek.

http://www.conservationgis.org/maps/quick-start-arcgis-online.pdf

Rodgers, Randy D. 1992. A technique for establishing sharp-tailed grouse in unoccupied range. Wildlife Society Bulletin 20 (1): 101-6.

Roersma, S. J. 2001. Nesting and brood rearing ecology of Plains Sharp-tailed Grouse (Tympanuchus phasianellus jamesi) in a mixed-grass/fescue ecoregion of southern Alberta. M. S. Thesis, University of Manitoba. 124 pp

Saab, V.A., and J.S.Marks. 1992. Summer habitat used by Columbian sharp-tailed grouse in western Idaho. Great Basin Naturalist 52 (2): 166-173.

Schroeder, M. A., and R. K. Baydack. 2001. Predation and the management of prairie grouse. Wildlife Society Bulletin 29:24–32.

Stinson, Derek W., and Michael A. Schroeder. 2010. Draft Washington state recovery plan for the Columbian sharp-tailed grouse. Olympia, Washington: Washington Department of Fish and Wildlife.

Sharp-tailed grouse transplant re-establishing population in southwestern Colorado. 2005. US Fed News Service, Including US State News, May 26, 2005, sec Wire Feed.

Vitale, Angelo, Frank Roberts, Ronald Peters, and Jason Scott. 1997-2002. Coeur d'Alene tribe fish and wildlife program habitat protection plan; implementation of fisheries enhancement opportunities on the Coeur d'Alene reservation", Plummer, Id: Coeur d'Alene Tribe, 199004400.

Ward,D. J. 1984. Ecological relationships of Columbian sharp-tailed grouse leks in Curlew National Grasslands, Idaho, with special emphasis on effects of visibility. M.S. Thesis, Utah State Univ., Logan. 63pp.

Whitney, Richard. 2003. Sharp-tailed grouse restoration; Colville tribes restore habitat for sharp tailed grouse. Portland, OR: Bonneville Power Administration, 2001-03-000.

Yocom, C. F. 1952. Columbian Sharp-Tailed Grouse (Pedioecetes Phasianellus Columbianus) in the State of Washington. American Midland Naturalist. 48 (1) 185-192.