A Site Suitability Assessment for Greater Sage-Grouse Habitat Conservation in the Intermountain West

Image: Cornell Lab of Ornithology

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Geospatial Software Design
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Background

The greater sage-grouse is both native and restrained to the North American sagebrush (*Artemesia* spp.) steppe, approximately 243,000 square miles of which currently exist in the Northwestern United States and the Alberta and Saskatchewan provinces of Canada (U.S. Fish and Wildlife Service 2014). The distribution of the sage-grouse is known to have a close correlation with the availability and historic range of the sagebrush, as the species is dependent upon sagebrush as both a source of food and shelter. As a sagebrush obligate, the sage-grouse requires an extensive, interconnected expanse of sagebrush of varying densities and heights, with a collection of native understory grasses and forbs for insect habitat and food supply (U.S. Fish and Wildlife Service 2014). Thus, the presence and proportion of sagebrush throughout the species range is a significant determinant of the ability of populations to move across the landscape.

Most of the sagebrush biome exists between the Sierra Nevada, Cascade, and Rocky Mountain ranges, but the plant species also extends east into the northern Great Plains of Wyoming and south-central Montana (Miller and Eddleman 2001). Sage-grouse populations that migrate can make annual movements of over 45 miles from their home ranges, which can exceed 575 square miles (Bird and Schenk 2005). Conclusive data regarding the minimum patch sizes of sagebrush necessary to support viable sage-grouse populations is unavailable, however (Bureau of Land Management 2004).

Soils, topography, and climate vary widely across the bird's range, allowing the sage-grouse to move from valley floors to higher elevations, and from semi-arid uplands to wet meadows (Miller and Eddleman 2001). Additionally, the species is known to exist between elevations ranging from 4,000 to over 9,000 feet (U.S. Fish and Wildlife Service 2014).

Image: U.S. Forest Service

Background

Sage-grouse have distinct habitat requirements throughout the year, categorized into breeding, late brood-rearing, and wintering periods. An ability to move effectively between these habitats is critical for annual sage-grouse fecundity and survivorship. Breeding habitat consists of areas used for lekking, nesting, and early brood-rearing, and commonly includes lake beds or ridge clearings, surrounded by regions of thicker shrub density. The adjacent dense sagebrush habitat provides shelter, food, and a means of protection from predation for displaying males. Nesting generally takes place under large sagebrush plants that provide cover and future sources of insects for young hatchlings (Bird and Schenk 2005).

Sage-grouse feed almost exclusively on sagebrush during the winter, so habitat is dictated by sagebrush availability. Because the birds are limited to habitat in which sagebrush remains unexposed from snow, weather conditions have a significant influence on the spatial distribution of sage-grouse during the winter (Bird and Shenk 2005).

Movement of the species across habitat types is dependent upon large, contiguous areas of sagebrush. However, sagebrush habitat has become increasingly degraded and fragmented with increased human use, particularly for agriculture, infrastructure development, and energy resources. Very little sagebrush habitat is currently undisturbed and approximately 50% to 60% has either been altered lost completely to land conversion, with only around 66,000 square miles remaining. Additionally, incursions from invasive plants, increased wildfire frequency and intensity, drought, and improper farming and grazing techniques have largely reduced the availability of essential land for the greater sage-grouse. Because the sage-grouse exhibits such strong site fidelity to seasonal habitats, the bird's ability to respond to local changes in its environment is extremely limited. Small changes in sagebrush habitat can have significant impacts on the connectivity of populations and the ability of birds to move across the landscape.


Image: U.S. Forest Service

Purpose

The goal of this work is to identify the most critical habitat for the greater sage-grouse in the intermountain west. Sites are identified to assist with future species conservation planning and protection efforts.

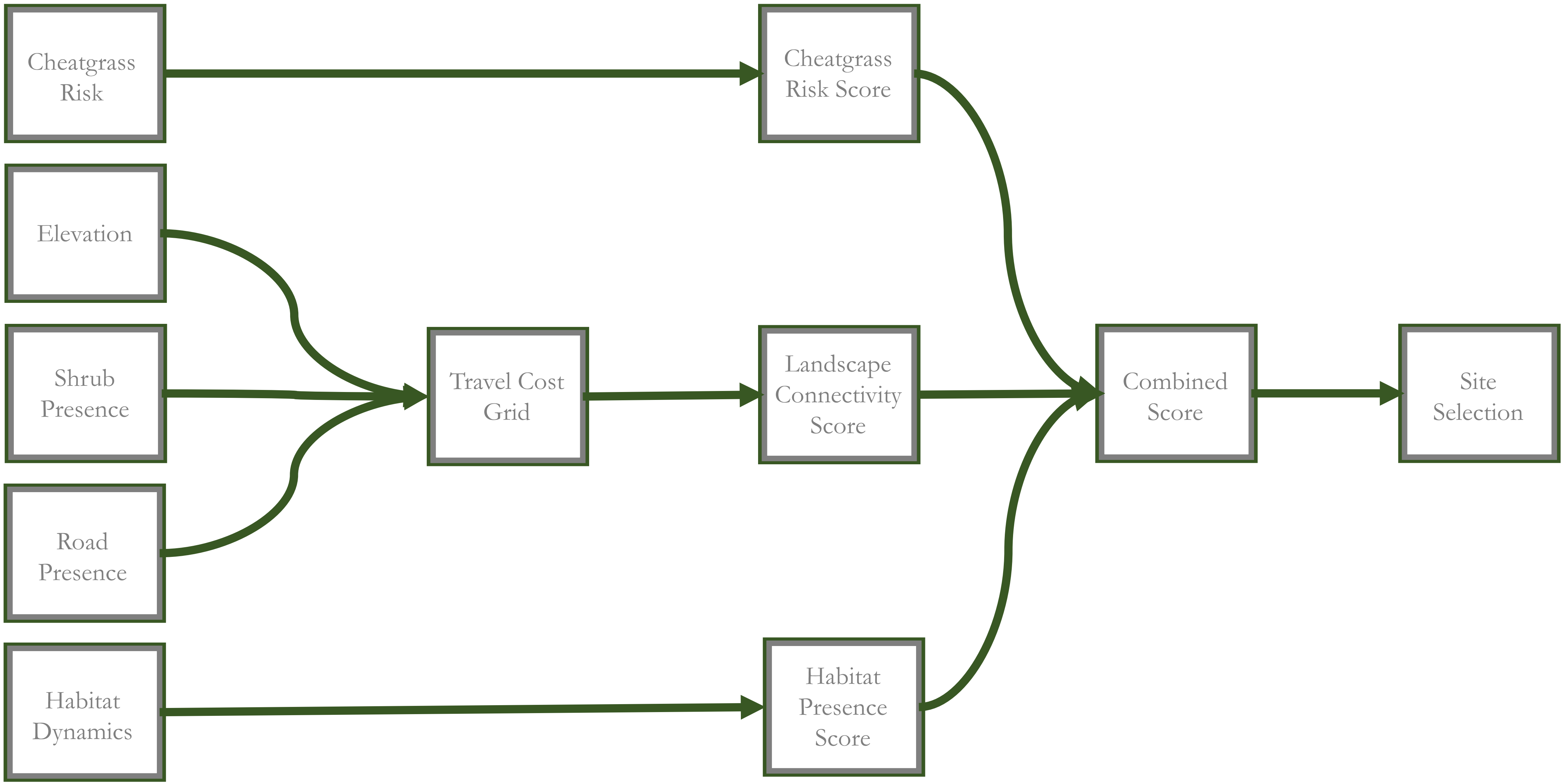
The nine western states that comprise the current rage of the greater sage-grouse are included in this assessment. Critical land for habitat protection is determined using the following criteria:

- The risk of invasion by Cheatgrass *(Bromus tectorum),* a historically problematic a non-native grass species
- Landscape connectivity and movement potential of sage-grouse populations
- Habitat lost and gained over time

A grid of scores ranging from 1 to 10 is constructed for each criterion and a composite grid generated to identify the western land parcels most critical for sage-grouse protection.


Image: U.S. Forest Service

Workflow


Cheatgrass Risk
Elevation
Shrub Presence
Road Presence
Habitat Dynamics
Travel Cost Grid
Cheatgrass Risk Score
Landscape Connectivity Score
Habitat Presence Score
Combined Score
Site Selection

Criterion 1: Cheatgrass Invasion Risk

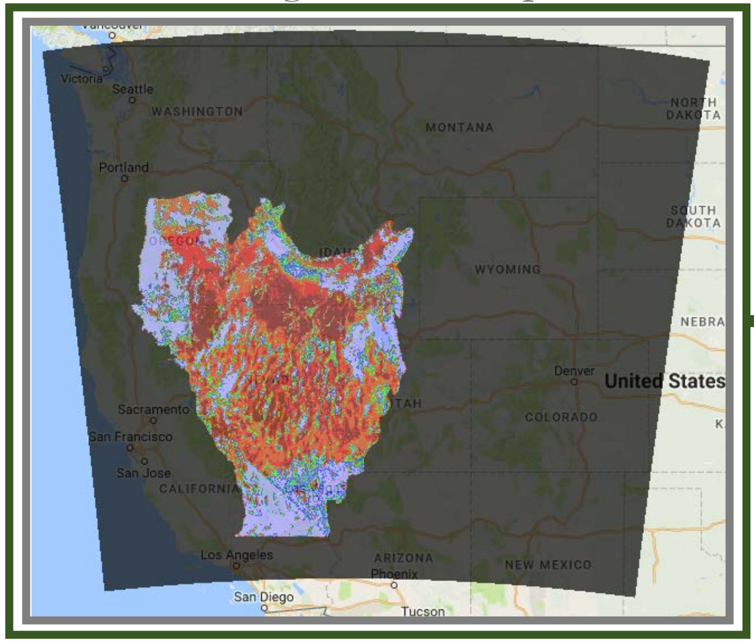
Background

Cheatgrass is an invasive species of grass capable of thriving in a variety of western ecosystems. With the increased fire regime present in he western region of the country, shrub vegetation has largely been degraded, leaving ecological space for the invasion of non-native grasses. Cheatgrass is of particular interest when considering risk to sage-grouse habitat, as it commonly dominates sage steppe ecosystems and replaces the native shrub vegetation necessary for sage-grouse survival.

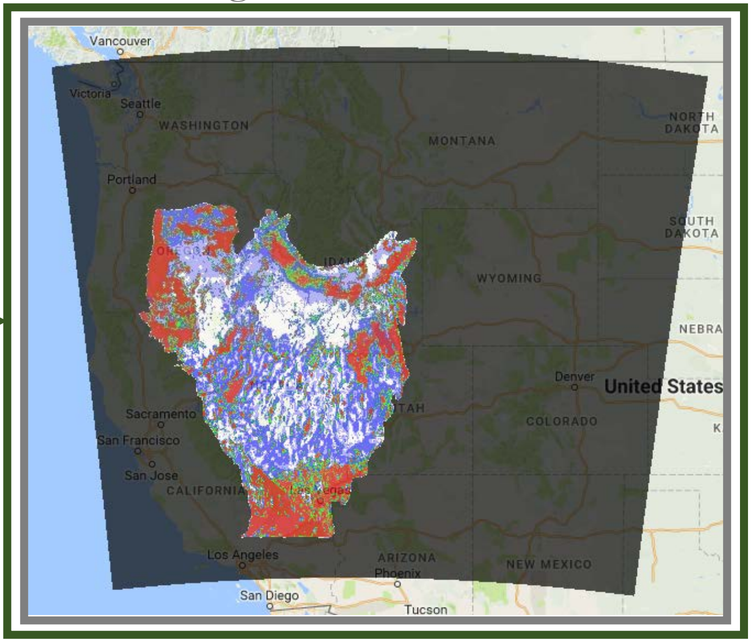
Methods

A layer of cheatgrass threat potential was downloaded from the United States Geological Service and imported into Google Earth Engine. The remap function was then used to generate a score grid ranging from 1 to 10, with higher scores designating areas associated with lower cheatgrass invasion risk.

Cheatgrass Risk Input



Cheatgrass Risk Score Grid



Criterion 2: Landscape Connectivity


Image: Montana Department of Environmental Quality

Background

Sage-grouse have distinct habitat requirements throughout the year, categorized into breeding, late brood-rearing, and wintering periods. An ability to move effectively between these habitats is critical for annual sage-grouse fecundity and survivorship.

The following factors were considered as potential reducers or enhancers of landscape connectivity and species movement ability across its range:

- **Elevation:** sage-grouse persist at elevations between 4,000 and 9,000 ft.
- **Land Cover:** the sage-grouse is a sagebrush obligate and requires high levels of sagebrush cover for survival across its range.
- **Road Presence:** roads and other development are known to fracture sage-grouse habitat and areas close to major roads are unsuitable for site selection.

Criterion 2: Landscape Connectivity

Methods

Elevation Cost

A national elevation layer was imported into Google Earth Engine and clipped to the states of interest. The image was scaled to values between 0 and 10 and the remap function was then used to generate a travel cost grid ranging from 0 to 10, with higher values designating those areas with those elevations outside a suitable range for sage-grouse habitation.

Land Cover Cost

A global land cover raster was imported into Google Earth Engine and clipped to the states of interest. The remap function was used to generate a travel cost grid ranging from 0 to 10, with higher values designating those land cover types less suitable for sage-grouse habitation, and low values reserved for shrubland.

Road Presence Cost

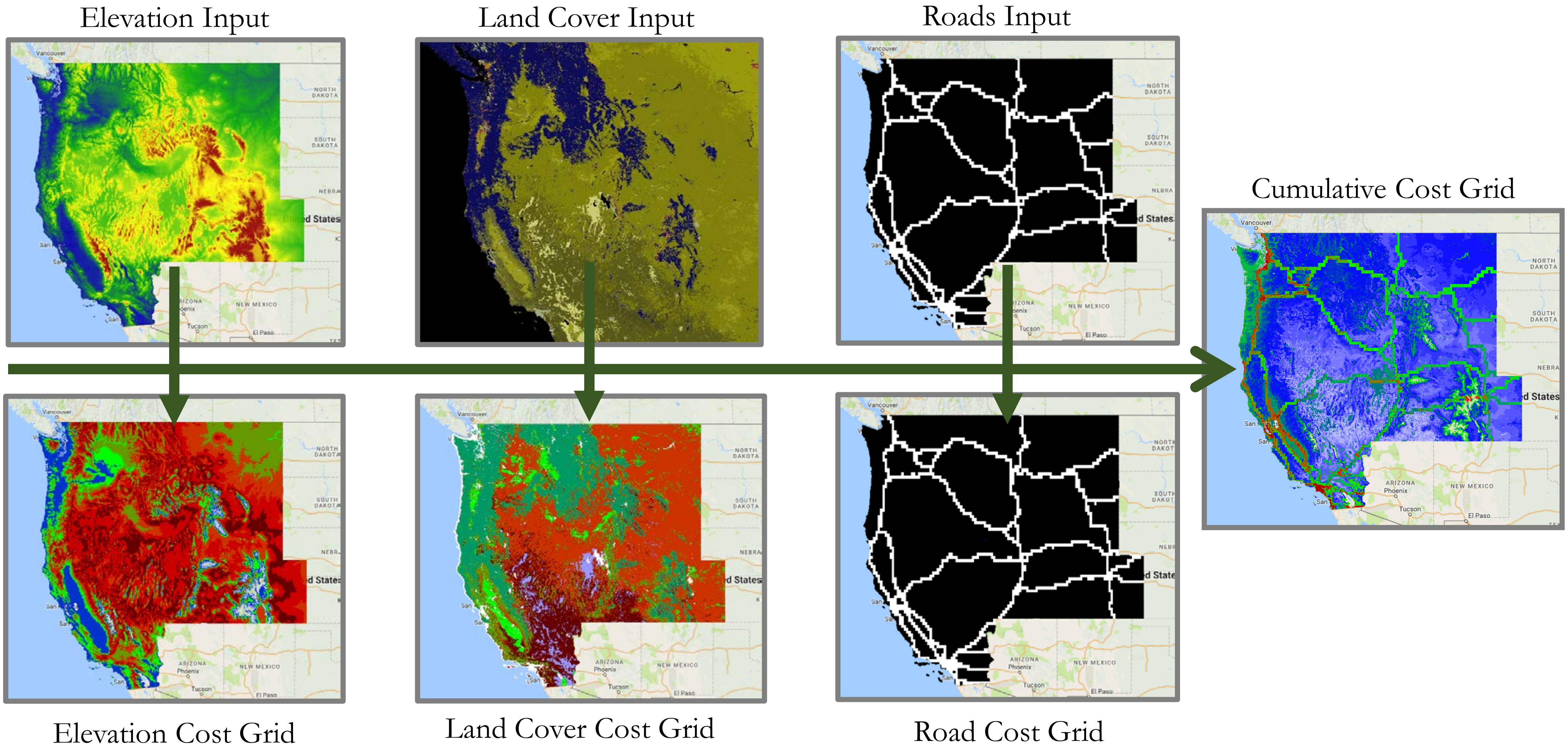
A raster layer of major U.S. highways and roads was imported into Google Earth Engine and clipped to the states of interest. The remap function was used to generate a travel cost grid, with roads assigned a high cost value of 8 and all else a value of 0.

Overall Cost

Individual cost grids were averaged to generate a final cost layer ranging from 0 to 10, with higher values designated for those parcels of land least suitable for sage-grouse habitation based on the above criteria. This overall cost grid was used as an input in later travel cost analyses.

Input	Cost Value
Elevation	
Low Elevations	6 to 10
Middle Elevations	1 to 4
High Elevations	5 to 10
Land Cover	
Water	10
Evergreen Needleleaf Forest	6
Evergreen Broadleaf Forest	6
Deciduous Needleleaf Forest	6
Deciduous Broadleaf Forest	6
Mixed Deciduous Forest	6
Closed Shrubland	1
Open Shrubland	1
Woody Savanna	4
Savanna	4
Grassland	3
Permanent Wetland	3
Cropland	5
Urban	10
Crop/Natural Veg. Mosaic	4
Permanent Snow/Ice	9
Barren/Desert	9
Unclassified	10
Road Presence	
Roads	8
Non-Road	0

Criterion 2: Landscape Connectivity



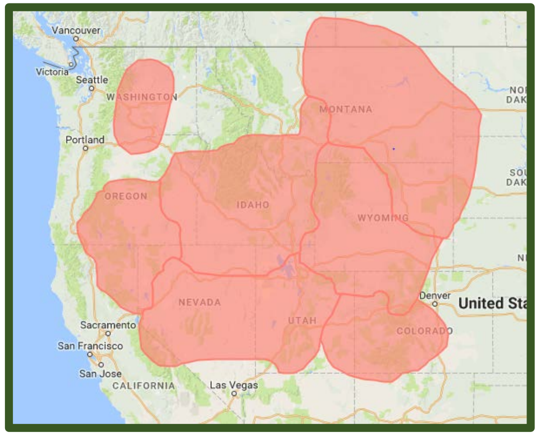
Criterion 2: Landscape Connectivity

Methods

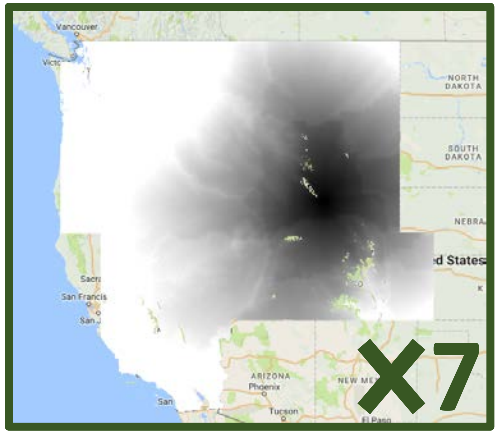
Travel Cost Analysis

A feature collection of seven Sage-Grouse Management Zones was imported into Google Earth Engine. An iterative algorithm was created to select each management zone, calculate its centroid, and buffer that point. Each management zone's centroid was used as a starting point in a cumulative cost analysis across the previously calculated overall cost raster. These seven cost travel cost rasters were then averaged to generate an overall grid of travel cost across the landscape. The image was scaled to values between 0 and 10 and the remap function was then used to generate a score grid ranging from 0 to 10, with higher values designating those areas with the lowest travel cost and greatest potential for sage-grouse mobility.

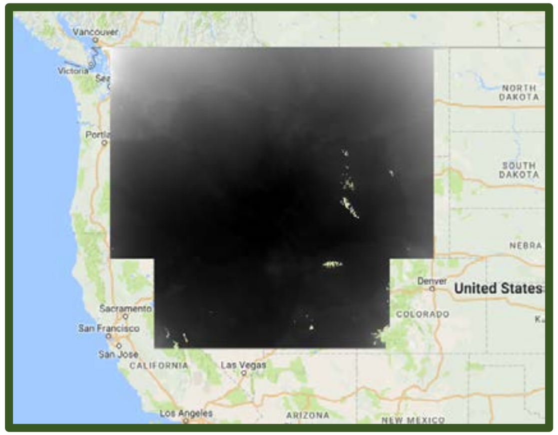
Sage Grouse Management Zones



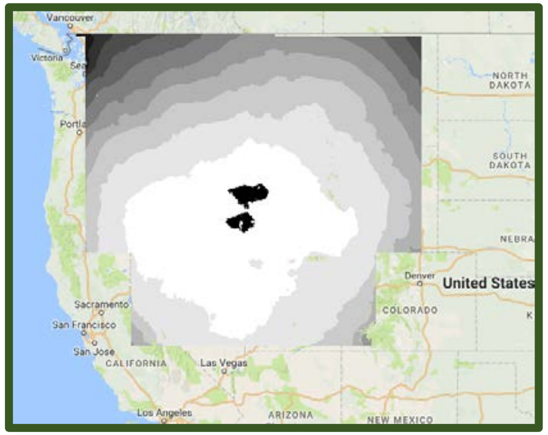
Individual Travel Cost Grids



Cumulative Travel Cost



Connectivity Score



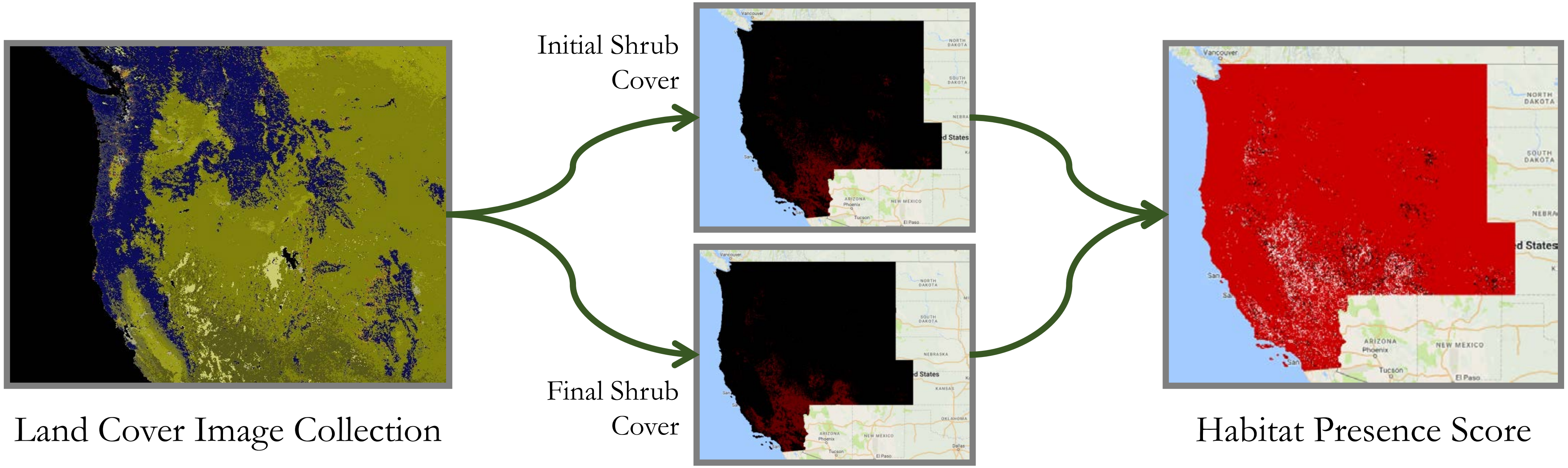
Criterion 3: Habitat Dynamics

Background

The sagebrush biome is under a heightened threat of reduction from nonnative annual grasses and the expansion of native woody species with a warming climate (Neilson et al. 2005). Neilson et al. found a clear tendency of sagebrush displacement from the southern to the northern ends of the species' current range. Higher temperatures are likely to move the frost line that separates southwestern deserts from frost-sensitive vegetation in the sagebrush ecosystem sharply north. As a result, many southwestern plant species could shift northwards into the Great Basin and displace current sagebrush vegetation. In fact, Neilson et al. found only a few small areas in the Great Basin where sagebrush is simulated to persist.

Methods

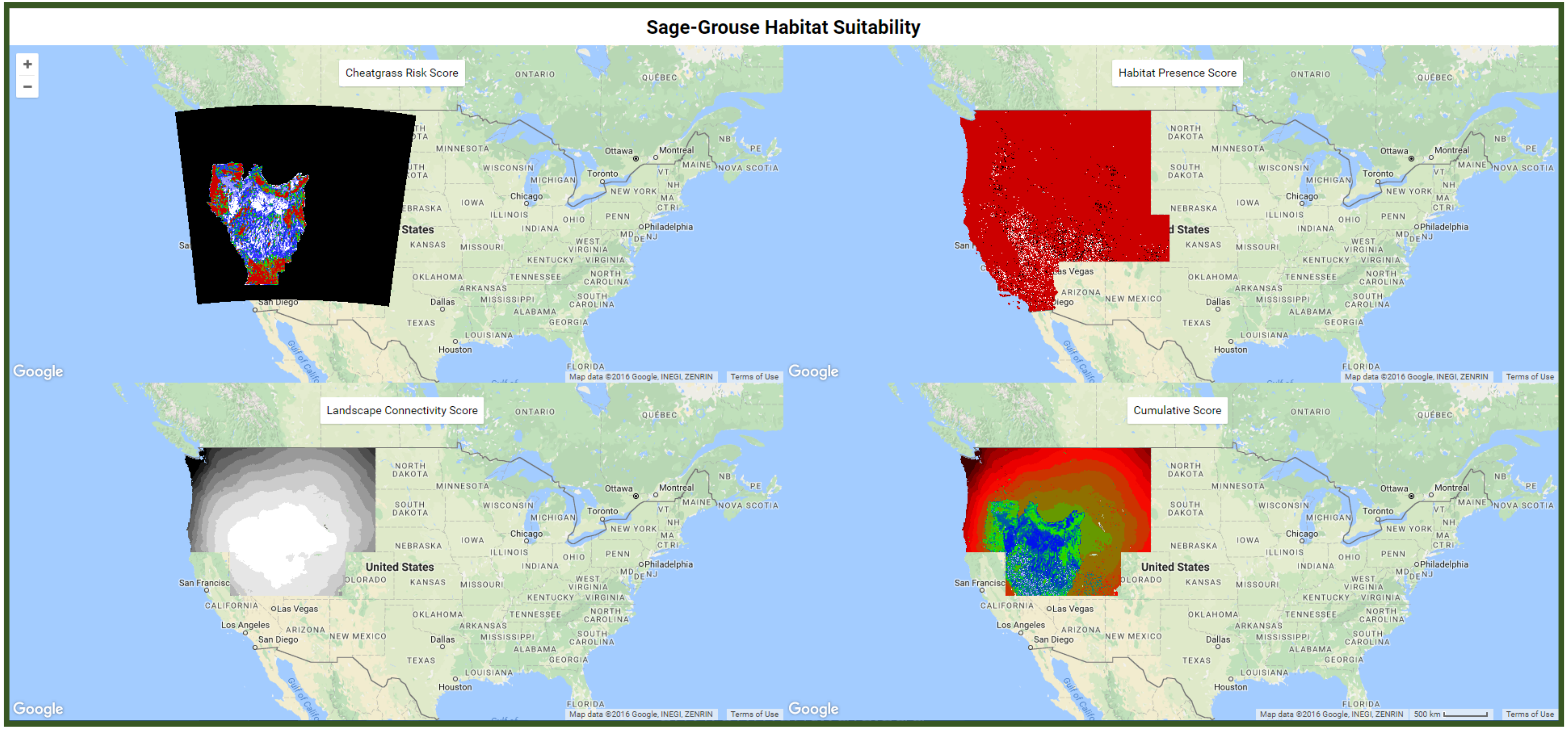
A land cover image collection ranging from 2001 to 2013 was imported into Google Earth Engine and shrubland was selected individually. A function was created to extract the median images from both the first and last 5 years of the collection and clip the image to the states of interest. Median shrubland in the last five years was subtracted from shrubland present in the first five years of the analysis to identify regions of shrubland expansion and contraction. This layer was remapped and a score grid generated, with pixels of decreased shrubland presence assigned a value of 0 and increased shrubland a value of 10.



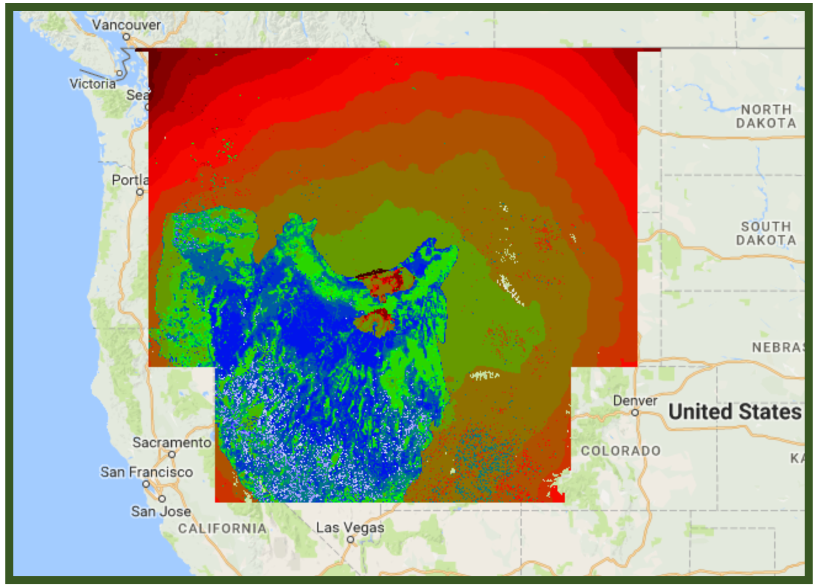
Cumulative Score

Methods

Score grids for each of the three aforementioned criteria were summed. This combined grid was scaled to values between 0 and 100. Scores greater than 90 were removed and identified as the areas most critical for sage-grouse conservation.

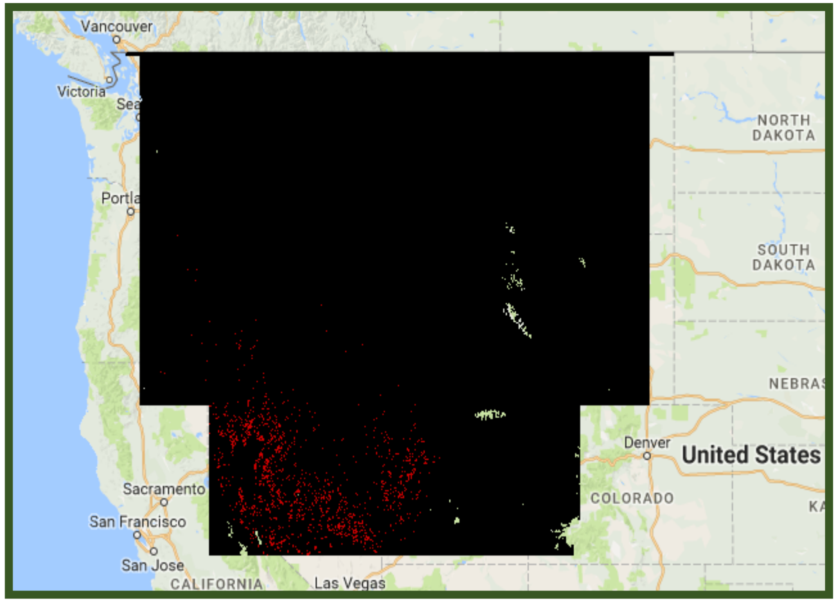


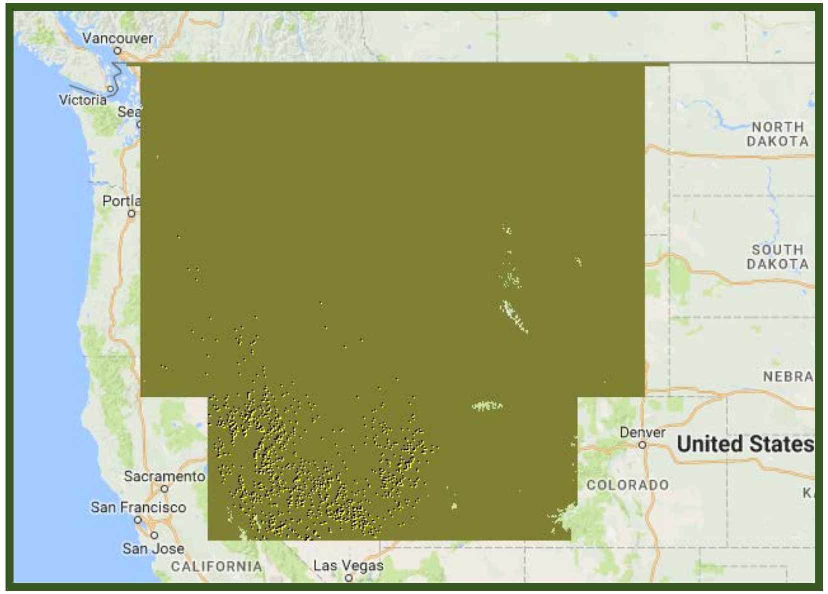
Cumulative Score



Cumulative Score

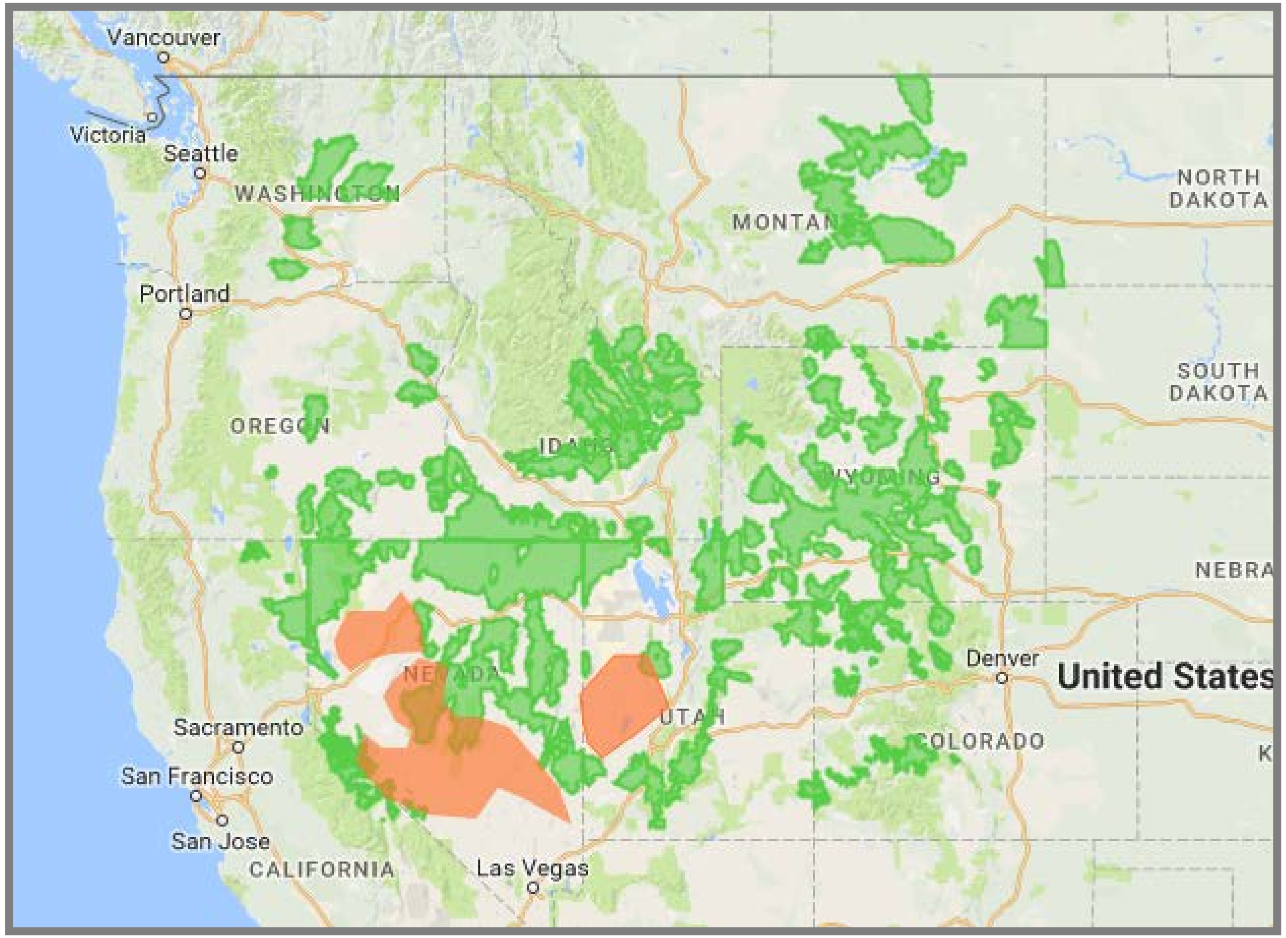
Top scores selected





Roberts Kernel

Cumulative Score



Polygons were drawn in Google Earth Engine around areas of high kernel density. Here, these polygons are compared with a feature collection of current sage-grouse protection areas.

While there is some overlap, our results suggest that much of the critical sage-grouse habitat determined using our criteria is not currently protected. These land parcels may be critical habitat areas or connectivity corridors linking source and sink populations across the landscape.

More robust modeling that accounts for additional criteria and on-the-ground analysis is needed.

```
// Center the map on Wyoming
Map.setCenter(-107.897, 43.149, 5);

//Define global variables -- thanks to Ethan Addicott for assistance here

//Create panel names
var NAMES = [
 'Cheatgrass Risk Score',
 'Landscape Connectivity Score',
 'Habitat Presence Score',
 'Cumulative Score'
 ];
var maps = [];
var map1 = ui.Map();
var map2 = ui.Map();
var map3 = ui.Map();
var map4 = ui.Map();

//Add labels to maps
map1.add(ui.Label(NAMES[0]));
map2.add(ui.Label(NAMES[1]));
map3.add(ui.Label(NAMES[2]));
map4.add(ui.Label(NAMES[3]));


//Load U.S. states and filter out those not included in sage grouse managament planning
var USStates = ee.FeatureCollection('ft:1fRY18cjsHzDgGiJiS2nnpUU3v9JPDc2HNaR7Xk8');
var SageStatesLIST = ee.List(['Washington', 'Oregon', 'California', 'Nevada', 'Idaho', 'Montana',
'Wyoming', 'Utah', 'Colorado']);
var SageFILTER = ee.Filter.inList('Name', SageStatesLIST);
var SageStates = USStates.filter(SageFILTER);
Map.addLayer (SageStates, {color: '997A66'}, 'Sage States');



// CRITERION 1: CHEATGRASS RISK

//Load a layer of sage-grouse habitat risk related to cheatgrass encroachment
var CheatgrassRisk = ee.Image('users/LukeMenard/Cheatgrass');
Map.addLayer(CheatgrassRisk, { min: 0, max: 10, palette:['000000','ff0000','00ff00','0000ff','ffffff']},
'Cheatgrass Risk' );
var CheatgrassSCORE = CheatgrassRisk.remap([1,2,3,4,5,6,7,8,9,10], [10,9,8,7,6,5,4,3,2,1], 0);
Map.addLayer(CheatgrassSCORE, { min: 0, max: 10, palette:['000000','ff0000','00ff00','0000ff','ffffff']},
'Cheatgrass Score' );



//CRITERION 2: LANDSCAPE CONNECTIVITY
```

```
//Factor 1: Elevation

//Load an elevation layer and clip to states of interest
var Elevation = ee.Image('CGIAR/SRTM90_V4').clip(SageStates);
//Elevation = Elevation.reduceNeighborhood(ee.Reducer.mean(), ee.Kernel.circle(2));
Map.addLayer(Elevation, { min: 0, max: 3000, palette:['0000aa','00aa00','ffff00','990000'],opacity:0.9},
'Elevation');

//Scale elevation layer
var ElevationUNITSCALE = Elevation.unitScale(0,3000);
var ElevationSLICED = ElevationUNITSCALE.multiply(10).floor().int();
Map.addLayer(ElevationSLICED , { min: 0, max: 10, palette:['000000','ff0000','00ff00','0000ff','ffffff']},
'Sliced Elevation' );

// var aspect = ee.Terrain.aspect(Elevation).unitScale(0,3000);
// var Aspect_Elev = Elevation.add(aspect).divide(2);


//Convert the sliced elevation layer into an elevation-specific cost layer based on species' habitat needs
var ElevationCOST = ElevationSLICED.remap([0, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10], [7, 5, 4, 3, 2, 1, 2, 3, 5, 7, 9]);
Map.addLayer(ElevationCOST, { min: 0, max: 10, palette:['000000','ff0000','00ff00','0000ff','ffffff']},
'Elevation Cost' );

//Factor 2: Land use

//Load an Image of 2009 worldwide land use allocations
var landuse = ee.Image('MCD12Q1/MCD12Q1_005_2009_01_01');
Map.addLayer(landuse, { min: 0, max: 20}, 'Land Cover');

//Land_Cover_Type_1_class_names:
// 0: Water
// 1: Evergreen Needleleaf Forest
// 2: Evergreen Broadleaf Forest
// 3: Deciduous Needleleaf Forest
// 4: Deciduous Broadleaf Forest
// 5: Mixed Deciduous Forest
// 6: Closed Shrubland
// 7: Open Shrubland
// 8: Woody Savanna
// 9: Savanna
// 10: Grassland
// 11: Permanent Wetland
// 12: Cropland
// 13: Urban
// 14: Crop/Natural Veg. Mosaic
// 15: Permanent Snow/Ice
// 16: Barren/Desert
```

```
// 17: Unclassified

//Reclassify land use values to create a land use cost grid
var LandCOST = landuse.remap([0,1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17],
[10,6,6,6,6,6,1,1,4,4,3,3,5,10,4,9,9,10]);
LandCOST = LandCOST.clip(SageStates);
Map.addLayer(LandCOST, { min: 0, max: 10, palette:['000000','ff0000','00ff00','0000ff','ffffff']}, 'Land
Cover Cost');


// Factor 3: Road Presence

//Load a road image and clip to states of interest
var Roads = ee.Image('users/LukeMenard/Reclass_Road').clip(SageStates);
Map.addLayer(Roads, {color: 'ff00ff'}, 'Roads');
// Reclassify to give roads a high travel cost value
var RoadCOST = Roads.remap([0,1], [0,8]);
Map.addLayer(RoadCOST, {color: 'ffffff'}, 'Road Cost');


// Create an overall cost grid

var OverallCOST = ElevationCOST.add(LandCOST).add(RoadCOST).divide(3);
Map.addLayer(OverallCOST, { min: 0, max: 10, palette:['ffffff', '0000ff', '00ff00', 'ff0000', '000000']},
'Overall Cost');


//Load Sage Grouse Management Zones data
var SageMZ = ee.FeatureCollection('ft:1pea9Z0wyeqaKxe5_aydQ-3cb8otJteAynBQFbXrN'); //Sage
Grouse Management Zones
Map.addLayer(SageMZ,{color: 'FF7F72'}, "Sage Grouse Management Zones");

//Create a function that extracts a centroid for each Management Zone
function CentroidALGORITHM(Polygon)
    { var CentroidFEATURE = Polygon.centroid( );
      return CentroidFEATURE.buffer( 10000 );
    }

//Filter out each Management Zone and create a centroid
var WBMZFilter = ee.Filter.eq('name', 'Wyoming Basins Management Zone');
var WBMZ = SageMZ.filter(WBMZFilter);
var WBMZCentroid = WBMZ.map(CentroidALGORITHM);
var WBMZsource = ee.Image().toByte().paint(WBMZCentroid, 1);
WBMZsource = WBMZsource.updateMask(WBMZsource);
Map.addLayer(WBMZsource);
var WBMZcost = OverallCOST.cumulativeCost({
      source: WBMZsource,
      maxDistance: 1000000
```

```
    });
Map.addLayer(WBMZcost, {min: 0, max: 1500000}, 'WBMZ Cost');

var SRPMZFilter = ee.Filter.eq('name', 'Snake River Plain Management Zone');
var SRPMZ = SageMZ.filter(SRPMZFilter);
var SRPMZCentroid = SRPMZ.map(CentroidALGORITHM);
var SRPMZsource = ee.Image().toByte().paint(SRPMZCentroid, 1);
SRPMZsource = SRPMZsource.updateMask(SRPMZsource);
Map.addLayer(SRPMZsource);
var SRPMZcost = OverallCOST.cumulativeCost({
     source: SRPMZsource,
     maxDistance: 1000000
    });
Map.addLayer(SRPMZcost, {min: 0, max: 1500000}, 'SRPMZ Cost');


var SGBMZFilter = ee.Filter.eq('name', 'Southern Great Basin Management Zone');
var SGBMZ = SageMZ.filter(SGBMZFilter);
var SGBMZCentroid = SGBMZ.map(CentroidALGORITHM);
var SGBMZsource = ee.Image().toByte().paint(SGBMZCentroid, 1);
SGBMZsource = SGBMZsource.updateMask(SGBMZsource);
Map.addLayer(SGBMZsource);
var SGBMZcost = OverallCOST.cumulativeCost({
     source: SGBMZsource,
     maxDistance: 1000000
    });
Map.addLayer(SGBMZcost, {min: 0, max: 1500000}, 'SGBMZ Cost');


var CPMZFilter = ee.Filter.eq('name', 'Colorado Plateau Management Zone');
var CPMZ = SageMZ.filter(CPMZFilter);
var CPMZCentroid = CPMZ.map(CentroidALGORITHM);
var CPMZsource = ee.Image().toByte().paint(CPMZCentroid, 1);
CPMZsource = CPMZsource.updateMask(CPMZsource);
Map.addLayer(CPMZsource);
var CPMZcost = OverallCOST.cumulativeCost({
     source: CPMZsource,
     maxDistance: 1000000
    });
Map.addLayer(CPMZcost, {min: 0, max: 1500000}, 'CPMZ Cost');


var GPMZFilter = ee.Filter.eq('name', 'Great Plains Management Zone');
var GPMZ = SageMZ.filter(GPMZFilter);
var GPMZCentroid = GPMZ.map(CentroidALGORITHM);
var GPMZsource = ee.Image().toByte().paint(GPMZCentroid, 1);
GPMZsource = GPMZsource.updateMask(GPMZsource);
Map.addLayer(GPMZsource);
```

```
var GPMZcost = OverallCOST.cumulativeCost({
        source: GPMZsource,
        maxDistance: 1000000
      });
Map.addLayer(GPMZcost, {min: 0, max: 1500000}, 'GPMZ Cost');


var NGBMZFilter = ee.Filter.eq('name', 'Northern Great Basin Management Zone');
var NGBMZ = SageMZ.filter(NGBMZFilter);
var NGBMZCentroid = NGBMZ.map(CentroidALGORITHM);
var NGBMZsource = ee.Image().toByte().paint(NGBMZCentroid, 1);
NGBMZsource = NGBMZsource.updateMask(NGBMZsource);
Map.addLayer(NGBMZsource);
var NGBMZcost = OverallCOST.cumulativeCost({
        source: NGBMZsource,
        maxDistance: 1000000
      });
Map.addLayer(NGBMZcost, {min: 0, max: 1500000}, 'NGBMZ Cost');


var CBMZFilter = ee.Filter.eq('name', 'Columbia Basin Management Zone');
var CBMZ = SageMZ.filter(CBMZFilter);
var CBMZCentroid = CBMZ.map(CentroidALGORITHM);
var CBMZsource = ee.Image().toByte().paint(CBMZCentroid, 1);
CBMZsource = CBMZsource.updateMask(CBMZsource);
Map.addLayer(CBMZsource);
var CBMZcost = OverallCOST.cumulativeCost({
        source: CBMZsource,
        maxDistance: 1000000
      });
Map.addLayer(CBMZcost, {min: 0, max: 1500000}, 'CBMZ Cost');


//Combine individual travel cost layers to create a Cumulative Cost layer
var CumulativeCost =
(WBMZcost.add(SRPMZcost).add(SGBMZcost).add(CPMZcost).add(GPMZcost).add(NGBMZcost).add(CB
MZcost)).divide(7);
Map.addLayer(CumulativeCost, {min: 1000000, max: 2500000}, 'Cumulative Cost');

//var HighConnectivity = ee.Image(CumCostSLICED).lt(15);
//HighConnectivity = CumCostSLICED.where(HighConnectivity.neq(1), 0);
//Map.addLayer(HighConnectivity, {min: 0, max: 1}, 'High Connectivity');

//Scale Cumulative Cost layer and reclassify to create a connectivity score layer
var ConnScoreUNITSCALE = CumulativeCost.unitScale(1000000,2500000);
var ConnScoreSLICED = ConnScoreUNITSCALE.multiply(10).floor().int();
var ConnectivityScore = ConnScoreSLICED.remap([0,1,2,3,4,5,6,7,8,9,10], [10,9,8,7,6,5,4,3,2,1,0], 0);
Map.addLayer(ConnectivityScore, {min: 0, max: 10}, 'Connectivity Score');
```

```
//CRITERION 3: HABITAT LOST AND GAIN

//Load a land cover image collection
var LandUseCOLLECTION = ee.ImageCollection('MODIS/051/MCD12Q1');
Map.addLayer(LandUseCOLLECTION, { min: 0, max: 20}, 'Land Cover');

//Sort by date and pull out first and last 5 images
var FirstFive = LandUseCOLLECTION.sort('system:index', true).limit(5);
var LastFive = LandUseCOLLECTION.sort('system:index', false).limit(5);

//Select only shrub bands from those layers
var FirstFiveSELECT = FirstFive.select(['Land_Cover_Type_1']);
var LastFiveSELECT = LastFive.select(['Land_Cover_Type_1']);

//create a function that finds the median values of first and last 5 images and clips to states of interest
function MEDIAN(featureCollection)
{
 var Median = featureCollection.median();
 var MedianCLIP = Median.clip(SageStates);
 return MedianCLIP;
}
var FirstFiveMEDIAN = MEDIAN(FirstFiveSELECT);
var LastFiveMEDIAN = MEDIAN(LastFiveSELECT);

var FirstFiveShrubland = FirstFiveMEDIAN.eq(7).or(FirstFiveMEDIAN.eq(6));
Map.addLayer(FirstFiveShrubland,{ min: 0, max: 10, palette:['000000','ff0000','00ff00','0000ff','ffffff']},
'Initial Shrubland');
var LastFiveShrubland = LastFiveMEDIAN.eq(7).or(LastFiveMEDIAN.eq(6));
Map.addLayer(LastFiveShrubland,{ min: 0, max: 10, palette:['000000','ff0000','00ff00','0000ff','ffffff']},
'Final Shrubland');


//Calculate change in shrub cover
var ShrubChange = LastFiveShrubland.subtract(FirstFiveShrubland);
Map.addLayer(ShrubChange,{ min: -1, max: 1, palette:['000000','ff0000','00ff00','0000ff','ffffff']},
'Shrubland Change');

//Reclassify to create a land change score grid
var LandChangeSCORE = ShrubChange.remap([-1,0,1], [0, 2, 10]);
Map.addLayer(LandChangeSCORE,{ min: 0, max: 10, palette:['000000','ff0000','00ff00','0000ff','ffffff']},
'Land Change Score');


// DETERMINE AN OVERALL SCORE
```

```
var FinalScore = LandChangeSCORE.add(ConnectivityScore).add(CheatgrassSCORE);
var FinalScoreUNITSCALE = FinalScore.unitScale(0,30);
var FinalScoreSLICED = FinalScoreUNITSCALE.multiply(100).floor().int();
Map.addLayer(FinalScoreSLICED,{ min: 0, max: 100, palette:['000000','ff0000','00ff00','0000ff','ffffff']},
'Final Score');
//var FinalScoreREDUCE = FinalScoreSLICED.reduceNeighborhood(ee.Reducer.mean(),
ee.Kernel.circle(2));

//Extract top scores
var TopScores = FinalScoreSLICED.gt(90);
TopScores = TopScores.eq(1);
Map.addLayer(TopScores,{ min: 0, max: 5, palette:['000000','ff0000','00ff00','0000ff','ffffff']}, 'Final
Score');



//ADDITIONAL ANALYSES

//Load Sage Grouse Priority Areas for Conservation data
var SagePAC = ee.FeatureCollection( 'ft:1iAeJSrHRA0KcoyAfi5JLbiDLxOHToHVcDbEzM5k3' );
SagePAC = SagePAC.filterBounds(SageStates);
Map.addLayer(SagePAC,{color: '59CC47'}, "Sage Grouse PAC");

var KERNEL = ee.Kernel.roberts();
var TopScoresKERNEL = TopScores.convolve(KERNEL);
Map.addLayer(TopScoresKERNEL, {min: -1, max: 1, palette: ['000044', 'ffff22']}, 'Top Scores Kernel');


//Create a map grid and add 4 score rasters
map1.addLayer(CheatgrassSCORE,{ min: 0, max: 10, palette:['000000','ff0000','00ff00','0000ff','ffffff']},
'Cheatgrass Score');
map1.setControlVisibility(false);
map2.addLayer(ConnectivityScore,{min: 0, max: 10},'Connectivity Score');
map2.setControlVisibility(false);
map3.addLayer(LandChangeSCORE,{ min: 0, max: 10,
palette:['000000','ff0000','00ff00','0000ff','ffffff']},'Land Change Score');
map3.setControlVisibility(false);
map4.addLayer(FinalScoreSLICED,{ min: 0, max: 100,
palette:['000000','ff0000','00ff00','0000ff','ffffff']},'Cumulative Score');
map4.setControlVisibility(false);
maps.push(map1);
maps.push(map2);
maps.push(map3);
maps.push(map4);

//Link map quadrants
var linker = ui.Map.Linker(maps);
// Enable zooming
```

```
maps[0].setControlVisibility({zoomControl: true});
// Show the scale
maps[3].setControlVisibility({scaleControl: true});
// Create a title.
var title = ui.Label('Sage-Grouse Habitat Suitability', {
stretch: 'horizontal',
textAlign: 'center',
fontWeight: 'bold',
fontSize: '24px'
});
// Create a grid of maps.
var mapGrid = ui.Panel([
ui.Panel([maps[0], maps[1]], null, {stretch: 'both'}),
ui.Panel([maps[2], maps[3]], null, {stretch: 'both'})
],
ui.Panel.Layout.Flow('horizontal'), {stretch: 'both'}
);
print(maps);
// Add the maps and title
ui.root.widgets().reset([title, mapGrid]);
ui.root.setLayout(ui.Panel.Layout.Flow('vertical'));


// CODE FOR FUTURE ANALYSES

//Calculate the number of pixels of critical land protect in Sage Grouse Priority Areas for Conservation
// var TopScoresCLIP = TopScores.clip(SagePAC);
// Map.addLayer(TopScoresCLIP,{ min: 0, max: 1, palette:['000000','ff0000','00ff00','0000ff','ffffff']},
'Final Score');

// var PACReducer = ee.Reducer.count();
// var PACstats = TopScoresCLIP.reduceRegion(PACReducer, SagePAC, 500, null, null, true);
// print('Pixels protected in Sage Grouse Priority Areas for Conservation: ', PACstats);

// var TopScoresKERNEL1 = TopScoresKERNEL.eq(1);
// var PACReducer = ee.Reducer.count();
// var PACstats = TopScoresKERNEL.clip(SagePAC).reduceRegion(PACReducer, SagePAC, 500, null, null,
true);
//print('Pixels protected in Sage Grouse Priority Areas for Conservation: ', PACstats);
```