**NASA DEVELOP National Program**

NASA Langley Research Center

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Southern Rockies Ecological Forecasting II

Tracking Mule Deer for Wildlife Corridors between

Seasonal Habitats in the Southern Rockies

 **Technical Report**

Rough Draft – Feb 18, 2016

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# I. Abstract

[Placeholder - do not put anything here until the final draft submission. The abstract in the project summary is where the working draft of the abstract should “live”]

**Keywords**

Insert here 2-8 keywords that relate to your project

Example: Remote Sensing, Biomass Burning, Erosion, Sea Level Rise, etc.

Remote Sensing, GPS, Phenology, Mule Deer, Migration Patterns, Land Corridors, Habitat Loss

# II. Introduction

Including the items listed below; write a synopsis of the following information. Be concise. Word count should be between 200-1000 as one to two pages should suffice.

Material to include:

* Background Information: Relevant information to inform the reader of current status, issues, previous studies, etc
* Project Objectives: These should be short decisive action items.
* Study Area: Describe the geographic location of the study
* Study Period: Explain the time period of data you are looking at (years and dates of data)
* National Application(s) Addressed: Explain which NASA national application areas this project addresses and how it contributes to them
* Project Partners: Explain who the project partners are, why they are interested in this project, how they will use it, what decision making they have to do and is being addressed with this research and methodologies, etc. How will they benefit from this project and methodology?

Mule deer, Odocoileus heminonus, are considered a migratory species with reports that have mule deer traveling up to 241 km in western Wyoming (Sawyer et al. 2014), although most migrations were found to be around 20-158 km (Sawyer et al. 2005). Migration occurs in the spring and fall months, spring migration occurs as the deer follow the “green up” of grasses and forbs to primarily higher elevations, and fall migration occurs when the deer travel to lower elevations to escape harsh conditions and deep snow that occurs at higher elevations during winter months (Sawyer 2014). Finding food becomes much more of a challenge during winter months, so their diet adjusts as their normal food supplies dwindle due to “brown down” (Monteith et al. 2011). During this time, their diets consist mainly of trees and shrubs (Olsen 1992). As temperatures warm and plants begin to “green up” in the spring, mule deer switch from eating nutrient deficient shrubs to nutrient rich herbaceous grasses and forbs located in higher elevations (Olsen 1992). During the summer, food is abundant and widely variant with grasses being consumed until they start to dry and cure in late summer, while forbs remain the dominant food source and consist of about 75% of their diet. The summer feeding season is in the elevation range of 6,500-11,500 feet (Watkins et al. 2007). The forbs include red clover (Trifolium pratense), yellow sweet clover (Melilotus officinalis), dandelion (Taraxacum), and huckleberry (Vaccinium spp.) (Olsen 1992). In the fall, as the weather begins to cool and the first frosts begin to arrive, forbs start to wane from their diet and are replaced predominantly by shrubby vegetation; during this time forbs consist of roughly 25% of their diet (Olsen 1992). Some especially important plants during the winter months include sagebrush (Artemisia spp.), antelope bitterbrush (Prushia tridentate), mountain mahogany (Cercocarpus spp.) and rabbit brush (Chryosthanmus spp.) (Olsen 1992). Supreme wintertime habitats consist of approximately 45% shrubland, 45% coniferous forest, and 10% forbs and grasslands (Olsen 1992) and are generally below 7,500 feet in elevation (Watkins et al. 2007).

Habitat fragmentation primarily caused by anthropogenic disturbances is affecting the migratory patterns of mule deer. The creation of oil and gas lines, along with urban sprawl have caused indispensable migratory corridors to disappear, which in turn is causing a decline in mule deer (Lendrum et al. 2013). Daryl Lutz of the Wyoming Game and Fish Department noted that in Wyoming alone there has been a 36% decrease in mule deer population from 1991-2012 (Madison 2014). Some herds of mule deer do not necessarily avoid roads and other anthropogenic features, but the increase in human features has caused these herds to migrate at different times. Research shows that herds near more-developed areas are migrating earlier and moving faster. The reason why they are moving faster and earlier is so that they can get around these areas and to lower elevations in time for the cold season. These changes in migration patterns have also caused more deaths of mule deer as more get killed due to cars, get stuck in fenced in areas, and other human-caused accidents (Lendrum et al. 2013). Habitat fragmentation is caused by the different levels of property ownership of federal, state, and privately owned lands. Federal lands occupy approximately 640 million acres, make up 28% of the total land in the United States, and are divided between disconnected private, state, and federal grounds (Gorte et al. 2012). Mule deer need land corridors between these different classified lands because as migratory animals, they move seasonally between high-elevation summer ranges with abundant food and low-elevation winter ranges with nutrient deficient shrubs (Sibbald and Gordon, 2001). These migratory paths have been tracked with collared mule deer and GPS technology that is accurate to 30m locations (Tomkiewics et al. 2010). The tagging process is referred to biologging and relays data about animal’s movements, behavior, and their environment (Rutz and Hays, 2009).

Southern Rockies Ecological Forecasting team II (SREF) has produced maps that show the best summer highlands and winter habitats and the long migration routes in between them for the deer that will help Western Association of Fish and Wildlife Agencies (WAFWA) Mule Deer Working Group and Southern Rockies Landscape Conservation Cooperative (SRLCC) create corridors. The study period spans four years, from 2011 to 2015, and looks at the mule deer population located within the borders of the SRLCC located in the southern Rocky Mountains that spans six states including Arizona, Colorado, Idaho, New Mexico, Utah, and Wyoming encompassing about 516,754 square km. NASA DEVELOP National Program and SREF has partnered with WAFWA as well as the SRLCC to examine ways in which humans can conserve land for mule deer and the decline in mule deer’s population.

# III. Methodology

This should be the focus of the paper - concise, yet explanatory, and highlight the NASA Earth observations utilized and its/their capabilities. Include a paragraph or more for each of the following items. No word cap, but be thoughtful and keep it in the two to six page range.

Content to include:

* Data Acquisition: What data did you get, what level products are they, for what dates did you get images, where did you get the images from, etc.
* Data Processing: What did you do to the data? Were there conversions needed to be able to analyze it? Did you have to mosaic images? Did you have to normalize anything to fit other datasets? Did you run an NDVI, change detection, etc?
* Data Analysis: How did you analyze the data? What methods did you use?

Data Acquisition

1. Land Cover

The USGS 2011 National Landcover Database (NLCD), which has a spatial resolution of 30 meters is based predominantly on a decision-tree classification of 2011 Landsat satellite data, was downloaded from the Multi-Resolution Land Characteristics Consortium (MRLC).

1. Southern Rockies LCC Boundary

The shapefile of the SRLCC boundary was downloaded through USGS’s ScienceBase catalog. The SRLCC spans six states and covers about 516,754 square km.

1. Mule Deer Habitat Ranges

Mule deer habitat range data was downloaded from Utah State University’s Remote Sensing and Geographic Information Systems Laboratory website. The database included six different shapefiles for the mule deer’s limited range, year-round population, summer range, winter range, winter concentration, and other important habitat. The six habitat areas were mapped using a minimum mapping unit of roughly six square miles and demarcated onto 1:250,000 scale sheet maps. The mule deer habitat range data was later used as a comparison to our mule deer range maps.

1. Elevation

Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) is one of the five instrument sensor systems on board Terra which utilizes a backwards looking telescope to create stereo coverage to obtain elevation data . ASTER Digital Elevation Model (DEM) data products are produced with a 30m resolution. The Global Digital Elevation Model V002 was downloaded from SGS global data explorer (GDEX) website and incorporated into our final Mule Deer Range Map.

1. Climate Data

Parameter-elevation Relationships on Independent Slopes Model (PRISM) Climate Group is modeled using climatologically-aided interpolation (CAI). PRISM datasets that included precipitation data in mm and mean temperature data were obtained. New M3 and D2 versions of AN81m, with a 4 km resolution, and AN81d improved consistency to the data. The data was downloaded in monthly intervals between January 2011 and December 2015. DEM was used for the predictor grid.

1. Vegetation Phenology Data

Land Surface Phenology (LSP) and vegetation phenology products were obtained through the Utah State Forest Service (USFS) ForWarn System for the years 2011, 2012, 2013, and 2014 at a 232m resolution. The ForWarn System relies on MODIS satellite data that tracks changes in the NDVI and shows average, minimum, and maximum NDVI values.

Data Processing

1. Land Cover
	1. Land Cover

The NLCD was clipped to the SRLCC boundary layer and incorporated into the mule deer range maps.

* 1. Mule Deer Habitat Ranges

The seasonal ranges were extracted from the dataset and created as a layer.

* 1. SRLCC Boundary

The shapefile of the SRLCC boundary was added to the used as the extent of the mule deer range maps.

1. DEM and Climate
	1. DEM

One raster file was produced to include and mosaic all of the ASTER data. The file was then clipped to show the study area and the mule deer winter range. Statistics that included mean elevation for the winter range were then calculated into ArcMap.

* 1. PRISM

PRISM monthly datasets were converted from Band Interleaved by Line (BIL) image files to tiff files. Python was then used to clip the study area and average monthly data to yearly data.

1. Vegetation phenology
	1. An Iterative Self-Organizing Data Analysis Technique (ISODATA) unsupervised classification technique in ERDAS Imagine was used to stack MODIS based NDVI and day of year phenology products into a single image and then classify it into 30 distinct classes.

Data Analysis

Data were analyzed using ArcMap 10.3.1 and ERDAS Imagine software.

# IV. Results & Discussion

Insert images, graphs, maps, charts, etc. here. Choose the most important results to highlight here. No word cap, but two to six pages is a good range.

Things to discuss:

* Analysis of Results: What can you tell from your graphs, images, etc? What does this mean for your project?
* Errors & Uncertainty: What factors could you not account for, what things didn’t work out like you expected they would, etc.
* Future Work: If this project was to be selected for another term, what would be the focus? What other areas would be of interest?

# V. Conclusions

Final conclusions. Word count: 200-600 (~a page).

# VI. Acknowledgments

Insert here. Keep to a concise paragraph or bullets of names. End with the following sentence.

This material is based upon work supported by NASA through contract NNL11AA00B and cooperative agreement NNX14AB60A.

# VII. References

Insert references here. Only include articles/content cited in the body of text above. It’s great if you read many other articles, but they should not all be listed here unless they are being cited in this report.

Use whatever style you want - here are some options:

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# VIII. Content Innovation

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# IV. Appendices

Insert here