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6 December 2023

Mapping Eastern Redcedar *[Juniperus Virginiana L.]* Encroachment in Western Oklahoma from 2015 through 2022

Introduction

Many studies have been executed over the previous decades that attempt to quantify the encroachment of the *Juniperus Virginiana L.*, or Eastern Redcedar throughout the state of Oklahoma [Eastern Redcedar, or Redcedar, will be the terms used for the remainder of this paper]. One of the most notable studies was performed in 1985 by the Soil Conservation Service that provided alarmingly high statistics of the amount of land inhabited by this invasive species throughout the state. This report concluded that 1.5 million acres had been invaded by the Redcedar in 1950, and this figure had reached 3.5 million acres by the year 1985 [Snook, 1985]. This equates to an average expansion rate of approximately 57,140 acres per year. Considering these increasingly high numbers, it is appropriate to conclude that this species must have substantial negative impacts on the natural ecosystems that exist throughout this beautiful landscape. Some of these consequences include, but are not limited to, negative effects on native wildlife habitats, negative effects on endangered or threatened plants, animals, and ecosystems, negative effects on wildlife urban interface, negative effects on water and air quality, negative effects on biological diversity and ecosystem management, negative effects on forage production for livestock, and negative effects on rangeland ecological conditions [Bidwell, 2009].

While there is an abundance of information synchronously portraying comparable statistics on the rate of encroachment of the Eastern Redcedar, there are also case studies that propose monitoring this invasion using methods outside the confines of traditional field survey techniques. One such case study, *Mapping the Dynamics of Eastern Redcedar Encroachment into Grasslands During 1984-2010 Through PALSAR and Time Series Landsat Images*, argues that "… it is imperative to produce annual and multi-year maps of woody plant encroachment at regional and continental scales." [Wang, 2017] This case study provides ample evidence that satellite imagery and remote sensing technologies can produce maps that illustrate the encroachment of invasive species, particularly the Eastern Redcedar. The methodologies used throughout the study include mapping algorithms, PALSAR and Landsat satellite imagery, the use of various vegetation indices, and field survey data [Wang, 2017] to accomplish their objective; while these methods are well beyond the scope of this research paper, the Wang, et al. case study does seek the same quantitative answers as this project, only this paper will focus on gathering the desired results using a much more fundamental, introductory level approach.

Objective

The objective of this paper is to utilize satellite imagery to estimate, in a very generalized manner, the increase of Eastern Redcedar encroachment [in a single confined study area] that occurred between 2015 and 2022 in western Oklahoma. The satellite imagery used, preprocessing techniques, and classification methods will be outlined throughout this paper in a very documented approach. Finally, a quantitative conclusion will be drawn to determine whether a rudimentary approach to monitoring Redcedar encroachment would be adequate to draw quasi-accurate conclusions on this alarming subject.

Study Area

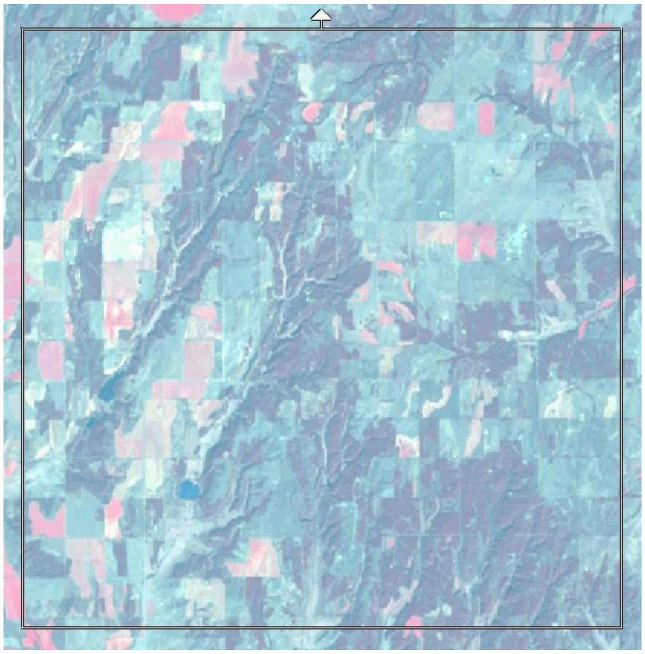
The location of the study area was approximated from a study area illustrated [page 240] in the *Mapping the Dynamics of Eastern Redcedar Encroachment into Grasslands During 1984-2010 Through PALSAR and Time Series Landsat Images* [Wang, 2017] case study; this specific study area was chosen because of the distinguishable geometries of Redcedar forest stands that exist within it. These geometries will facilitate the ability to make a generalized visual comparison to ensure that an encroachment map can, in fact, be produced using fundamental remote sensing techniques only. The study area lies within the western half of the state of Oklahoma, within the confines of Canadian and Caddo counties. The physical extents of this study area are as follows: North [35°26'29.67"], East [-98°13'2.1"], South [35°19'53.94"], West [-98°13'2.1"].

Data

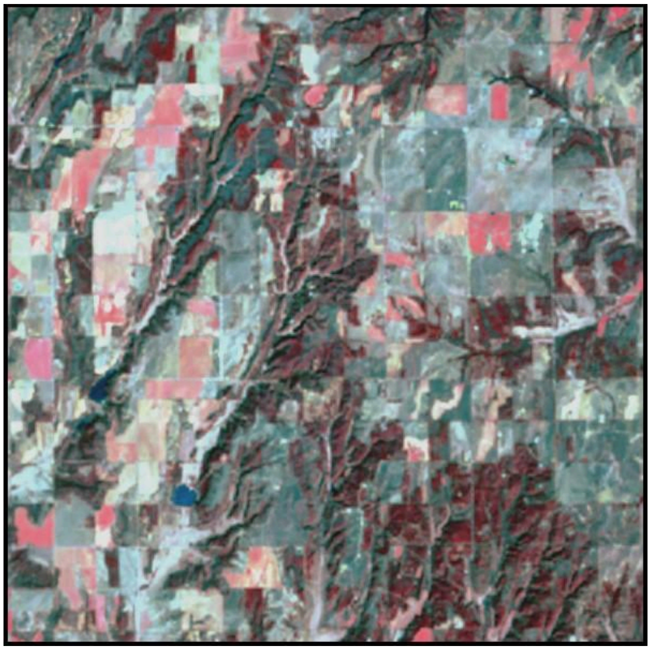
The temporal range of this research paper is from 2015 through 2022; with this range in mind, the obvious choice of satellite imagery would be the most recent and technologically advanced satellites: Landsat 8. Landsat 8 has been in orbit since early 2013 and carries two new additional sensors: the first is the Operational Land Imager and the second is the Thermal Infrared Sensor. The satellite also has two additional spectral bands in its multispectral scanner: Band 1 [Coastal Blue and Aerosol] and Band 9 [Cirrus cloud detection] [Acharya, 2015; NASA, 2023; USGS, 2023]. While the added technologies of this satellite provide no use to this research paper, the quality of data available in the winter months of 2015 and 2022 were significantly better than imagery provided by earlier model Landsat satellites. The study area, or region of interest, falls within Path 28 / Row 35 [satellite orbit path around the earth] and the imagery date used for this study are from January 16th, 2015, and February 12th, 2022. These two dates were chosen because they provide the clearest imagery with the least amount of cloud cover. Also, imagery from the winter months was sought because [Hunt, 2003] suggests that "some noxious rangeland species can be remotely distinguished best in winter… due to its evergreen foliage." While [Hunt,2003] is focused on the Redberry Juniper *[Juniperis pinchotii]*, this same principle can be applied to the Eastern Redcedar encroachment happening throughout the state of Oklahoma. Both data sets were downloaded as Collection 2, Level 2. These data sets provide improved geometric accuracy, improved digital elevation modeling, improved radiometric calibration, updated metadata files, and cloud optimized file formatting [USGS, 2023], which will eliminate certain preprocessing requirements that lie outside the scope of introductory remote sensing procedures utilized in this paper.

Preprocessing

Once the acceptable data sets were located and downloaded from the EarthExplorer website [provided free by the United States Geological Survey], the preprocessing tasks could begin. For this research project, the bands that were utilized from the data set were: Band 1 Coastal Aerosol [0.43 – 0.45µm], Band 2 Blue [0.450 – 0.51µm], Band 3 Green [0.53 – 0.59µm], Band 4 Red [0.64 – 0.67µm], Band 5 Near-Infrared [0.85 – 0.88µm], Band 6 SWIR [1.57 – 1.65µm] and Band 7 SWIR [2.11-2.29µm] [USGS, 2023]. After the individual bands had been stacked and exported into a multispectral format, the subset image was extracted from the Path 28 / Row 35 satellite imagery that included the study area; once this was completed, a suitable band combination could be utilized to set apart Redcedar forest stands from any different land classes that lie within the study area. The subset image of the study area [before any preprocessing functions had been applied] is shown on the image to the right.

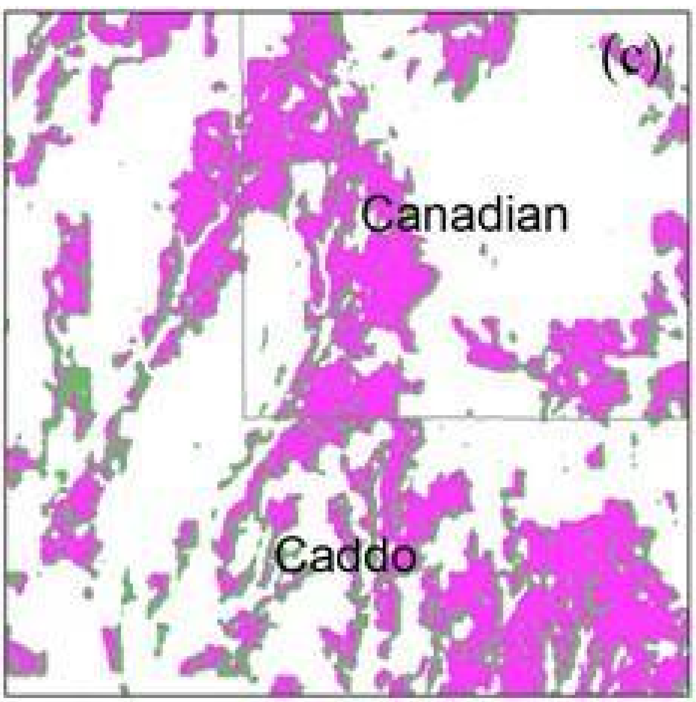


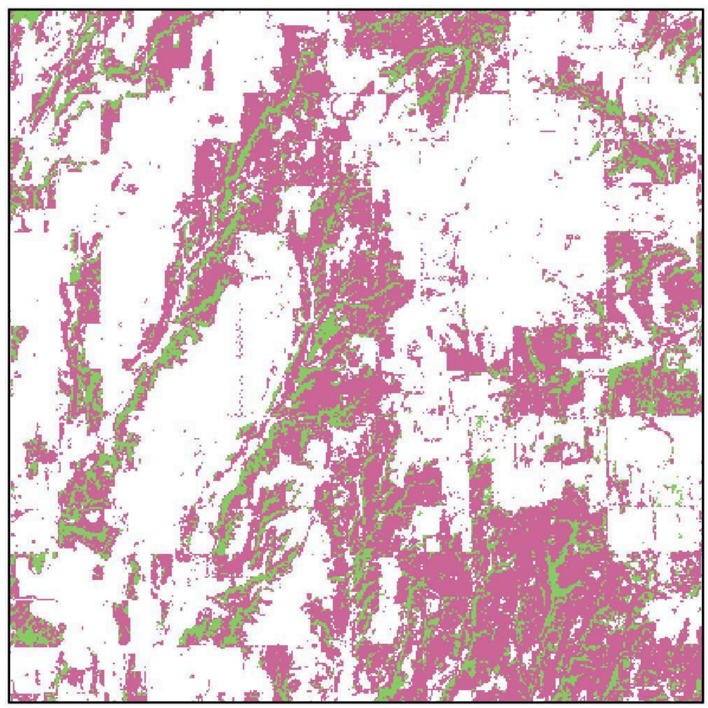
Since healthy vegetation undergoing photosynthesis reflects light in the near-infrared spectrum and vegetation that experiences periods of senescence throughout the winter months does not [Ustin, 2010], a false color band combination is most appropriate for this research paper. To make the near-infrared electromagnetic radiation visible, this spectral range [Band 5] was assigned the color red. This shift was accompanied by assigning the color green to energy in the red spectral range [Band 4] and the color blue to energy in the green spectral range [Band 3]. The result of this band combination is that healthy vegetation will appear red, crops will appear pink to red, water will appear as shades of black or blue, and urbanized / bare earth areas will appear cyan to light green. After this band combination was determined, a Basic Gaussian Stretch was applied to this image to transform the pastel colors into bold, contrasting red and blue tones. These colors were also emphasized by increasing the contrast of the image to slightly polarize the amount of difference in pixel values between areas of mixed forest and Redcedar forests. Finally, a 3X3 Low Pass Filter was applied to eliminate some of the “salt and pepper” areas by homogenizing regions with similar pixel values. Once these preprocessing techniques had been applied, it was easy to determine, along with Google Earth Street View spot checking, that agricultural land classes were displayed in a bright pink tone for winter crops, and bluish tones for grasslands and agricultural fields that were not utilized during the winter months, water was a bright blue tone, and bare earth areas were also a bluish tone. Finally, the Redcedar forest stands were also displayed in a bold red color that contrasted them with the deciduous forests that display a bluish brown tone. The resulting study area [after preprocessing functions had been applied] is shown on the image to the right.



Processing

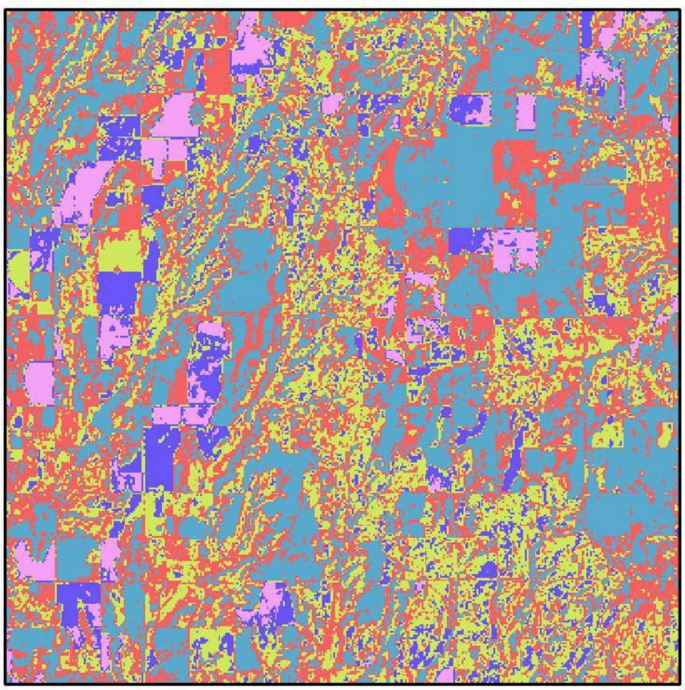
The first objective of the processing stage of this project was to determine if a successful encroachment map could be produced using introductory knowledge of remote sensing; if this objective cannot be completed using these techniques, then all processing techniques would be halted until a more strategic approach could be implemented. This objective will be accomplished by, first classifying the various land classes that exist within the study area and then extracting Redcedar forest areas so it can be compared to the similar study area illustrated in the *Mapping the Dynamics of Eastern Redcedar Encroachment into Grasslands During 1984-2010 Through PALSAR and Time Series Landsat Images* [Wang, 2017] case study. Careful examination of the subset image concludes that the major land classes present in the subset image were agricultural [active and dormant fields], bare earth, grasslands, mixed forest, redcedar forest, and water; however, the land class of concern is the amount of redcedar forest within the subset image. A supervised classification technique was utilized to separate the redcedar forests from all other land classes. This was achieved by drawing polygons around the various land classes [in ERDAS Imagine] on an AOI [Area of Interest] layer and saving them to a signature file. After a satisfactory number of signatures had been created, the supervised classification function was run, and a classified map was produced. To simulate that map that was provided in [shown below on the left] [Wang, 2017], all land classes were turned white in color, except for Redcedar forests and mixed forests. As you can see from the images below, the basic geometries of these two maps are very similar in nature.

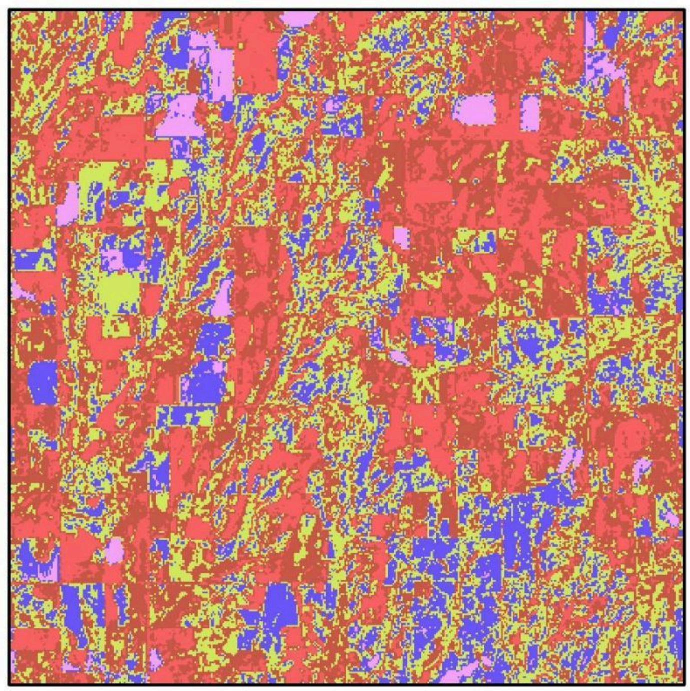




However, considerably apparent discrepancies do exist between the two maps for two outlying circumstances that cannot be ignored. The primary reason for discrepancies between the two maps is due to the extent of processing performed in the [Wang, 2017] case study, which fell well beyond the scope of an introductory course in remote sensing. The second reason was that the [Wang, 2017] map was created using 2010 satellite imagery while the rudimentary map created for this research project utilized datasets of imagery that was collected in 2015; that equates to five years of undocumented growth that is being captured and also causing a discrepancy between the two maps shown above. After this comparison was made, it was determined that the map produced in this project met acceptable standards to proceed further into the investigation of Redcedar encroachment.

Following this decision, the same process was undertaken to produce a land classification map from February 12th, 2022. The exact subset image was extracted from this Landsat 8 dataset, the same preprocessing image modifications were made, and a new signature file was created for this image that utilized the exact same AOI's [Areas of Interest] that were used in the 2015 image. The only difference that was made in the processing stage of this research was adding two signatures for bare earth / grasslands. This decision was based on visual interpretation of the satellite imagery, and research performed on the climatic conditions of this time. Many states in the southern Midwest, including Kansas, Oklahoma, and Texas were blanketed with a severe drought that began in September 2021, causing record-breaking temperatures and extremely low amounts of precipitation [NIDIS, 2022]. Upon the discovery of this information, it was apparent that this drought perpetuated the inability to recreate the contrast / tones captured in the 2015 subset image. This drought also explains the vast difference between the reclassified NDVI [Normalized Difference Vegetation Index] of 2015 versus the NDVI created from 2022 [see below, 2015 is on the left].





The Normalized Difference Vegetation Index is a simplified image that is created by applying a band transformation that equates to near-infrared radiation minus red radiation divided by near -infrared plus red radiation [Kriegler, 1969]. The benefit of these simplified drawings is that they have the "ability to quickly delineate vegetation and vegetative stress, which has great appeal in commercial agriculture and land-use studies" [Huang, 2021]. The importance of the NDVI is clearly illustrated by the two images above. The 2015 image [left] was produced from vegetation thriving in a year of bountiful precipitation and normalized temperatures, while the 2022 image [right] was produced from vegetation highly stressed as the local environment was being plagued by an extremely detrimental drought. Both NDVI's were created using the same symbiology, and a quick examination clearly demonstrates that most levels categorized in the 2022 image are shifted to a completely different range class than their 2015 counterparts.

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Analysis

Despite the contradicting climactic conditions between the two years, the remainder of the processing of these images produced significantly similar results. By visually comparing the map created from 2015 data [Page 8] with the map created from 2022 data [Page 9], the purple geometries are more prevalent in the 2022 Encroachment map. This evidence was further supported by calculating the area [in acres] for each of the land classes present in the subset image. From Winter 2015 through Winter 2022, the area of Eastern Redcedar forest stands grew from 12,344 acres to 14668 acres. This yields a 7% increase throughout the subset image over a 7-year span, increasing its presence by approximately 1% each year. It is safe to say that Eastern Redcedar encroachment presents itself as a serious problem to the landscape of Oklahoma, and that the negative consequences to native ecosystems will continue to propagate into the future.

Conclusion

The most notable increase of Eastern Redcedar infestation has occurred throughout the southwestern region of Oklahoma, where participants of a 1985 survey responded this plant was "scattered throughout" while participants of a 1994 survey responded this plant had "widespread occurrences" in the same areas [Bidwell, 2009]. Until an efficient and reliable method of quantifying this encroachment is readily available, the extent of negative effects caused by this invasive species will remain largely unknown. [Wang, 2017] proposes that remote sensing technology can be implemented to track the invasion of the Eastern Redcedar across the state of Oklahoma. As [Wang, 2017] demonstrated that this could be accomplished using mapping algorithms, PALSAR and Landsat satellite imagery, the use of various vegetation indices, and field survey data, this paper sought to objectively produce a successful encroachment map from two different years utilizing fundamental remote sensing techniques. After the datasets were obtained and preprocessing and processing techniques were executed, land classification maps were created that clearly illustrate the spread of this noxious species throughout a single study area of approximately 36,000 acres. Because the techniques used were solely based on an introductory knowledge of remote sensing, two definitive conclusions can certainly be made. The first conclusion is that no field accuracy assessments were performed on this data, so these maps serve a purely rudimentary and estimative purpose. The only accuracy assessments performed during this study were visual comparisons with the results found in [Wang, 2017]. The second conclusion that can be drawn from this paper is that the Eastern Redcedar [*Juniperus Viginiana*] is a highly invasive, rapidly spreading species that has entangled itself into the Oklahoma landscape. Knowledge and awareness of an issue is the first step to seeking out a resolution, and this paper demonstrates that a relatively simple land classification map of Oklahoma can, in fact, provide a generalized estimate of the rate of invasion of the Eastern Redcedar.

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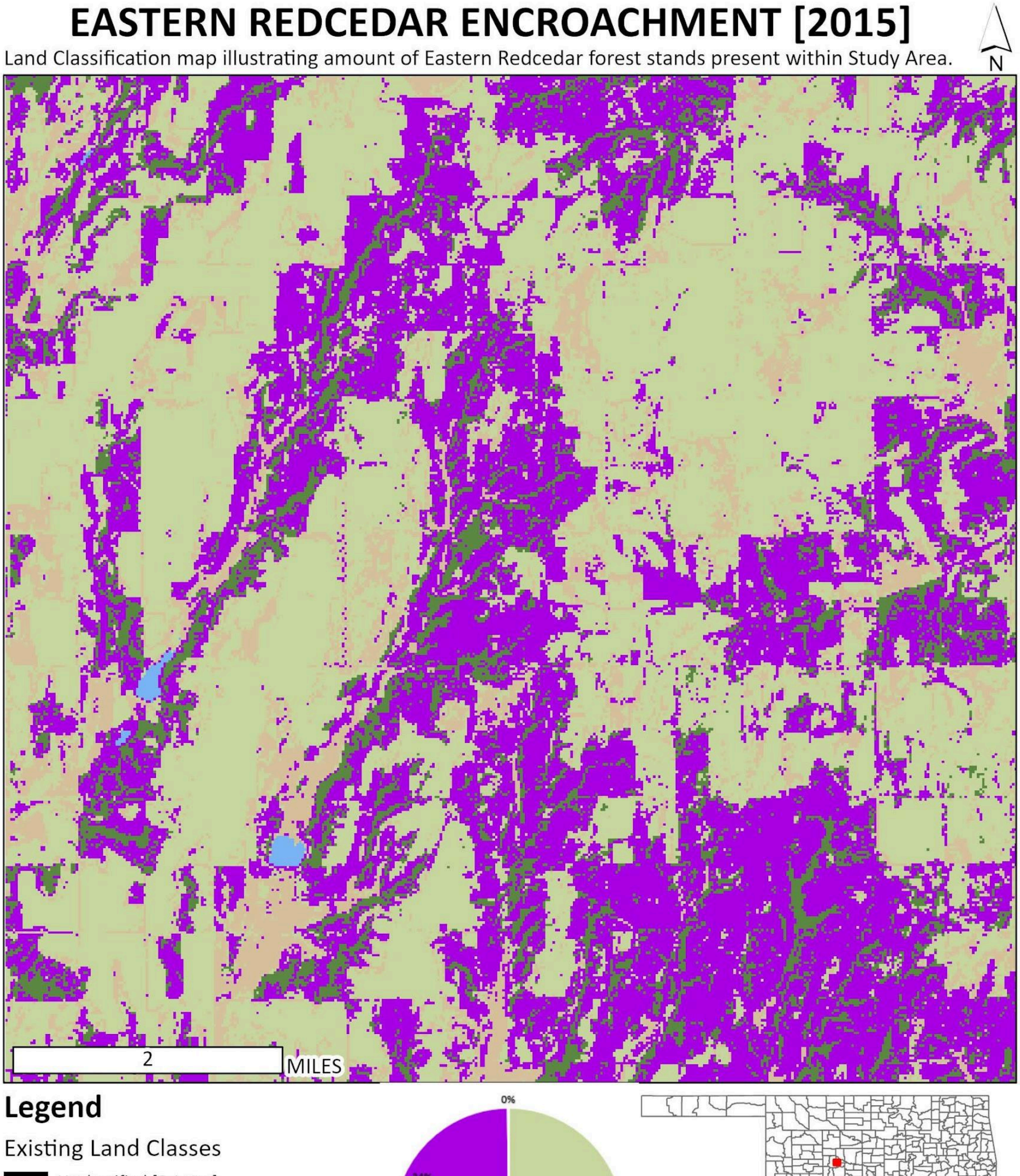
EASTERN REDCEDAR ENCROACHMENT [2015]

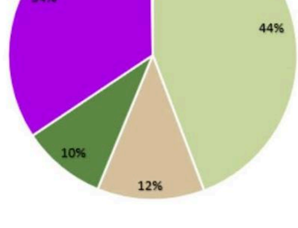
Land Classification map illustrating amount of Eastern Redcedar forest stands present within Study Area.

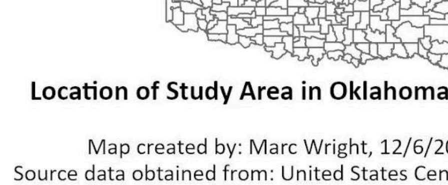


Legend

Existing Land Classes

- Unclassified [0 Acres]
- AGRICULTURE [15969 Acres]
- BARE EARTH/GRASSLANDS [4335 Acres]
- MIXED FOREST [3405 Acres]
- REDCEDAR [12344 Acres]
- WATER [66 Acres]





Location of Study Area in Oklahoma

Map created by: Marc Wright, 12/6/2023
Source data obtained from: United States Census Bureau and United States Geological Survey

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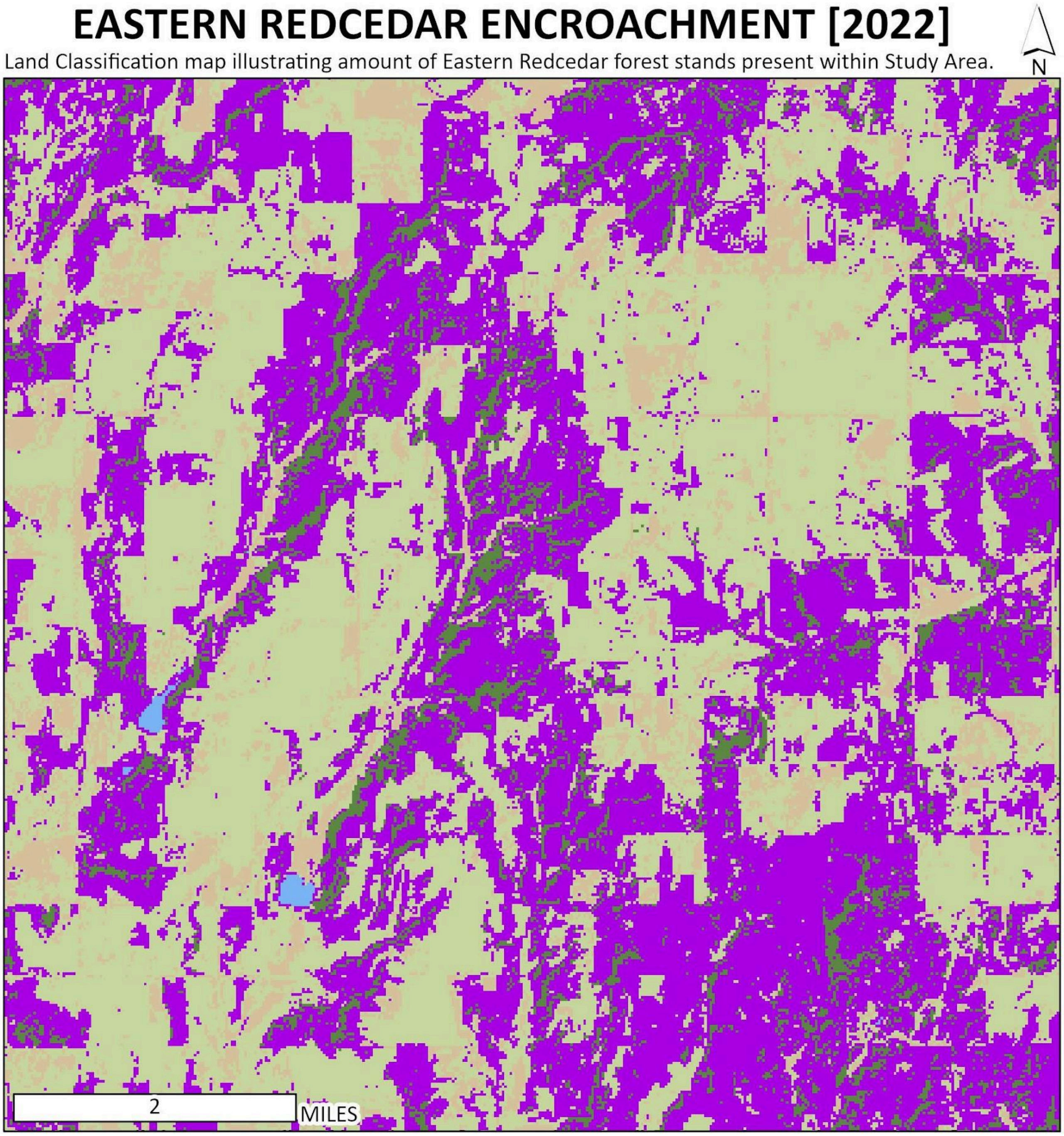
EASTERN REDCEDAR ENCROACHMENT [2022]

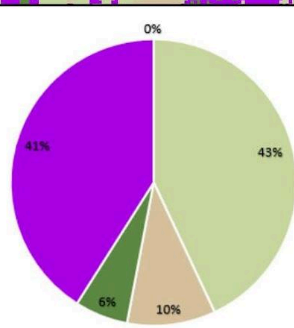
Land Classification map illustrating amount of Eastern Redcedar forest stands present within Study Area.

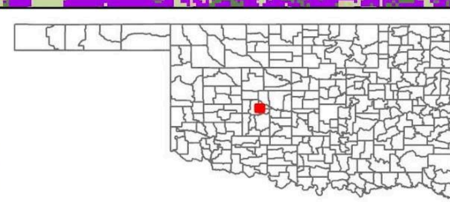


Legend

Class_Names

- Unclassified [0 Acres]
- AGRICULTURE [15402 Acres]
- BARE EARTH/GRASSLANDS [3687 Acres]
- MIXED FOREST [2305 Acres]
- REDCEDAR [14668 Acres]
- WATER [58 Acres]





Location of Study Area in Oklahoma

Map created by: Marc Wright, 12/6/2023
Source data obtained from: United States Census Bureau and United States Geological Survey