IDENTIFYING ACTIVELY GROWING VEGETATION USING NDVI THRESHOLD VALUES

John H. Walz, GIS/RS Technician, GIS Training and Research Center, Idaho State University, Pocatello, ID 83209-8104

Keith T. Weber, GISP. GIS Director. GIS Training and Research Center, Idaho State University, Pocatello, ID 83209-8104

ABSTRACT
Accurate satellite-derived vegetation indices are critical for the delineation and assessment of vegetation cover. There is a pressing need to better identify and evaluate actively growing vegetation (AGV) along with its relationship to wildfire occurrence. In this study we set out to determine Normalized Difference Vegetation Index (NDVI) threshold values to identify actively growing vegetation in conifer, grassland, and shrubland vegetation types (VT). The Landscape Fire and Resource Management Planning Tools Project (LANDFIRE) Existing Vegetation Type (EVT) product was used to identify these three vegetation types and Moderate Resolution Imaging Spectroradiometer (MODIS) 16-day composite NDVI data was used to estimate plant productivity within each vegetation type. A threshold NDVI value of 0.30 was initially used to indicate AGV for all vegetation types. However, the 0.30 NDVI threshold for grassland and shrublands did not result in an accurate representation of AGV. These data were re-processed in the current study using 0.10, 0.15, and 0.20 NDVI threshold values. Graphs were made for all three vegetation types and each of the three NDVI threshold values. The conifer VT showed little difference between the various NDVI threshold values. Grassland and shrubland vegetation types showed very little difference using 0.10 as opposed to 0.15. Graphs of growth curves created using the threshold value of 0.20 appeared more ecologically reasonable for grassland and shrubland. The use of vegetation type-specific NDVI threshold values may produce a more accurate determination of AGV.
KEYWORDS: *NDVI threshold value, LANDFIRE, NDVI, climate, wildfire*

INTRODUCTION
Identifying actively growing vegetation (AGV) is a necessary step in determining biomass production and ultimately, fuel load for wildfire management. The identification of AGV is usually done using the Normalized Difference Vegetation Index (NDVI). NDVI is an indicator of the condition of plant health derived from the reflectance in the red and near-infrared (NIR) wavelengths of the electromagnetic spectrum. The chlorophyll in plant leaves absorb visible light from 400-700nm (with peak absorption occurring around 600nm) while the cell structure of plant leaves reflects near-infrared light between 700 and 1100nm. Using multispectral sensors like Landsat or the Moderate Resolution Imaging Spectroradiometer (MODIS), a simple band ratio (e.g., the normalized difference vegetation index (NDVI)) of the difference between NIR and RED band reflectance divided by the sum of these same bands can be used to estimate plant photosynthetic activity. Resulting NDVI values ranges from -1 to 1 where a value of -1 suggests no photosynthetic activity while a value of +1 indicates very active photosynthesis. From these values the presence or absence of plant life can be fairly readily assumed.

In this study we set out to evaluate three NDVI thresholds (0.10, 0.15 and 0.20) that might reliably indicate AGV within three vegetation types (VT): conifer, grassland, and shrubland. Previous studies suggest an NDVI value of 0.30 is a good indicator of AGV (Myneni 1995 & Al-doski 2013). However, in our initial study using the NDVI threshold value of 0.30, we saw limited AGV even during the peak growing season (May-June) in both grassland and shrubland ecosystems (Walz and Weber 2021). The threshold value of 0.30 did seem to work well to identify AGV in coniferous forest ecosystems. The ability to accurately determine AGV will be important for future studies on the effect of weather and climate on wildfire fuels.

The study area (**Figure 1**) is a region covering approximately 3 million km^2, including 11 states (Arizona, California, Colorado, Idaho, Montana, Nevada, New Mexico, Oregon, Utah, Washington, and Wyoming). The study area contains many different VT including conifer, grassland, shrubland, sparsely vegetated, hardwood, and riparian areas. However, the conifer, grassland, and shrubland VT make up 78% of the study area (**Figure 2).** These ecosystems consist of a wide variety of species depending on latitude, elevation, and the general precipitation regime. Conifer ecosystems can be dominated by one species or a mix of several species. For example, the conifer VT in Wyoming is predominantly Lodge Pole Pine (*Pinus contorta*), while the same VT in the Cascades is a mix of Fir (*Abies spp.*), Douglas fir (*Pseudotsuga menziesii*), Arborvitae (*Thuja spp.*), and Pine (*Pinus spp.*). The shrubland VT in Idaho is mostly Sagebrush (*Artemisia tridentata*) and Rabbit brush (*Ericameria spp.*), while California's chaparral shrublands consists of Chamise (*Adenostoma fasciculatum*), several varieties of Oaks (*Quercus spp.*), Manzanita (*Arctostaphylos spp*.), Sagebrush (*Artemisia californica*), Buckbrush (*Ceanothus megacarpus*), and Sumacs (*Rhus spp.*).

METHODS

Vegetation types were identified using the LANDFIRE Existing Vegetation Type (EVT) layer. The LANDFIRE program produces nearly two dozen geospatial data products derived principally from the Landsat sensor, and thus each data product has a 30-meter x 30-meter spatial resolution. The LANDFIRE (EVT) product maps assimilated complexes of plant communities following the NatureServe terrestrial ecological system classification (Comer et al. 2003). The vegetation types of conifer, grassland, and shrubland were chosen as they represent the majority of the study area (Figure 2).

MODIS 16-day composite NDVI data were used to estimate vegetation production across the study area. This dataset library contained 23 NDVI images annually (2001-2019) and has a 250-meter x 250-meter spatial resolution. The ArcGIS Pro Greater Than Equal tool was used to identify those pixels describing healthy, actively growing vegetation (i.e., pixels with NDVI values > 0.10, ≥0.15, and ≥ 0.20). All pixels that satisfied this criterion were assigned a value of one (1, true). The resulting layers were henceforth referred to as Actively Growing Vegetation (AGV) to distinguish these data from the original NDVI source data. The specific NDVI values (≥ 0.10, ≥0.15, and ≥ 0.20) were chosen based on observations from our previous study where the NDVI threshold value of 0.30 was used. Together, these 23 data layers characterize the spatio-temporal extent or the annual "green wave" and allow for the visualization of the growing season throughout each year. The MODIS composite NDVI data were processed using all three potential threshold values.

Figure 1. *The study area is a region including 11 states (Arizona, California, Colorado, Idaho, Montana, Nevada, New Mexico, Oregon, Utah, Washington and Wyoming). A substantial number of wildfires in the conterminous United States occur in this region.*

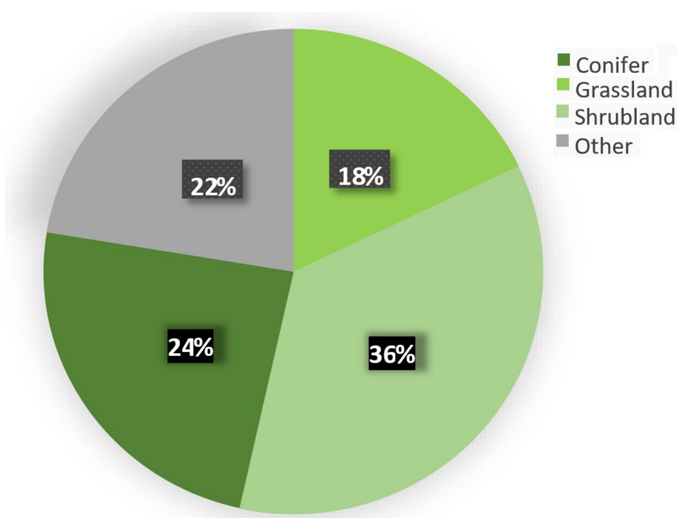


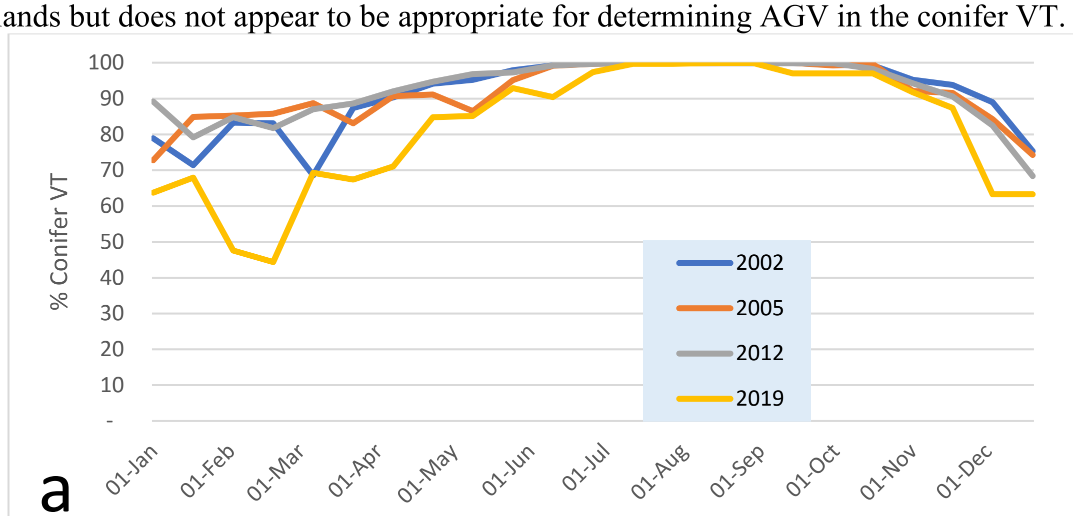
Figure 2. *Percent cover by vegetation type for the study area. Conifer, grassland, and shrubland make up 78% of the land cover.*

Each Boolean VT layer (e.g., shrubland) (n = 3) was multiplied by each Boolean AGV layer (n = 23 annually) resulting in 69 discrete AGVxVT layers annually (n = 1,311 layers in total for the 19-year study period). The resulting raster value attribute tables were exported to Microsoft Excel spreadsheets where each column provided AGV data (0 or 1) for a given time period. Descriptive statistics were calculated for these data and graphs created showing the growing curves for the three VT for the years 2002, 2005, 2012, and 2019. These years were chosen by identifying the years which showed the lowest (2002 and 2012) and highest (2005 and 2019) amplitude of growth curve graphs following the previous study (Walz & Weber 2021).

Maps were created for each NDVI threshold value (0.10, 0.15, and 0.20) for each VT in each year (2002, 2005, 2012, and 2019). These maps helped visualize these data and observe subtle changes between years for the peak month (June) of the growing season. The shrubland VT map for June for the years 2002, 2005, 2012, and 2019 was included in this report as an example.

RESULTS AND DISCUSSION

The threshold value of 0.10 suggests all (100%) or nearly all of the study area was experiencing active vegetation growth throughout June through October. Ecologically, this is unrealistic as vegetation in some areas will experience senescence, dormancy, or simply reduced photosynthetic activity as a normal part of the growing season (**Figure 3**). Graphs made using the NDVI threshold value of 0.15 (**Figure 4**) showed slightly more variation in grassland and shrubland and a slightly shorter period of time where the entire study area was considered to be actively growing, however the conifer VT still reached 100% AGV from July through October. There was very little difference between years in these data for the threshold values of 0.10 and 0.15 in either grasslands or shrublands. However, a clear difference between years for grassland and shrublands was observed using the NDVI threshold value of 0.20 can be seen (**Figures 5b-c**). The value of 0.20 may be ideal to characterize actively growing vegetation in grasslands and shrublands but does not appear to be appropriate for determining AGV in the conifer VT.



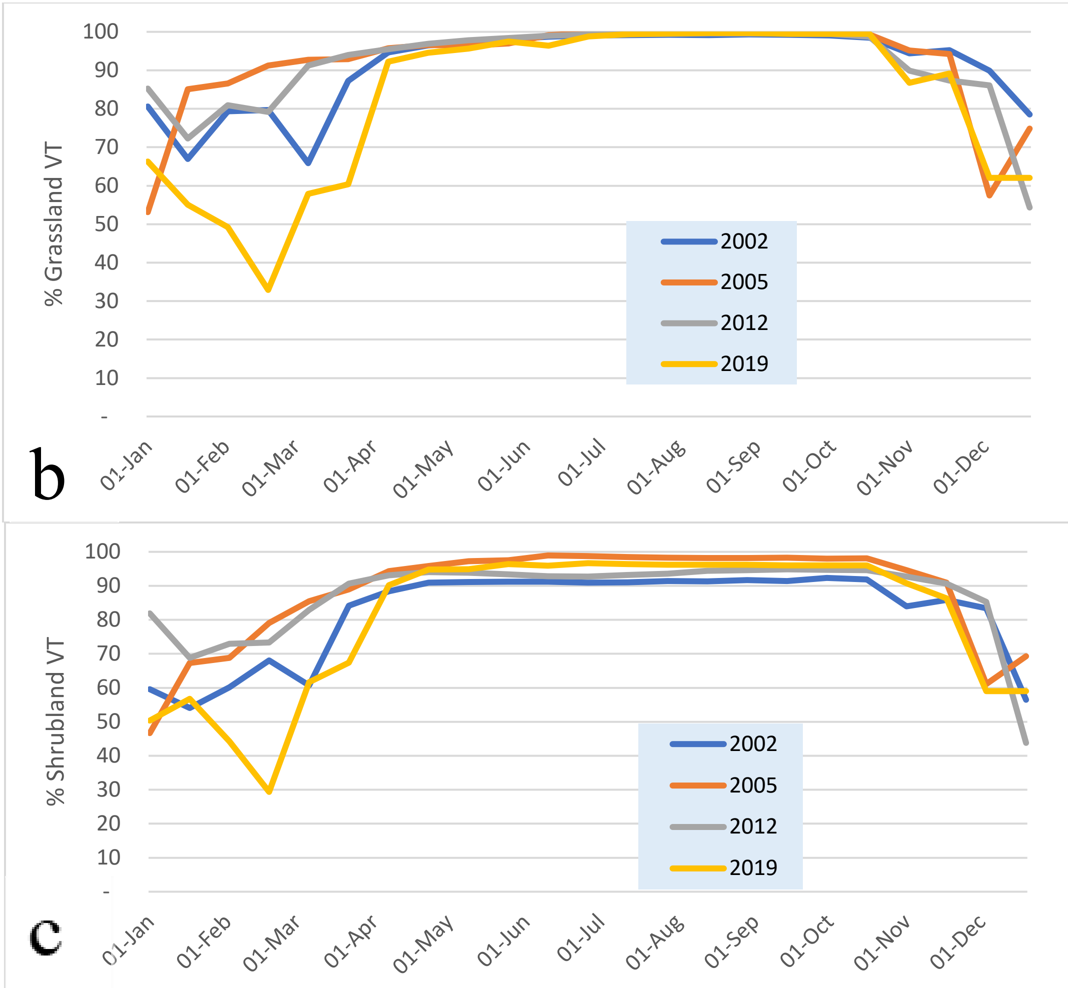


Figure 3. *Percent of each vegetation type's full extent determined to be actively growing using an NDVI threshold value 0.10 for (a) conifer, (b) grassland, and (c) shrubland vegetation types.*

Results of this analysis showed that the NDVI threshold value of 0.20 was much more effective at identifying AGV in the grassland and shrubland VT than the threshold value of 0.30. Growth curves created for four years of these data at an NDVI threshold value of 0.20 show a plateau for conifer (**Figure 5a**) at just under 750,000 km^2 or 100% of the VT's total area and for grassland (**Figure 5b**) at just over 450,000 km^2 or almost 90% of the VT's total area Growth curves for shrubland however, never reached a plateau (**Figure 5c**). To illustrate this spatially the extent of AGV for shrubland was mapped using the NDVI threshold level of 0.20 on June 10th for the years 2002, 2005, 2012, and 2019 (**Figure 6**). The subtle differences between years can be visualized well using the NDVI threshold value 0.20.

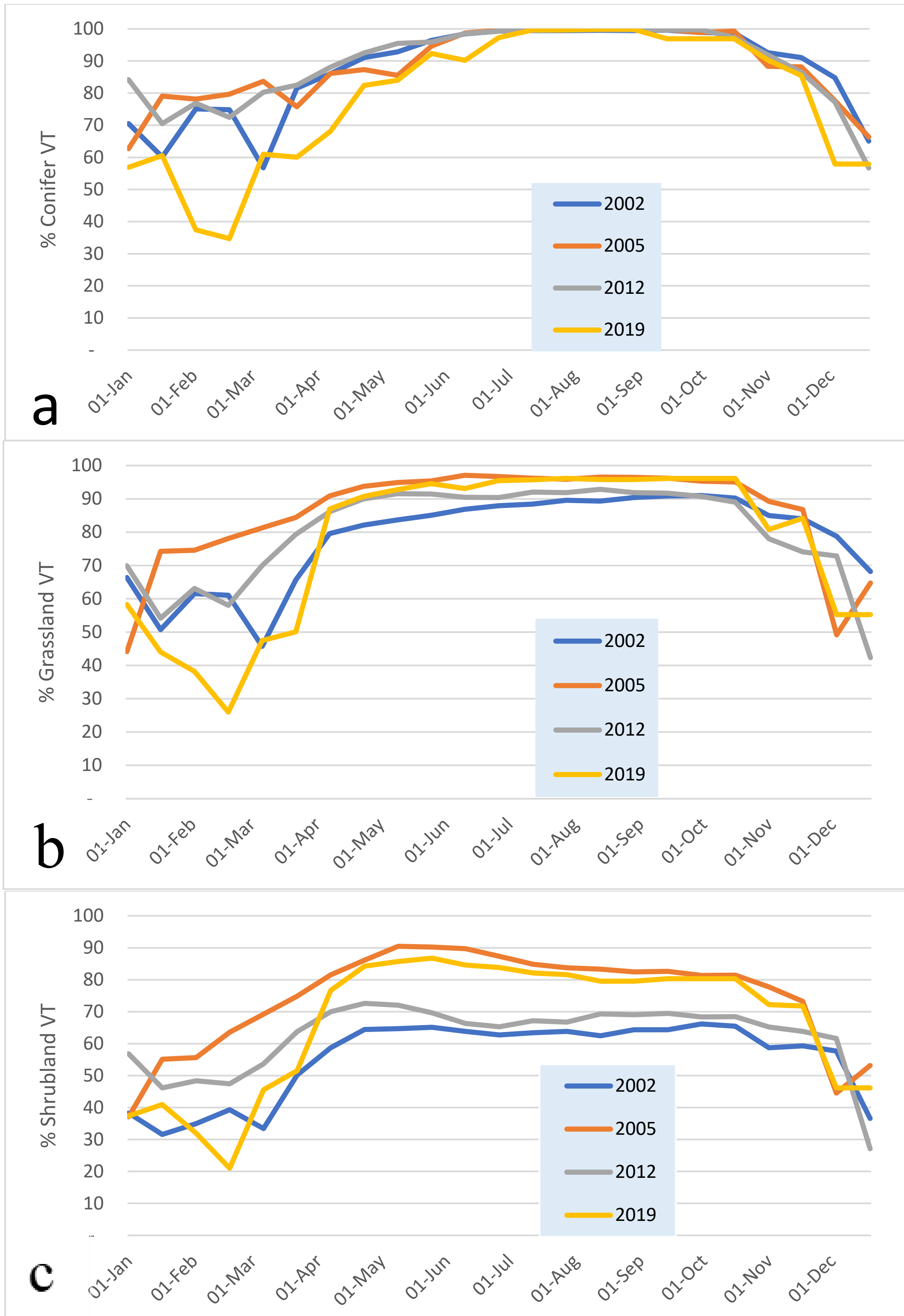
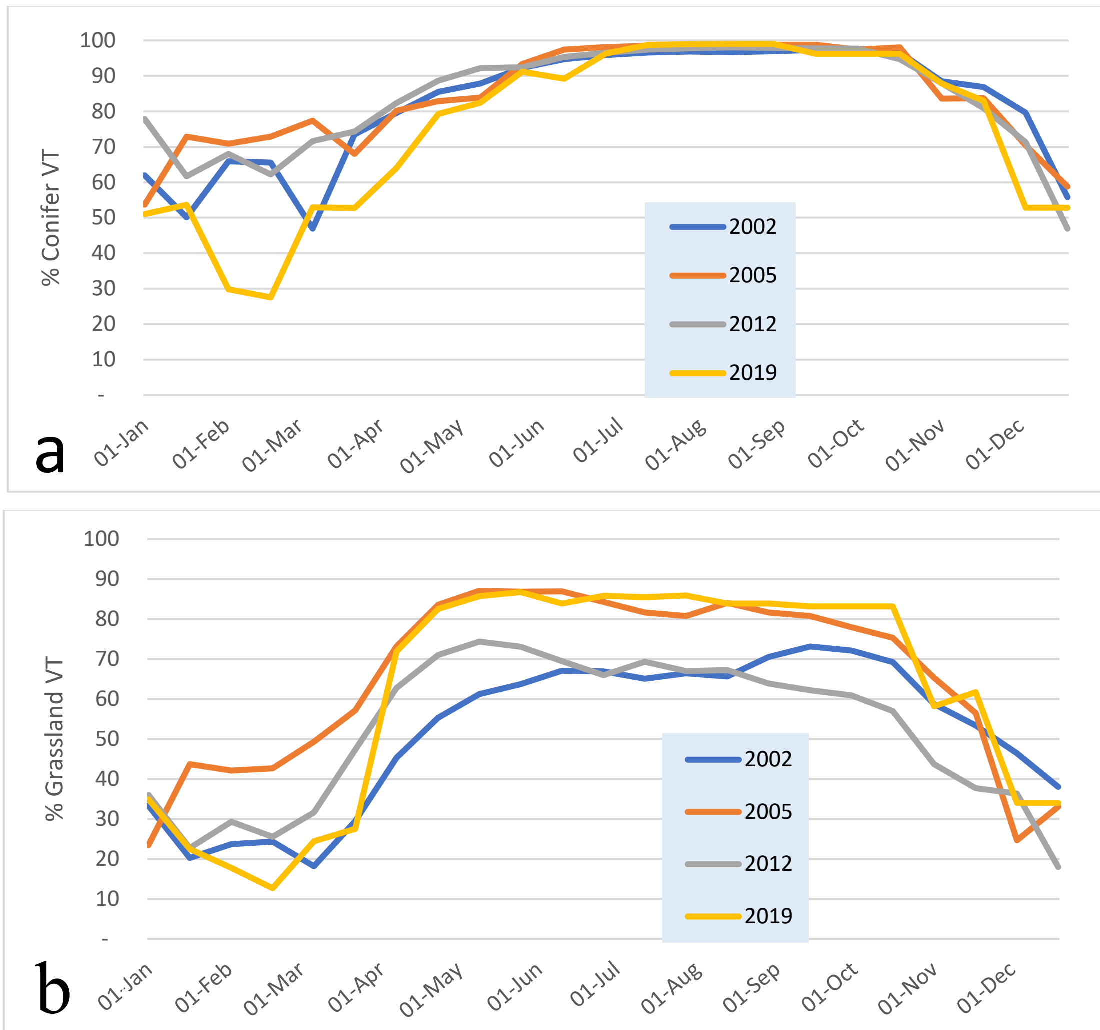


Figure 4. *Percent of each vegetation type's full extent determined to be actively growing using an NDVI threshold value 0.15 for (a) conifer, (b) grassland, and (c) shrubland vegetation types.*

In reality the idea of 100% of any VT actively growing at the same time in such a large study area with diverse vegetation is hard to accept. It is not likely that 100% of grassland or shrubland could be active at the same time when these VT are comprised of various ecosystems and plant communities, not to mention elevation (a range of 4,500 meters) and latitude differences (approximately 18°). This finding concurs well with other studies suggesting grassland and shrubland ecosystems exhibit different maximum and minimum NDVI values (Paruelo an Lauenroth 1995) relative to other vegetation types (e.g., coniferous forests). They found pinyon-juniper had the highest maximum NDVI values while Great Basin sagebrush-steppe ecosystems exhibited a significantly smaller range of NDVI values.



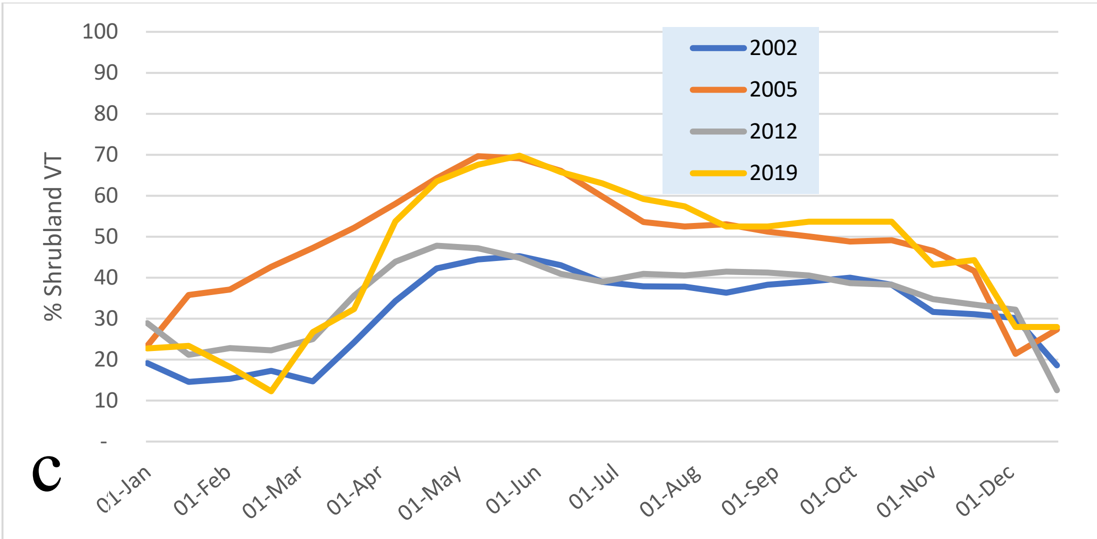


Figure 5. *Percent of each vegetation type's full extent determined to be actively growing using an NDVI threshold value 0.20 for (a) conifer, (b) grassland, and (c) shrubland vegetation types.*

Other conditions may need to be considered in order to achieve a comprehensive picture of AGV on a monthly or annual basis. Observations by Shoshany and Karnibad (2015) showed large differences in NDVI values gathered from similar VTs under different precipitation levels. An increase in the amount of water available to plants normally results in increased vigor. This may increase the Leaf Area Index (LAI) within a pixel, and can result in an increase in NDVI with no significant change in vegetation cover. Drori et al. (2020) created a precipitation-sensitive dynamic NDVI threshold method to detect and monitor forest and woody vegetation cover in sub-humid to arid areas. They used the empirical relationship between NDVI and mean annual precipitation (MAP) to fit a curve that can be used as a dynamic threshold. This method may be worth consideration in future studies and can be used to more accurately determine vegetation types. However, this approach would suppress detection of increased photosynthetic activity as a result of increased precipitation and is not applicable to studies focusing on the identification of actively growing vegetation.

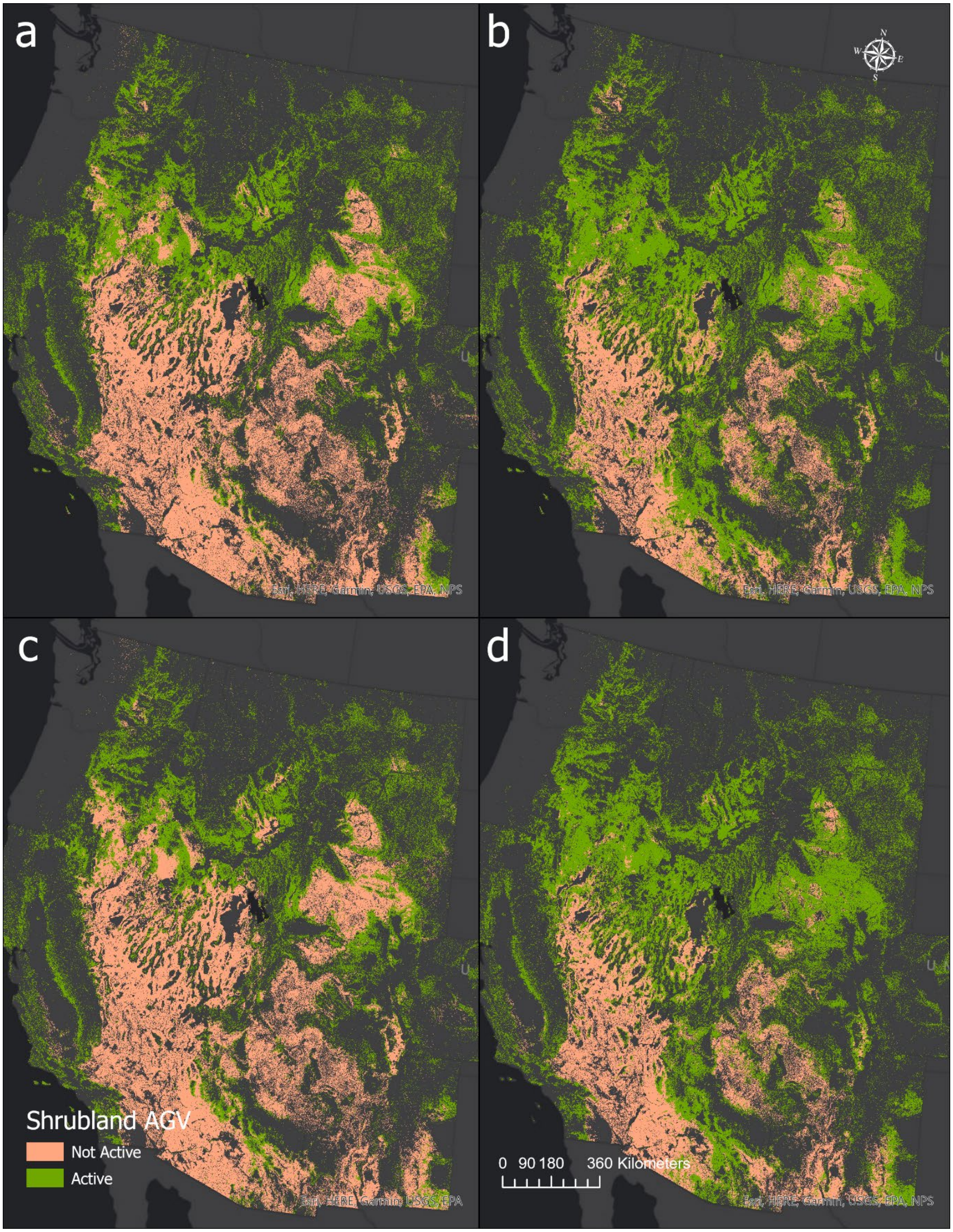


Figure 6. *Spatial distribution of actively growing vegetation for the shrubland vegetation type at an NDVI threshold level of 0.20 on June 10th for the years (a) 2002, (b) 2005, (c) 2012, and (d) 2019.*

CONCLUSIONS

The grassland and shrubland vegetation types in the western United States includes a diverse range of climates, plant species, and percent bare ground. This makes evaluation of AGV more difficult relative to the coniferous forest vegetation type. Vegetation production and vegetation characteristics drive wildfire fuel load and fuel continuity. The majority of wildfire fuels are derived from vegetation and are typically classified into four groups: grasses, brush, timber, and slash (Anderson 1982). Assessing accurate vegetation productivity is important to understanding fluxes in wildfire fuels.

This study found the NDVI threshold value of 0.20 may be ideal to identify AGV for grassland and shrubland vegetation types, but 0.30 is better suited to the conifer VT. It was determined that an NDVI threshold value 0.10 or 0.15 were too low, as the entire study area exhibited 100% concurrent active growth for most of each year. In future research it may be appropriate to use the NDVI threshold value of 0.30 for conifer and 0.20 for grassland and shrubland.

Although the use of the NDVI threshold value of 0.20 produced more accurate maps for grassland and shrubland, other factors should be considered in order to get the complete picture of AGV for grassland and shrubland. Different classifications of grassland and shrubland have different maximum and minimum NDVI values and some classifications reach their maximum NDVI values earlier than other vegetation types. One possible way to get a more accurate representation of grassland and shrubland would be to use a smaller study area or break up the study area so that the different NDVI values and timing of the various classifications of grassland and shrubland can be used.

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