An Accuracy Assessment of Tree Detection Algorithms in Juniper Woodlands

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Abstract

This research provides a comprehensive accuracy assessment of five methods for classifying western juniper (Juniperus occidentalis) canopy cover from 1 m, 4-band National Agriculture Imagery Program (NAIP) imagery. Two object-oriented classification approaches (image segmentation and spatial wavelet analysis, (SWA)) are compared to three pixel based classification approaches (random forests, Iterative Self-Organizing Data Analysis (ISODATA), and maximum likelihood). Methods are applied to approximately 250 km² in the intermountain western USA. A robust suite of statistical approaches, which offer an alternative to traditional kappa-based methods, are utilized to determine equivalence between methods and overall effectiveness. Object-oriented approaches have the highest overall accuracy among the assessed methods. Each of the methods varied considerably in cover class accuracy. SWA has the highest class accuracy when juniper canopy cover is low (0 to 40 percent cover), ISODATA performs best at moderate cover (60 to 80 percent) and maximum likelihood performs best at higher cover (60 to 100 percent cover).

Introduction

Western juniper (*Juniperus occidentalis* Hook.) is a tree species native to the semi-arid shrub-steppe ecosystem of the western United States. Low density juniper woodlands that are subordinate or codominant with native shrubs (e.g., mountain big sagebrush (*Artemisia tridentata spp. vaseyana*)), provide excellent habitat for 23 species of mammals and 83 species of birds (Davies *et al.*, 2011; Miller *et al.*, 2005; Miller and Wigand, 1994; Poddar and Lederer, 1982). Furthermore, 3 to 5 percent of western juniper woodlands are old-growth forests, which provide increased biodiversity, structural diversity, high quality habitat, genetic diversity, and serve as ecological legacies (Miller *et al.*, 2005; Miller *et al.*, 1999; Waichler *et al.*, 2001).

Characterizing the magnitude and rate of encroachment of woody plants into semi-arid lands is important in further understanding the assessment of ecological dynamics (Hunt *et al.*, 2003; Miller *et al.*, 2000; Sankey and Germino, 2008; Sankey *et al.*, 2010; Smith *et al.*, 2008; Strand *et al.*, 2008). Western juniper historically grew in rocky refugia and other areas that were protected from relatively frequent fire return intervals common to the region (Camp *et al.*, 1997; Miller and Wigand, 1994). However, the intensity and frequency of fires have decreased, allowing for expansion and establishment of woody species like mesquite and juniper into deeper, more productive soils (Burkhardt and Tisdale, 1976; Miller and Rose, 1999; Waichler *et al.*, 2001). Additional studies indicate the historic range and density of western juniper has been increasing since the late 1800s due to what is believed to be the interacting effects of fire suppression, increased cattle grazing, and favorable climatic conditions for juniper growth at the turn of nineteenth century (Archer *et al.*, 1995; Blackburn and Tueller, 1970; Burkhardt and Tisdale, 1976; Crawford *et al.*, 2004; Johnsen, 1962; McPherson *et al.*, 1988; Miller and Rose, 1999; Miller and Wigand, 1994). In eastern Oregon, it is estimated that juniper has increased in range from approximately 600,000 to 2.63 million hectares since the turn of the nineteenth century (Azuma *et al.*, 2005). Given these large extents, developing and evaluating computer assisted classification methods to identify and map juniper trees across large spatial extents are critical to managing a changing landscape and maintaining the biodiversity and ecological functioning of the western sage-steppe ecosystem (Campbell *et al.*, 2012).

Various methods have been developed to identify woody plant encroachment over large spatial extents from remotely sensed data. Common approaches include sub-pixel methods (Sankey and Glenn, 2011), pixel-based analysis methods such as maximum likelihood and ISODATA clustering (Anderson and Cobb, 2004; Ball and Hall, 1965; Pillai *et al.*, 2005), contrast thresholding (Knapp and Soulé, 2002), and texture-based assessment (Hudak and Wessman, 1998). These approaches produce assemblies of pixels based on statistically determined criteria that have similar spectral characteristics (Jensen, 2005).

Object oriented image analysis (OBIA) methods such as image segmentation (Laliberte *et al.*, 2004; Laliberte *et al.* 2007; Pillai *et al.*, 2005), feature extraction, and object identification (e.g., Spatial Wavelet Analysis (SWA)) (Falkowski *et al.*, 2006; Garrity *et al.*, 2008, 2012; Smith *et al.*, 2008; Strand *et al.*, 2006; Strand *et al.*, 2007) are also gaining popularity in the assessment of woody plant encroachment. Feature extraction methods for OBIA utilize texture, spatial context, and reflec-

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