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Identifying Surface Mine Extent Across Central Appalachia Using Time Series Analysis, 1984-2015

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ABSTRACT

The Appalachians, and Central Appalachia in particular, have a long history of resource extraction including coal mining. In the past half century, the region experienced a shift from underground to surface mining, which leaves highly visible changes on the landscape. This study presents an analysis of changes in surface mining extents between 1984 and 2015 using remote sensing techniques, and tests the methods of previous research over a broader study area. The authors found that 3070 km2 (7.1%) of land within the central Appalachian coalfield was classified as mined land through the study period, and that the rate of newly mined land, as well as total mined land has decreased in recent years. The overall classification accuracy was 0.888 and the kappa coefficient was 0.880. Study results indicate that previously developed methods for identifying surface mines in a sub-region of Central Appalachia can successfully be applied over the broader region. The resulting surface mining datasets will be applied to a future study examining the potential human health impacts of surface mining.

KEYWORDS

Appalachian Coalfield, Surface Mining Extent, Time Series Analysis

INTRODUCTION

The landscape of Appalachia reflects the varied history of the region along with the numerous land use/land cover changes (LULCC) that the region has experienced since human settlement began. Appalachia in general, and Central Appalachia in particular, have in more recent history been subjected to intensive natural resource extraction such as timber harvesting and mineral extraction. Both became important agents of environmental change in the early 1800s, and large-scale coal mining began in earnest in the early 1900s; 80% of the nation's coal was sourced from the region by 1930 (Yarnell, 1998). The impacts of underground mining on the landscape were visually apparent with large swaths of vegetation cleared around mine entrances and the creation of waste piles, as well as changes to aquatic environments. During the mid-1900s, the shift from underground to surface mining resulted in even greater permanent alteration of the landscape (Rouse & Greer-Pitt, 2006).

During surface mining, large swaths of vegetation are removed, exposing barren ground. As the process of accessing coal seams continues, mountaintops are typically removed and nearby valleys filled with that overburden in order to reach coal beneath the surface (Environmental Protection Agency, 2016). As the coal supply is exhausted from a section of the mined area, the ground is

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regraded and eventually revegetated, as operations move on to another part of the area permitted for coal removal. For the purposes of this research, we define "surface mining extents" as areas identified on satellite imagery as disturbed, barren lands within the USGS-defined Appalachian coalfield region that have experienced vegetation removal but have not yet seen revegetation occur. The Surface Mining Control and Reclamation Act of 1977 requires that a mined area be returned to the "approximate original contours." These landscape alterations associated with surface mining, particularly removal of vegetation to expose bare ground and then the return to a vegetated state, are readily visible on the landscape with the use of remotely sensed data.

This research is part of a larger study responding to a need for the analysis of fine-scale individual-level human health impacts of surface mining in Central Appalachia (Krometis et al., 2017), which requires a reconstruction of historical surface mining extents. In particular, the broader study seeks to examine environmental exposures and human health outcomes associated with surface mining, as mining processes can result in air pollution and water contamination in the vicinity of a mine; minimal research has focused on premature mortality, adverse birth outcomes, and other human health concerns that could potentially be tied to surface mining (Hendryx 2015; Krometis et al., 2017). Therefore, the objective of this study is to delineate the annual extent of active surface mining within Central Appalachia for 1984-2015 to contribute to the body of research examining mining delineation within the region, and to meet our applied need as we examine human health impacts of surface mining. Li et al. (2015) developed a methodology, with a focus on the accurate identification of surface mines as compared to non-mined areas, for identifying surface mines using Landsat data and remote sensing techniques in a subset of Central Appalachia, and we respond to their suggestion to test their methods over a broader study area by applying them to the full coalfield region within Central Appalachia.

BACKGROUND

The identification of mined areas is a common application in remote sensing (Campbell & Wynne, 2011), but with a few exceptions, there has been minimal study of changes in the extent of surface mining across all of Central Appalachia, where there is a long history of land disturbance due to mining. Slonecker and Benger (2002) thoroughly reviewed the extent of research using remote sensing to evaluate surface mining through the end of the 1990s and determined that it is an effective way to examine mining and its impacts. More specific to our region of interest, Townsend et al. (2009) presented an examination of changes in surface mining extent and reclamation over time using Landsat in a coalfield region of Appalachia, with accuracy levels above 85%. A combination of LiDAR-derived data and satellite imagery in the coalfields of southern West Virginia proved to be an effective way to classify land cover within a mine-permitted area (Maxwell, Warner, Strager, & Pal, 2014). Although these studies proved that their methods were effective at identifying surface mining extents, both examined relatively small regions within the Appalachian coalfield.

More recently, Li et al. (2015) developed an approach of examining time series of Landsat-derived vegetation indices for detecting surface mining in the Central Appalachian coalfield, with a specific focus on southwestern Virginia. Specifically, Li, Zipper, Donovan, Wynne, and Oliphant (2015) determined that the normalized difference vegetation index (NDVI; Rouse Jr, Haas, Schell, & Deering, 1974) was best at distinguishing bare ground from vegetation during leaf-on periods (i.e., the growing season) when compared to the Normalized Burn Ratio (NBR; Key & Benson, 1999), the Normalized Difference Moisture Index (NDMI; Hardisky, Klemas, & Smart, 1983), the tasseled cap greenness-brightness (TC-GB; Kauth & Thomas, 1976) difference index, and the "Red" band, and the "Near Infrared" (NIR) Band. NDVI, which quantifies photosynthetic activity, has been widely used in change detection research (e.g., Lunetta, Knight, Ediriwickrema, & Worthy, 2006; Shao, Taff, Ren, & Campbell, 2016). Li et al. (2015) found that 8% of the region experienced mining over the 28-year period with a kappa coefficient of 0.9252. Furthermore, Li et al. (2015) suggested that the Appalachian coalfield is ideal for examining surface mine detection techniques due to the intensive