Groundwater and surface-water contamination susceptibility determination through automated geospatial models using combined modeling approach of DRASTIC and RUSLE

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In the 1970s, coal mining in Appalachians changed dramatically with the advent of mountaintop removal strip-mining. The result is catastrophic for both the environment and the people of this region due to the toxic byproducts the strip-mining generates. Dams constructed for the slurry impoundments can and do fail to pollute the streams downstream. The most tragic example was in 1972 when a dam failed, resulting in the deaths of 125 people along the Buffalo Creek Hollow. Reclamation, a major aspect pf mining, is the process of attempting to convert the mined area back to its previous state, by filling in the open mines and planting grass and shrubs. Mines are required by law to be reclaimed after the mining process has been completed. However, this process is flawed due to the use of compromised soil that was mined. As a result, the reclamation areas can barely support grasses and many areas remain bare, prone to soil erosion, which pollutes the rivers or wells of the region due to soil's toxicity. The goal of this study was to show the land-use change in the surface coal-mining in southern West Virginia and analyze its impact on ground- and surface-water quality in the region.

The area of interest (AOI) is the southern portion of the State of West Virginia. The study was completed by performing an object-based supervised classification of two multi-temporal (2008 and 2018) Landsat images and carrying out land-use change analysis. A groundwater contamination vulnerability DRASTIC model was developed to show the spatial vulnerability of groundwater pollution. Finally, a comprehensive soil erosion model, modified RUSLE model, was developed to show the erosion potential in active and post mined areas. A thorough literature review was conducted to find the possible bioenergy crop that can be grown in the ill-managed area with low maintenance for efficient reclamation. A Soil and Water Assessment Tool (SWAT) hydrologic model was completed to observe the reduction in soil erosion and water contamination.

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Land-use change analysis completed with NDVI developed for 2008 and 2018 showed the spatial extent within the AOI that have experienced regreening. Regreening areas were earlier mined while many reclaimed mining areas are still in barren state, thus explaining the reclamation process either working or failing.

A DRASTIC model looks at seven environmental conditions that can determine aquifer vulnerability due to surface pollutants (Babiker and others 2005). The factors associated with the DRASTIC models are the **D**epth of the water, net **R**echarge, **A**quifer Media, **S**oil Media, **T**opography, **I**mpact of the vadose zone, and Hydraulic **C**onductivity. A consensual model DRASTIC vulnerability rating equation used for determining groundwater contamination vulnerability is shown in Equation 1:

$$\text{DRASTIC index} = 5Dr + 4Rr + 3Ar + 2Sr + Tr + 5Ir + 3Cr \quad [1]$$

where r represents the rating of individual factors of D, R, A, S, T, I, and C as explained above.

Data needed for this study were acquired from the University of West Virginia Geospatial Server, the USGS' Groundwater and evapotranspiration database, NOAA's PRISM meteorology database, and Web Soil Survey of the U.S. Department of Agriculture. The Delphi method-based weighted scale was compiled and used to develop the DRASTIC model to provide groundwater/aquifer contamination spatial vulnerability (fig. 1A). Major coal mining locations in the study area are very vulnerable to groundwater contamination as analyzed by correlating the location of surface mine refuse ponds and the vulnerability of groundwater pollution produced by this

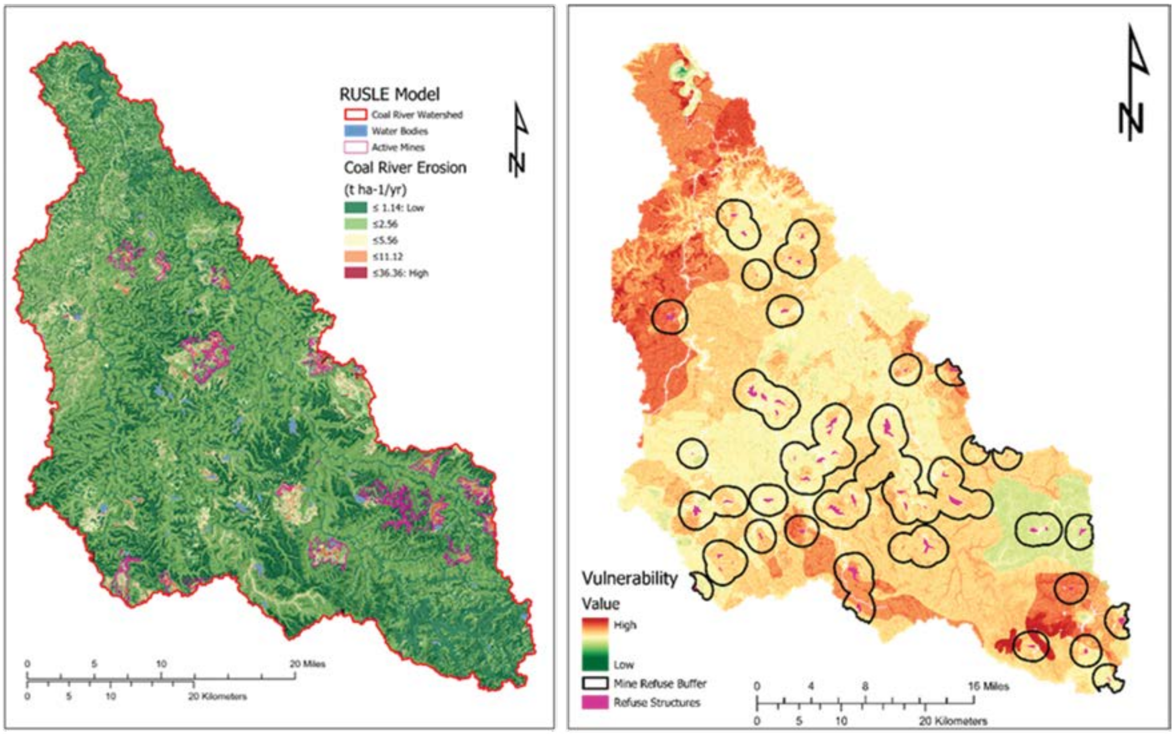

Figure 1—(A) Groundwater contamination spatial distribution map of the area of interest (AOI); (B) final soil erosion spatial distribution map of the AOI.

DRASTIC Index (fig. 1A). From our results, we observed that many slurry ponds are situated in the highly vulnerable groundwater contamination spatial zones and need to be constantly monitored.

A modified RUSLE soil erosion model was developed for the AOI with the unique development of the R-factor using NOAA PFDS 100-year 30 min. rainfall intensity raster of the study area, C-factor using an NDVI based formula ($C = 0.1(\frac{NDVI+1}{2})$, and P-factor using the classified land-use map of the study area. The K, L, and S factor rasters were developed from the STASGO2 data downloaded. Figure 1B is the output soil erosion distribution map of the AOI showing vulnerable spatial locations of severe soil erosion potential. We observed that major high soil erosion potential areas coincide with coalmines or slurry ponds. Therefore, environmental managers of the study area should be cautious in managing the watershed concerning soil and land-use reclamation. Interestingly, there are high rates of erosion around the refuse ponds created during the mining process. Areas of reclamation show up as moderate levels of erosion. Valley floors and ridgelines had, on average, the lowest erosion rates. Areas that maintain their dense forest cover saw comparatively little soil loss.

Sahoo and others (2019) used miscanthus (bioenergy crop) at reclaimed mines and found it advantageous in improving environmental quality. Our SWAT model of AOI with miscanthus as a cover crop (instead of the natural grass or shrub) obtained sediment and nitrate load reduction by ~1 percent and 7.7–22.5 percent, respectively. Thus, to reclaim we propose using bioenergy crops like miscanthus, switchgrass, and tannin-rich forage (e.g., lespedeza sericea, which can grow well in arid and semi-arid conditions and is best for rearing small ruminants) should be grown in the reclaimed areas.

LITERATURE CITED

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