Mapping and Estimation of Phosphorus and Copper Concentrations in Fly Ash Spill Area Using LANDSAT TM Data

B. B. Maruthi Sridhar* and Robert K. Vincent
Department of Geology, Bowling Green State University, Bowling Green, OH 43403
*Email: balajim@bgsu.edu

Abstract

The LANDSAT Thematic Mapper (TM) images have been used to monitor the largest coal fly ash spill in U.S. history that occurred in Tennessee on December 22, 2008. The total phosphorus (P) and copper (Cu) concentrations in the fly ash spill vicinity were mapped and determined by application of LANDSAT algorithm models, which we previously developed for monitoring the P and Cu concentration in soils amended by sewage sludge in NW Ohio. LANDSAT image analysis reveals the occurrence of elevated P and Cu concentrations on December 22, 2008 as a result of the fly ash spill a few hours before LANDSAT overpass, compared to P and Cu concentrations of bare soils in the pre-spill image of November 20, 2008. The progress in clean-up operations, through spreading of grass and straw mulch over the spilled fly ash, was evident in a February 1, 2009 image, where the P and Cu concentration values were recorded at significantly lower levels than were recorded in the December 22, 2008 image. The display of surface chemical concentrations in exposed soils and piles of fly ash demonstrates how satellite data can be used to quantitatively map certain occurrences of environmental contamination and to track surface manifestations of remediation/restoration efforts.

Study Approach

The purpose of this study is to show that the chemical concentrations in the fly ash spill vicinity can be estimated and mapped using LANDSAT TM data.

• For this purpose, the spectral ratio models that we developed to estimate and map the P and Cu concentrations in surface soil samples of sewage sludge amended soils (Sridhar *et al*., 2009) were applied to each of the three LANDSAT TM images covering the fly ash spill study area.

The algorithms used for estimation of P and Cu concentrations are as follows:

P (ppm) = 4156 -1690 (R51) + 2257 (R73);

Cu (ppm) = 75 -17.9 (R51) + 21.9 (R73),

where R51 and R73 are the dark-object-subtracted (haze corrected) values of TM band 5 divided by TM band 1 and TM band 7 divided by TM band 3, respectively.

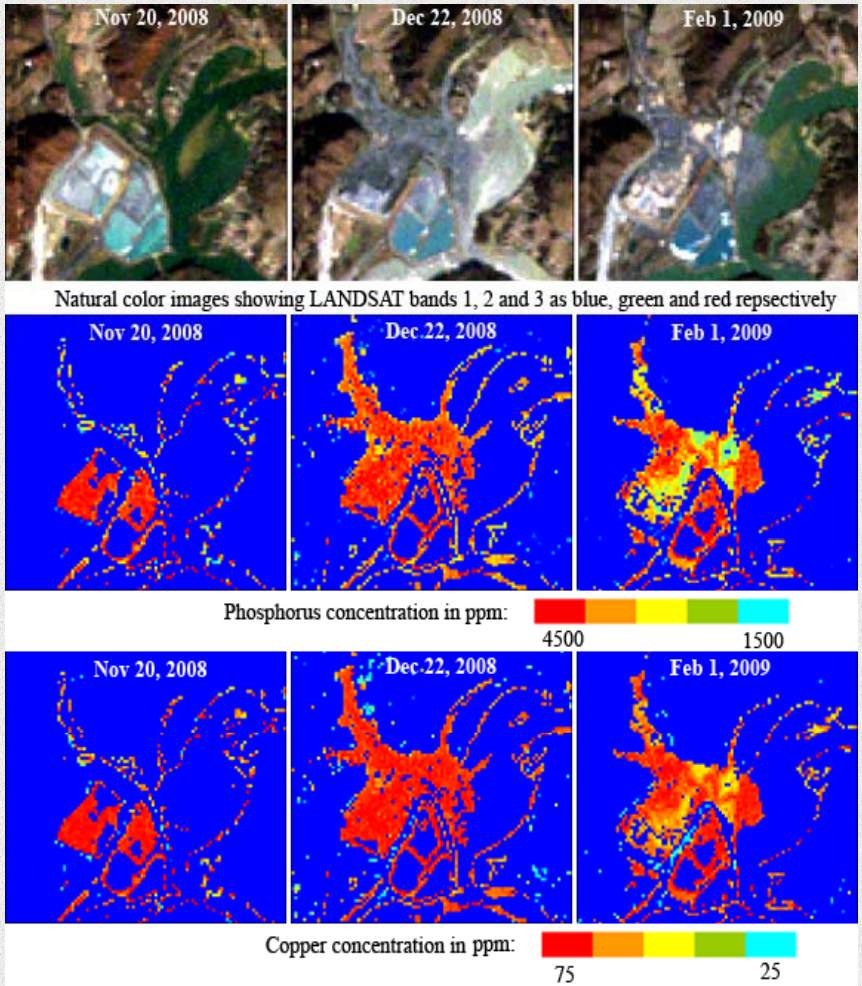

Fig 1. The LANDSAT TM images of the Tennessee fly ash spill area acquired on November 20, 2008 (32 days before fly ash spill); December 22, 2008 (9 hours after fly ash spill) and February 1, 2009 (40 days after fly ash spill), respectively. The images in the rows 1-3 represent the natural color image, surface P concentration image, and surface Cu concentration image, respectively.

Results

• The LANDSAT TM derived P concentrations range from 1,500 to 4,500 ppm and the Cu concentrations from 25 to 75 ppm in the November, 2008 and February, 2009 images.

• The intense red color in the December 22, 2008 image clearly stands out due to larger areas of high P and Cu concentrations exposures at the surface, compared to the November 20, 2008 image acquired before the fly ash spill. (Fig. 1)

• In November, before the fly ash spill, the high concentrations of P and Cu were shown to be confined to the fly ash ponds. In December, a large extent of increased P and Cu concentrations is clearly evident towards the northern and north eastern side of the ash holding ponds as shown in Figure 1. These high P and Cu concentration features agree with the fly ash spill towards the northern and north eastern sides of the ash holding ponds. In February, the P and Cu concentrations mapped with the same LANDSAT TM algorithms were lower than those recorded in December.

Conclusions

- The application of P and Cu mapping algorithms from LANDSAT TM images have allowed us to map and estimate the increase in surface concentrations of these two elements as a result of fly ash spill.
- These results show the effective use of multispectral satellite image analysis in determining surface soil chemical concentrations.
- As LANDSAT TM has 30-m spatial resolution, there is a measurement by the satellite for every 1/5of an acre (the area covered by one pixel) during each overpass, which would be cost prohibitive for point measurements that require manual soil sample collection and laboratory analysis of each sample.
- Satellite monitoring of surface soil elemental concentrations for environmental purposes can surpass point measurements on the ground and measured in the laboratory, at least for P and Cu.

Reference

Maruthi Sridhar, B. B. and R. K. Vincent. 2009. Mapping and estimation of phosphorus and copper concentrations in fly ash spill area using LANDSAT TM Images. Photogrammetric Engineering and Remote Sensing 75 (9): 1030-1033.