Assessment of land use and land cover, water nutrient and metal concentration related to illegal mining activities in an Austral semi–arid river system: A remote sensing and multivariate analysis approach

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Abstract

The mining sector in various countries, particularly in the sub–Saharan African region, faces significant impact from the emergence of small–scale unlicensed artisanal mines. This trend is influenced by the rising demand and prices for minerals, along with prevalent poverty levels. Thus, the detrimental impacts of these artisanal mines on the natural environment (i.e., rivers) have remained poorly understood particularly in the Zimbabwean context. To understand the consequences of this situation, a study was conducted in the Umzingwane Catchment, located in southern Zimbabwe, focusing on the variations in water nutrient and metal concentrations in rivers affected by illegal mining activities along their riparian zones. Using multi–year Sentinel–2 composite data and the random forest machine learning algorithm on the Google Earth Engine cloud–computing platform, we mapped the spatial distribution of illegal mines in the affected regions and seven distinct land use classes, including artisanal mines, bare surfaces, settlements, official mines, croplands, and natural vegetation, with an acceptable overall and class accuracies of ±70 % were identified. Artisanal mines were found to be located along rivers and this was attributed to their large water requirements needed during the mining process. The water quality analysis revealed elevated nutrient concentrations, such as ammonium and nitrate (range 0.10–20.0 mg L−1), which could be attributed to mine drainage from the use of ammonium nitrate explosives during mining activities. Additionally, the prevalence of croplands in the area may have potentially contributed to increased nutrient concentrations. The principal component analysis and hierarchical cluster analysis revealed three clusters, with one of these clusters showing parameters like Ca, Mg, K, Hg and Na, which are usually associated with mineral gypsum found in the drainage of artisanal mines in the selected rivers. Cluster 2 consisted of B, Cu, Fe, Pb, and Mn, which are likely from the natural environment and finally, cluster 3 contained As, Cd, Cr, and Zn, which were likely associated with both legal and illegal mining operations. These findings provide essential insights into the health of the studied river system and the impacts of human activities in the region. They further serve as a foundation for developing and implementing regulatory measures aimed at

protecting riverine systems, in line with sustainable development goal 15.1 which focuses on preserving and conserving terrestrial and inland freshwater ecosystems, including rivers. By acting on this information, authorities can work towards safeguarding these vital natural resources and promoting sustainable development in the area.

Keywords: Artisanal mines; Dryland rivers; Mercury; River health; Water contamination