Spatiotemporal Analysis of Land Use/Land Cover Transitions Using Google Earth Engine: A Case of Tendele Coal Mine, Somkhele, In KwaZulu Natal Province, South Africa

Thobelani Jiyane, Zandile Mncube and Solomon A Zondo (South Africa)

SUMMARY

Coal mining is a cornerstone of South Africa's economy, contributing significantly to GDP and energy production, with over 90% of Africa's coal output. However, it poses severe environmental risks, including land degradation, biodiversity loss, and water contamination. The Tendele Coal Mine in Somkhele, KwaZulu-Natal, operational since 2008 and expanded in 2016, exemplifies these challenges. Mining activities, such as vegetation clearance, soil erosion, and open-pit excavation, have driven significant land use/land cover (LULC) transitions, disrupting ecosystems. These changes exacerbate water scarcity, pollute resources, and impact local communities reliant on subsistence agriculture, leading to socio-economic challenges. Despite global research on mining-induced LULC changes, localized studies in Somkhele remain scarce, hindering sustainable land management and environmental conservation efforts.

This study investigates spatio-temporal LULC transitions around Tendele Coal Mine from 2008 to 2023 at 3-year intervals, assesses mining and quarrying impacts on surrounding classes via change detection, and predicts future LULC scenarios for 2024–2028 to inform sustainable land management.

Landsat imagery (2008–2023) was processed in Google Earth Engine (GEE) using Random Forest classification to map LULC. Pre-processing included cloud masking <10% cover and geometric correction. Classified maps were analyzed in ArcMap for change detection. Accuracy was assessed via confusion matrices, yielding overall accuracy and Kappa statistics. Future LULC for 2028 was simulated using Cellular Automata-Markov (CA-Markov) modelling in IDRISI software, based on 2008–2023 transition probabilities.

LULC maps revealed dynamic shifts around Tendele Coal Mine from 2008 to 2023: mines/quarries

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expanded slightly from 2008–2011, peaked in 2014 due to active operations, contracted marginally in 2017–2020 due to resource depletion or stricter regulations, and resurged by 2023. Grassland and forest cover decreased cumulatively by approximately 15–20%, primarily converting to built-up areas and mining sites, while waterbodies showed minimal variation but faced pollution risks. Change detection analysis indicated mining drove approximately 25% of transitions from natural covers. Random Forest classification achieved overall accuracies of > 85% and Kappa statistics of > 0.82 across periods. CA-Markov modelling projected further mining expansion by 2028, reducing grasslands by 10% and forests by 15%, increasing built-up areas by 10%, and threatening biodiversity.

Mining significantly drives LULC degradation, aligning with global trends but highlighting regional monitoring gaps. GEE enabled efficient analysis, though ground-truthing limitations suggest hybrid validation approaches. Recommendations include stricter rehabilitation policies, community restoration efforts, and GEE-based real-time monitoring to balance economic gains with ecological sustainability, enhancing evidence-based land planning in South Africa's mining regions.