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A Comprehensive Review of Hybrid Quantum–Classical Approaches for Satellite-Based Deforestation Detection

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Abstract: *Monitoring deforestation accurately and on a large scale is a vital environmental issue, increasingly dependent on analyzing large amounts of satellite images. Although traditional deep learning models like Convolutional Neural Networks (CNNs) have shown effectiveness, they are nearing their limits in terms of performance and computational capacity as data volumes continue to grow. Quantum Machine Learning (QML) offers a revolutionary alternative by utilizing quantum computing principles to identify complex patterns in high-dimensional feature spaces that classical methods cannot handle. This paper thoroughly reviews circuit-based hybrid quantum-classical models, which are suitable for current Noisy Intermediate-Scale Quantum (NISQ) devices, and assesses their use in classifying land use and land cover from satellite data. We examine and contrast two leading architectures: the Quantum Convolutional Neural Network (QCNN), which incorporates a quantum processing layer into a classical network, and the Neural Quantum Kernel (NQK) approach, which employs a quantum circuit to create a robust feature kernel for a classical Support Vector Machine (SVM). The review emphasizes that the effectiveness of these models is greatly affected by the incorporation of quantum entanglement in the circuit design, and they can achieve accuracy levels comparable to or better than the most advanced classical models with significantly reduced complexity. By synthesizing the current state of these emerging technologies, this review highlights the substantial potential of hybrid quantum-classical systems to enhance real-time environmental monitoring, while also identifying the main challenges and future research directions in this promising field.*

Keywords: Remote sensing, EuroSAT, quantum machine learning, hybrid models, neural quantum kernels, deforestation detection, dimensionality reduction, quantum kernels

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