Problem and SDG Alignment

The Congo basin faces dangerous levels of deforestation driven by Agro-Industrial Plantation encroachment. The expansion of intensive agriculture has led to biodiversity loss across the Congo basin. This project aims to apply a previously developed Attention U-Net semantic segmentation approach to identify deforestation in Cameroon specifically.

The first step of applying the same Attention U-Net semantic segmentation approach entails training the model to perform pixel-wise classification of Sentinel-2 satellite imagery. The primary function of this classification is to distinguish between intact forest and large-scale deforested areas, with the aim of generating accurate, current geographical data on where large commercial operations are converting natural ecosystems into monoculture plantations.

The Nkoteng commune of Cameroon's Centre Region was identified as an optimal location for study due to the expansion of sugar cane cultivation there by the Cameroon Sugar Corporation (SOSUCAM), the company owning monopoly rights over sugar cane production in Cameroon [1]. Such land use changes accelerate forest loss, intensify habitat fragmentation, and outpace natural woodland regeneration [2]. They are also tied to social and governance issues, including land grabbing, elite-driven land allocation, and the dispossession of local populations [3]. By generating transparent, spatially explicit land cover maps, the model offers the necessary evidence to navigate these conflicts and inform responsible land-use decisions.

This deforestation detection task directly supports targets related to environmental sustainability, climate mitigation and poverty eradication.

- Target 15.2 [4]: Argo industrial expansion is a major driver of forest loss [2]. Mapping these precise boundaries provides objective metrics to measure progress towards halting forest-conservation and informing sustainable land management plans.
- Target 15.5 [4]: Plantation encroachment contributes to habitat fragmentation, threatening critically endangered forest elephants and other megafauna, as well as the unique flora, like the endemic moabi tree [1,5].
- Target 13.2 [4]: Monitoring the conversion of forest to agricultural land provides crucial data for national planning and strategies aimed at climate change adaptations. Forests in Cameroon act as climate-adaptive infrastructure by mitigating floods and stabilising soils [2].
- Target 1.4 [4]: Large-scale land conversion often results in the dispossession of indigenous and forest-dependent communities [2]. Accurate, high-resolution mapping data support calls for inclusive policies that strengthen land tenure and aid governments in verifying claims related to resource control and land access.

Limitations and Ethical Considerations

A significant limitation of this AI approach is its dependence on data quality and the accuracy of ground truth masks. Because the original masks were generated using an imperfect classification method [6], their limitations directly affected model performance. The model occasionally detected deforested polygons that were not present in the ground truth. This highlights the risk of under-detection in the ground truth, if the Cameroon ground truth contains similar gaps this could limit the model. This means that replicating the model requires careful sourcing or generation of ground truth masks, as any biases or omissions will be transferred to the new system. Another limitation is model transferability and generalisability. Biophysical differences between the Amazon/Atlantic Forest and the Congo Basin may reduce accuracy when applying the model in Cameroon. African rainforests store more carbon per hectare (≈183 t) than the Amazon (≈140 t), despite lower tree density, due to larger and taller trees with greater diameters [7]. These distinct forest structures, combined with the Congo Basin being comparatively under-studied, may limit direct model transfer without local adaptation [7].

An ethical and governance concern in Nkoteng, Cameroon is the amplification of power disparities and land dispossession. Agro-industrial, logging, and mining companies often act under the belief that they can impose their will without consequences, frequently with the support of authorities [1]. In such a setting, AI-generated maps could be weaponised by powerful actors to justify or formalise land acquired through coercive or forceful means. Forest loss also disproportionately affects indigenous and forest-dependent communities who rely on natural woodland resources for food, culture, construction materials and medicine [2]. Because the model detects forest loss regardless of scale or intent, there is a risk of policies that unfairly penalise subsistence livelihoods while overlooking large-scale industrial drivers. Additionally, increasing fuelwood extraction, often linked to limited energy alternatives [2], must be considered to avoid unjustly targeting rural households. Implementing AI without community involvement may further exclude local knowledge and deepen existing marginalisation.

Scalability Analysis

The characteristics of the Attention U-Net and the use of globally available satellite data make this AI approach scalable, but effective expansion requires addressing computational infrastructure and data management. The Attention U-Net architecture supports scalability through its efficient design. Reduced model complexity, using fewer learnable parameters and trains 20–56% faster than benchmark models such as standard U-Net, Residual U-Net, and ResNet50-SegNet [6]. Even with fewer filters, the attention mechanism preserves spatial information, allowing the model to maintain strong performance despite lower computational cost. However, scaling the model depends on sustained access to cloud-based GPU resources and well-managed data pipelines.

The method shows strong potential for expansion across Cameroon, the wider Congo Basin, and other global forests. The baseline model trained on Amazon data generalised well to the Cameroon dataset. This demonstrates the architecture's robustness across distinct ecological and spectral contexts, supporting its transferability to the Congo Basin. The model's efficiency and performance make it suitable not only for deforestation detection but also for broader land-cover segmentation tasks. Finally, Sentinel-2 imagery is globally accessible through SentinelHub, enabling consistent monitoring of large areas such as the Dja-Ngoyla Complex. Scaling geographically requires automating data acquisition, preprocessing, and storage to handle high-volume, continuous time-series data.

Sustainability Analysis

Long-term sustainability depends on integrating the model's outputs into governance frameworks, aligning local incentives with global environmental benefits, and securing durable financial support. For sustained impact, segmentation outputs must be embedded within land-use planning and conflict-resolution systems. High-resolution maps can identify deforestation hotspots and ecologically stable areas, directly informing decision-making by institutions such as the Ministry of Forestry and Wildlife. In regions like Nkoteng, land pressure from agro-industrial operators, including SOSUCAM, is closely linked to existing power imbalances [1]. In this context, transparent and verifiable spatial data can help counter coercive land acquisition by making land-use changes visible to regulators and affected communities. Integrating forest condition metrics into national land-use classifications and fiscal transfer systems further reinforces the role of forests as climate-adaptive infrastructure that mitigates floods and stabilises soils.

A sustainable long-term strategy must also address the economic imbalance between Cameroon's global contribution to climate stability and the limited domestic benefits it receives. Although Cameroon's forest carbon storage was valued at USD 59 billion in 2020, only about 0.3% of this value is retained domestically [2]. As a result, achieving sustained impact requires expanded international support through mechanisms such as REDD+, Article 6 carbon markets, and performance-based climate finance. In parallel, reducing dependence on deforestation-linked industries necessitates investment in alternative economic sectors, including ecotourism and high-value service industries that leverage the country's natural wealth.

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