Research Poster

A Suitability Assessment of the Best Eco-Engineering Agroforestry Tree Species for Landslide Control in Mt. Elgon Region, Uganda

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Introduction

The socioeconomic and environmental impacts of landslides have led to several studies on causal factors and solutions including the use of agroforestry trees (Graham et al., 2021). The agroforestry idea known as eco-engineering, involves the planting of trees with good soil stability characteristics that restrain landslides (Tardío et al., 2016). In the Mount Elgon region, tree-planting initiatives have long been carried out, however, landslides continue to occur even in restored areas (Kempango et al., 2024; Nakileza & Nedala, 2020; Opedes et al., 2024), threatening not only agriculture and the environment but also schools (Akello et al., 2025). There is limited research conducted on testing the mechanical root properties of common agroforestry tree species in the region. This study seeks to contribute towards the development of an effective landslide eco-engineering mitigation and resilience plan for landslide risk reduction. In the agriculture education and extension realm, this study contributes toward the environmental health of the AAAE research value by focusing on "examining climate variability and its impact on agriculture and agricultural-related activities" (AAAE, 2023, p. 9). The study objectives were twofold including an analysis of the spatial distribution and characteristics of selected agroforestry tree species with the potential to reduce slope failure in landslide zones; and to determine root reinforcement characteristics as a feature for promoting adoption by farmers.

Conceptual Framework

This study adopted and modified the framework from Mulyono et al. (2018) on landslides causative factors including geomorphic, topographic, hydrologic, vegetation, geologic, meteorological, human, and pedological which operate synergistically. Understanding each factor's contribution is a significant milestone toward landslide management and other hydroclimate hazards (Kempango et al., 2024; Nedala et al., 2025). Vegetation is the most important factor during landslide risk management. It emerges as both landslide control when well managed and a trigger when mismanaged, resulting in negative feedback or positive feedback loops respectively. Vegetation in the negative feedback loop can be conceptualized as *planting the right tree in the right place* and in positive feedback as *planting the wrong tree in the right place*. *Planting a right tree in a right* is conceptualized as the act of planting specific trees with good characteristics of slope stabilization with the ability to facilitate more runoff compared to infiltration in the process known as interception. It also, accelerates evapotranspiration (Nakileza et al., 2018), enhancing the formation of well-drained soil surface horizon and high shear and tensile strength by roots (Yu et al., 2020). Characteristics may include root density and root architecture used to measure horizontal root reinforcement using the index of root binding (Lee et al., 2020). On the contrary, *planting the wrong trees in the right place* means planting trees with poor slope stability traits, and rising landslide formation. *Planting the right trees in the right place* after accurate prediction would produce an effective landslide control plan.

Method

The study was confined to the Tsume micro catchment of Mount Elgon in Eastern Uganda comprising unique relief features like V-shaped valleys, sharp ridges and cliffs, and montane forest types. Mapping surveys and experiments were used in the very high-risk zones of the landslide areas. Stratified random sampling was used based on ArcGIS to generate sample elements (landslide scars) and n=12 from N=171 were generated. Identification of selected tree species, diameter at breast height (DBH) measurements, and mapping of trees were confined within a 20-meter buffer (Dias, 2019). For root tensile strength analysis, nine samples of saplings of each tree species with a DBH≤5cm (Hairiah et al., 2020) were selected and roots with a diameter ≤6mm were considered. A total of 198 soil shear strength samples were collected at an interval of ≤2m from the tree base; from which 168 were tested *in situ* and 30 were tested in the lab for validation (Islam et al., 2021). Replicates (28) for *in-situ* and 5 for validation per species were carried out. The spatial distribution and direction of selected tree species were analyzed using the standard deviation ellipse method of ArcGIS (Zhao et al., 2022). The relationship between tree distribution and landslide occurrence was achieved through Pearson's correlation. Root reinforcement characteristics were determined by analyzing root tensile strength, the index of root binding (IRB) of soil, and soil shear strength (Ettbeb et al., 2020). A one-way ANOVA was conducted to test for differences within the tree species.

Results

A total of 129 trees were mapped and the most abundant were *Eucalyptus Spp* (28%), followed by *Markhamia lutea* (23%), *Cordia africana* (15%), *Grevillea robusta* (14%), *Albizia coriaria* (12%) and *Croton macrostachyus* (8%). *Croton* and *Markhamia* were the most dispersed species; *Albizia* was most localized downstream; *Croton* were more in the western direction while *Markhamia* were at the center of the axis. *Albizia* and *Eucalyptus* were dispersed towards the Southwestern while *Grevillea* and *Cordia* to the Northwest direction.

The relationship between landslide size and tree diameter (DBH) revealed a weak negative correlation ($r=-0.20 <0.01$). On root characteristics for slope stability, specifically with tensile strength, ANOVA results indicated that all species' means were significantly different from each other ($p<0.001$). *Grevillea, Albizia,* and *Markhamia* had higher tensile strength with an average weight of 3.02±1.217kg/mm², 2.53±1.382kg/mm², and 2.28±1.01kg/mm² respectively. *Croton* (1.78±1.167kg/mm²) and *Cordia* (1.69±1.153kg/mm²) had the least tensile strength.

A Scheffe *post hoc* criterion for significance confirmed variability within species. The root tensile strength of *Albizia* (2.206±0.832) was significantly different from *Grevillea* ($p<0.001$) and *Markhamia* ($p<0.001$). Similarly, *Cordia* (3.065±0.872) was different from *Markhamia* (5.096±0.358; $p<0.001$). A same pairwise comparison also revealed that *Croton* (2.143±0.683) was significantly different from *Eucalyptus* ($p=0.049$), *Grevillea* ($p<0.001$), and *Markhamia* ($p<0.001$). *Eucalyptus* (3.457±0.144) significantly ($p=0.002$) differed from *Markhamia*.

The index of root binding was highest for *Albizia* (81.31), and lowest for *Markhamia* (47.84). All the tree species indicated an inverse relationship between tensile strength and root diameter. Sharp slopes were observed among *Cordia, Grevillea, Eucalyptus,* and *Markhamia*. On shear strength, the best-performing species was *Albizia* with an average of 52.46±10.24kpa followed by *Markhamia at* 50.70±15.47kpa. The least performing species was *Eucalyptus* 46.75±12.92kpa. Soil texture results indicate an average highest clay content (27.8%) in soil samples picked near *Markhamia*, sand (33.6%) in *Eucalyptus,* and silt (54.0%) in *Albizia* soil samples.

Conclusion/Implications/Recommendations

This study revealed how knowledge of diameter at breast height (DBH), tensile strength, index of root binding, and soil shear strength could be harnessed in controlling landslide risk in the Mount Elgon region of Eastern Uganda to improve agricultural production, settlement, and overall environmental protection. The presence of trees reduced landslide risk in the area and DBH was a very important guiding factor. An increase in DBH directly decreased landslide scar size and landslide risk. Results also showed that *Grevillea, Albizia,* and *Markhamia* were the best eco-engineering tree species with high tensile and shear strength. *Albizia* and *Cordia* had the added advantage of holding soil particles together. However, the study found that trees need to be left to grow up to a size (DBH≥20cm) for full realization of the slope stability characteristics.

A regulatory impact assessment policy review is required for extension education and sensitivity analysis toward the establishment of a landslide mitigation and resilience plan to promote tree planting in mountainous areas. An important strategy is engaging the community members in research and relaying the information back to these stakeholders to increase the chances of acceptance of scientific and sustainable innovation that arise from such participatory action research and ensure innovative ideas are communicated in a non-scientific format (Ikendi, 2023; Kempango et al., 2024; Nedala et al., 2025; Opedes et al., 2024). For future research, an in-depth tensile strength analysis using a modern tensile machine of higher capacity is recommended to test bigger roots for proper comparison of the results. Also, an investigation on other indigenous tree species, fruit trees, shrubs, and grasses would be beneficial for widening the scope of other tree varieties and grasses that communities may prefer for adoption in their agroforestry systems.

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