DEVELOPMENT OF AN IOT-BASED LANDSLIDE EARLY WARNING SYSTEM USING A DYNAMICS FACTOR OF SAFETY MODEL

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Landslides are a recurring geohazard in Sri Lanka's highland regions, causing loss of life and infrastructure damage each monsoon season, yet most at-risk communities rely on single-variable empirical rainfall thresholds that fail to represent a slope's true geomechanically state. This study developed a low-cost IoT-based landslide early warning system (LEWS) integrating a dynamic Factor of Safety (SF) model for real-time slope stability assessment. The system employed an ESP32 microcontroller with a nine-sensor network (rainfall, soil moisture, soil temperature, ambient temperature, humidity, wind speed, slope angle, ground vibration, and atmospheric pressure) and GPS-tagged SMS alerting via a SIM808 GSM/GPS module. The SF model extended the classical infinite slope framework to incorporate five driving stress components: gravitational shear, rainfall infiltration, moisture-dependent cohesion reduction, seismic vibration, and wind loading with effective cohesion dynamically adjusted as a linear function of measured soil moisture. SF values were classified into five risk tiers (Safe, Watch, High, Very High, Failure) at thresholds of 1.3, 1.1, and 1.0, triggering local (LED, buzzer, OLED) and remote (Wi-Fi cloud, GPS-tagged SMS) alerts at one-minute intervals. Laboratory evaluation across 611 acquisition cycles yielded a mean SF of 8.69 (range: 0.808–76.05); 96.07% of readings were classified Safe (SF ≥ 1.3), while the 3.93% non-safe alerts (7 Watch, 7 High, 6 Very High, 4 Failure) arose exclusively under imposed steep-slope (45°) and high-moisture (up to 100%) conditions, confirming correct five-tier escalation. Pearson correlation identified soil moisture as the dominant SF determinant ($r = -0.606$, $p < 0.001$), with an even stronger slope-angle effect ($r = -0.851$, $p < 0.001$) in controlled tests, where SF declined from 5.04 to 1.13 (sandy soil) and 4.91 to 0.96 (mixed soil) across 10–45°. At a cost of LKR 18,000–22,000, the system represents a feasible community-scale LEWS for Sri Lanka's landslide-prone highlands, pending field calibration for site-specific deployment.

Keywords: ESP32, factor of safety, internet of things, landslide early warning, multi-parameter monitoring, slope stability