Debris Run-Out Modeling Without Site-Specific Data

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***Abstract*—Recent population growth and actions near hilly areas increase the vulnerability of occurring landslides. The effects of climate change further increase the likelihood of landslide danger. Therefore, accurate analysis of unstable slope behavior is crucial to prevent loss of life and destruction to property. Predicting landslide flow path is essential in identifying the route of debris, and it is essential necessary component in hazard mapping. However, current methodologies of determining the flow direction of landslides require costly site-specific data such as surface soil type, categories of underground soil layers, and other related field characteristics. This paper demonstrates an approach to predict the flow direction without site-specific data, taking a large landslide incident in Sri Lanka at Araranyaka region in the district of Kegalle as a case study. Spreading area assessment was based on deterministic eight-node (D8) and Multiple Direction Flow (MDF) flow directional algorithms. Results acquired by the model were compared with the real Aranayaka landslide data set and the landslide hazard map of the area. Debris paths generated from the proof of concept software tool using the D8 algorithm showed greater than 76% agreement, and MDF showed greater than 87% agreement with the actual flow paths and other related statistics such as maximum width of the slide, run-out distance, and slip surface area.**

***Keywords*—Landslide flow path; route of debris; hazard mapping; D8 Algorithm; multiple direction flow algorithm**

I. Introduction

A landslide is widespread in earth motion when the slope changes from a steady to an unsteady state. It happens due to geological, morphological causes, or human activities. There are many categories of landslides, namely Rock Slides, Earth Flows, Debris Slides, Debris Flows, and Rock Falls [1].

Rainfall is a major initiating factor for most landslides in Sri Lanka [2]. During heavy rains, water penetrates the top layer of soil into the deep layers of the earth beneath them, filling the ground's empty pores. When the water in the pores reaches saturation, it causes an internal pressure, called the "pore pressure of water," and in most cases, it causes a landslide.

Predicting a landslide flow path is very important for determining the flow path and the sedimentation area. It is also vital for mapping the hazards of landslides, early warnings, evacuation, and mitigation. Hence flow direction is a prime component in risk assessment and measures to eliminate rapid landslides [3].

When dispensing early warnings, it is impossible to visit every site before issuing of warning. Even without site-specific information, if there is a method that can be used to get an idea of the landslide-prone area, accordingly, the landslide's flow path can be predicted, and evacuation paths can be decided. Instructing people as per prediction will reduce the possible damages to lives during the landslide. Therefore, this work can be used to get an idea about the elevation and possible flow paths of a site prior to visiting without expensive site-specific data.

II. Literature Review

Many research works have been carried out globally to predict, mitigate, and manage these disasters and do better decision-making. The following are some attempts done by people worldwide to predict landslide initiation points, flow path, and run-out distance.

The paper by Gomes et al. [4] elaborates on how to combine spatial models for landslides and flows prediction. A map has been constructed with landslides starting points, flows size, and run-out distance of mass movements in Quitite and Papagaio in Rio de Janeiro city, Brazil, using this combined model. In this study, the landslide model (SHALSTAB) was combined with the debris-flow simulation model (FLO-2D).

In 2020, Zhao et al. came up with landslide run-out modeling method [5] with the integration of Gaussian process emulation and open-source simulation tool r.avaflow.The developed model is then tested with the landslide that happened in Bondo in 2017.

Tesfahunegn Abera Gebreslassie carried out dynamic simulations of landslide run-out for his master's research using DAN3D and BING models [6]. Finneidfjord quick-clay landslide has been taken as the case study to stimulate the above models. DAN3D and BING models require terrain models of the path and the mass at the release area, shear strength, and the dynamic viscosity as inputs and calculate the run-out distance and the flow velocity. This study shows that the run-out distance is higher using DAN3D than the BING model; however, DAN3D uses ten times execution time than the BING model.

"Linking rainfall-induced landslides with debris flows runout patterns towards catchment scale hazard assessment", a paper by LinfengFan et al. [7] described a methodology to predict landslide pathways with the integration of the novel Landslide Hydro-mechanical Triggering (LHT) model. The obtained result is compared with the continuum-based model RAMMS, which showed a reasonable agreement.

In 2016, a paper presented by Formetta et al. came up with a methodology to systemically calibrate, verify, and compare different models and select the models whose behavior is the most reliable for a particular case study. This approach