Landslide Typology as a Tool for the Main Triggering Factor Description in Monsoon Landslides in North Vietnam

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Abstract: Classifications of the landslide landforms are not only a way of naming reality. This is the tool to analyze the main factors and triggers that cause the process and lead to the formation of the specific landforms. Field research conducted by the authors in Northern Vietnam allowed for a comprehensive review of the landslide forms identified in the region and proposed five specific landslide types based on three main criteria: type of rock on the sliding surface, permeability of the sliding surface, and depth of the sliding surface.

Keywords: ***Landslides, Monsoon regions, Triggering factors, North Vietnam.***

Introduction

Regions with monsoon climate patterns and the atmosphere dynamics driven by typhoons are simultaneously global hotspots for landslides. One of these areas most prone to landsliding is Northern Vietnam (Pham et al., 2021a). Each year, numerous related phenomena are reported, including deep-seated landslides, clusters of shallow landslides, multiple landslides, debris flows, and more (Pham et al., 2021b).

The identified landslide forms often deviate from widely used classifications (e.g., Hungr et al., 2014), which justifies the need to present their diversity and critical evaluation of the existing classification approaches. At the same time, landslide forms recognized during the field survey can often be classified on the most general level, suggesting limited possibility for a precise typology of the studied landforms. When trying to use landslide classifications as tools for planning and forecasting (Khositashvili, 2015), rather than only for academic discussion, the absence of certain types or classes within the landslide identification systems creates a significant knowledge gap.

Study Site

Northern Vietnam is a mountainous area with a denivelation from about 30 m a.s.l. in the Red River valley bottom to the highest peak, Phan Xi Păng (3147 m a.s.l.). Differences in relative heights have a consequence in a relief with long, steep slopes with high potential energy. Warm climate with high humidity causes intensive weathering of the rocks and covering slopes with strongly weathered soils, even on the steep slopes (Gian et al., 2017) These initial environmental conditions, combined with seasonal monsoon conditions and occassional intensive rainfalls generated during typhoons, cause a significant level of landslide hazard.

Methodology

Review of the landforms presented in this paper is an effect of classical field observation with mapping and measurements of the heights of the main scarp, slope angle of the sliding surface and transport zone, and observation of other manifestations of morphogenetic processes (Figure 1). Field investigation was realized during three consecutive post-monsoon / post-typhoon field campaigns at autumns 2022, 2023, 2024. Field works included observation of the whole catchment or slope geomorphological conditions, field documentation, landslide geomorphological mapping, UAV survey, and soil sampling. Detailed data was taken from 14 landslides. In addition, the analysis of orthophoto maps from Google Earth was done.

Results and Discussion

The landslide landforms in the research area are highly diverse. The same initial trigger—monsoon or typhoon rainfall—can result in different processes and mechanisms. In nearby areas or neighboring catchments, a similar amount of rainfall can trigger isolated landslides, clusters of shallow landslides, or deep-seated landslides—all during the same event. This suggests that while intense rainfall acts as the primary trigger, other environmental factors, such as geology, topography, soil depth, etc., serve as modifiers that determine the specific mechanisms, geomorphological processes, and ultimately, the resulting landform types.

Most of the identified landforms can be classified into only one, perhaps two, of the standard categories following widely accepted, updated version of Varnes' classification (Hungr et al., 2014). The very different landslides presented in Figure 1 meet the criteria for this classification as translational slides in their source areas and as earth (partly debris) flows in their accumulation zones. Therefore, all must be

classified as a single type in the Varnes' typology, namely the "complex" type. This paradox highlights the need for additional classifications, even when established general landslide typologies are used.

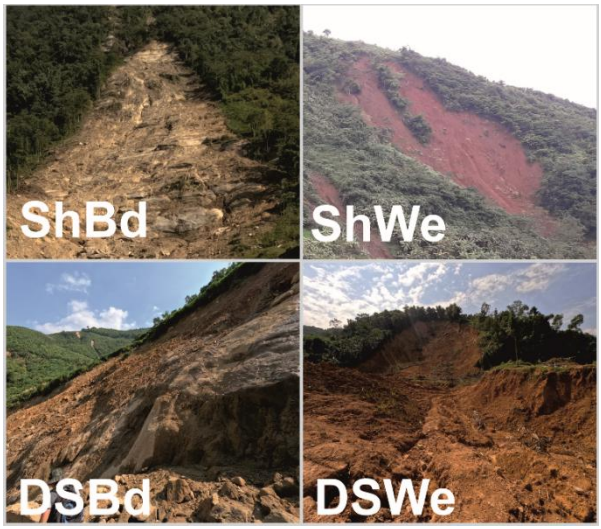

Figure 1, Examples of different types of landslides. Muong Hoa, Ky Son, Nam Tong, Minh Xuan. Photo by authors.

The most important factors that differentiate observed landforms are: 1) the type of rock material on the sliding surface, which affects 2) the permeability of the sliding surface. When the sliding surface is built of solid bedrock, rainfall seepage into the soil profile is stopped and very strong saturation and probable liquefaction are the main landslide triggers. When weathered material on the slope is thicker, seepage of rainfall water does not cause liquefaction, but rather causes an increase in saturation and weight inside the weathered material mass. The third criterion in typology is depth of the sliding surface, dividing landforms into shallow and deep-seated. It suggests a potential impact of the rock mass volume on the environment. The proposed typology includes five types (Table 1). Assigning a form to each landslide type helps identify the main triggering factor (beyond precipitation) and the likely geomorphic consequences, such as the displaced earth volume.

Conclusions

Strongly weathered slope materials combined with high saturation conditions mean that in northern Vietnam almost all landslides can be classified as the same complex type in Varnes' classification. This is because all types of processes operating in landslide source areas ultimately lead to changes in the accumulation zone typical for earthflows. If we treat landslide classifications as tools for analyzing the main factors and triggers responsible for these processes and their resulting landforms, general typologies become insufficient. This demonstrates that specific regional environmental conditions require their own classification systems, which consider not only the resulting landforms but also the triggering factors involved.

Table 1, Types of landslides in the study area.

Type code	Depth	Sliding surface	Permeability
ShBd	Shallow	Solid bedrock	No
ShWe	Shallow	Deep weathered	Yes
DSBd	Deep-seated	Solid bedrock	No
DSInt	Deep-seated	Cracks in bedrock	No
DSWe	Deep-seated	Deep weathered	Yes

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