271. LANDSLIDE SUSCEPTIBILITY MAPPING IN LUNAR SOUTH POLE REGION

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CURRICULUM 1 – OBSERVATION OF THE UNIVERSE
Topic of research: 1J - Multi-disciplinary applications of new space technologies: from the detection of cosmic radiation to geomorphology - E66E23000110001
Research project: GIS-based landslide susceptibility mapping and monitoring: integration of space technology, laboratory analysis and fieldwork.

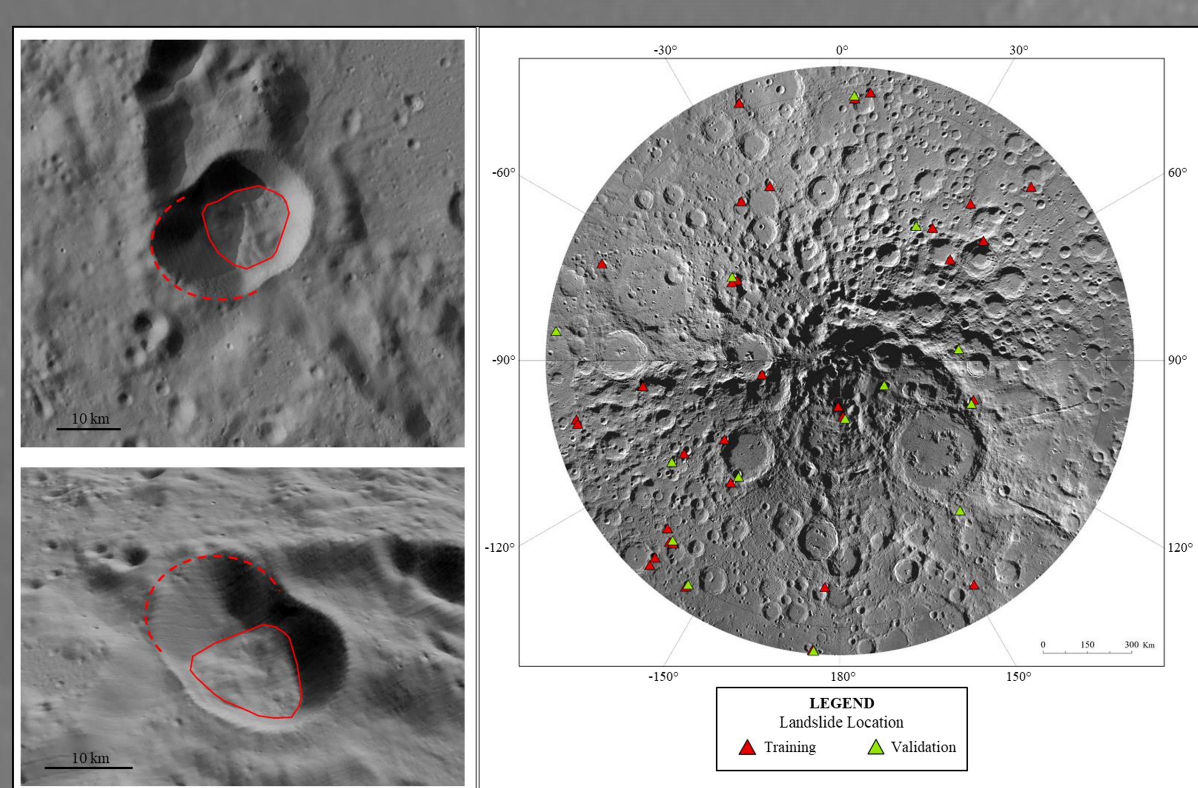
INTRODUCTION

Landslides are recognized as dominant geomorphic events of morphological evolution in most mountainous and hilly landscapes. Different types of gravitational events have been observed on other planets and minor bodies such as the Moon. This study aims to contribute to the understanding of landslide susceptibility on the lunar surface, focusing specifically on the Lunar South Pole Region (LSPR). The LSPR has garnered increasing attention due to its geological features, including Permanently Shadowed Regions (PSRs) and volatile deposits such as water ice. For this reason, many space agencies are planning or actively working on lunar missions (ex. NASA's Artemis missions). In this work, to evaluate the safety conditions, not only for the sites chosen for the Artemis lunar mission landing, but also for future missions, a Landslide Susceptibility Map (LSM) was created in LSPR. Starting from a landslide inventory map, created through the photointerpretation of data from the Lunar Reconnaissance Orbiter mission (LRO), the Frequency Ratio model (FR) was utilized to assess the probability of landslide occurrence in different zones. In this type of study, it is crucial to consider both causative and triggering factors. Causative factors, represented by geological and morphological characteristics, derived from existing thematic maps (Fortezzo et al, 2020) and by the processing of Lunar Orbiter Laser Altimeter (LOLA) Digital Elevation Model (DEM). This activity has been carried within ESRI™ ArcGIS Pro software environment. Considering the studies already carried out on the Earth, many authors have analyzed the contribution of heavy rainfall and earthquakes as triggering factors of landslides. Similarly, on the Moon, recent scientific papers proposed by Mishra & Kumar, 2022 and Watters et al., 2024, assert that moonquakes, produced by lobate thrust fault scarps movement, have the greatest impact on regolith landslides that are triggered in the steepest slopes of impact craters. To include this contribution as a triggering factor into the FR model, it was decided to consider the PGA variation as function of epicentral distance, as suggested by previous studies (Mishra & Kumar, 2022; Watters et al., 2024). Once the causative and triggering factors were implemented into the FR model and the LSM was produced, its accuracy was assessed by using the AUC method.

MATERIALS AND METHODS

1 CREATION OF LANDSLIDE INVENTORY

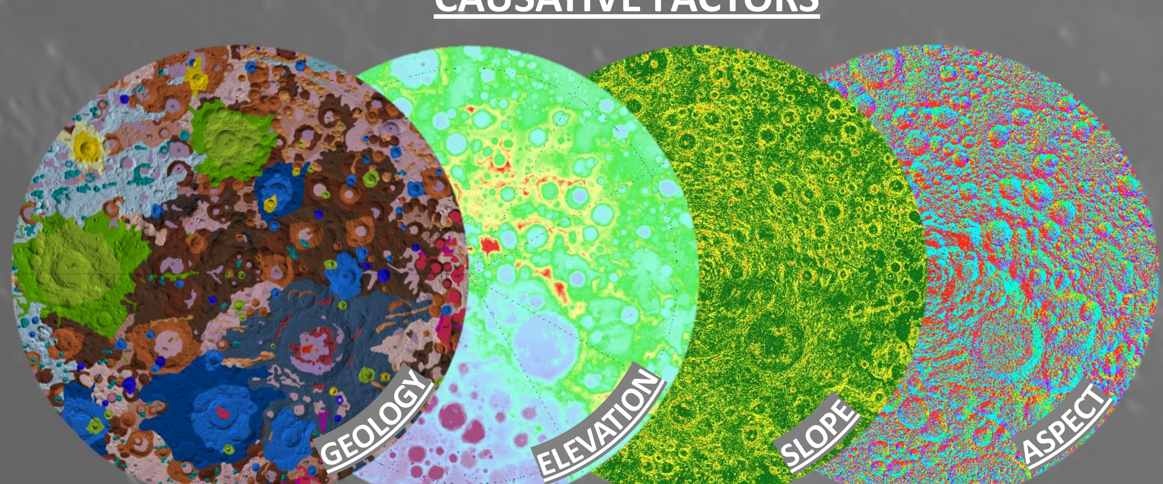
The identification and mapping of landslides on the lunar surface were obtained by the analysis of images from the Lunar Reconnaissance Orbiter Camera (LROC) Wide Angle Camera (WAC), at a spatial resolution of 100 meters, and hillshaded LOLA DEM (118 m/pixel resolution).



2 LANDSLIDE CAUSATIVE AND TRIGGERING FACTORS

In this type of study, it is crucial to consider both causative factors, which influence the predisposition of an area to geomorphological phenomena over long periods, and triggering factors, which are short-term events that can originate landslides. Causative factors, represented by geological and morphological characteristics, derived from existing thematic maps (Fortezzo et al, 2020) and by the processing of Lunar Orbiter Laser Altimeter (LOLA) Digital Elevation Model (DEM). To include the contribution of moonquakes as a triggering factor, it was decided to consider the Peak Ground Acceleration (PGA) variation as function of epicentral distance, as suggested by Mishra & Kumar (2022).

CAUSATIVE FACTORS



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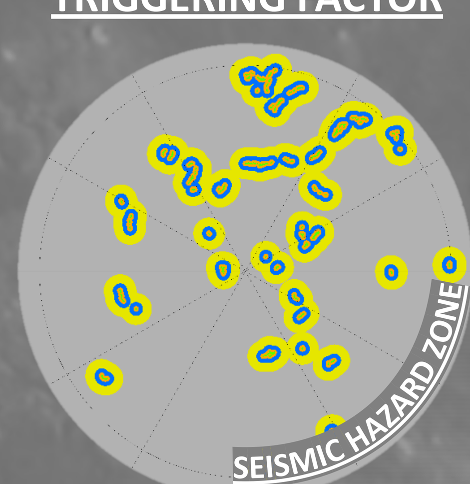
TRIGGERING FACTOR



3 APPLICATION OF FREQUENCY RATIO MODEL

The Frequency Ratio (FR) is a statistical model widely used in landslide susceptibility mapping. It calculates the ratio between the presence of landslides within each factor class compared to the total area of that class on the map.

$$FR = \left[\frac{N_{pix}(SX_i)/\sum_{i=1}^{m} SX_i}{N_{pix}(X_j)/\sum_{j=1}^{n} N_{pix}(X_j)}\right]$$

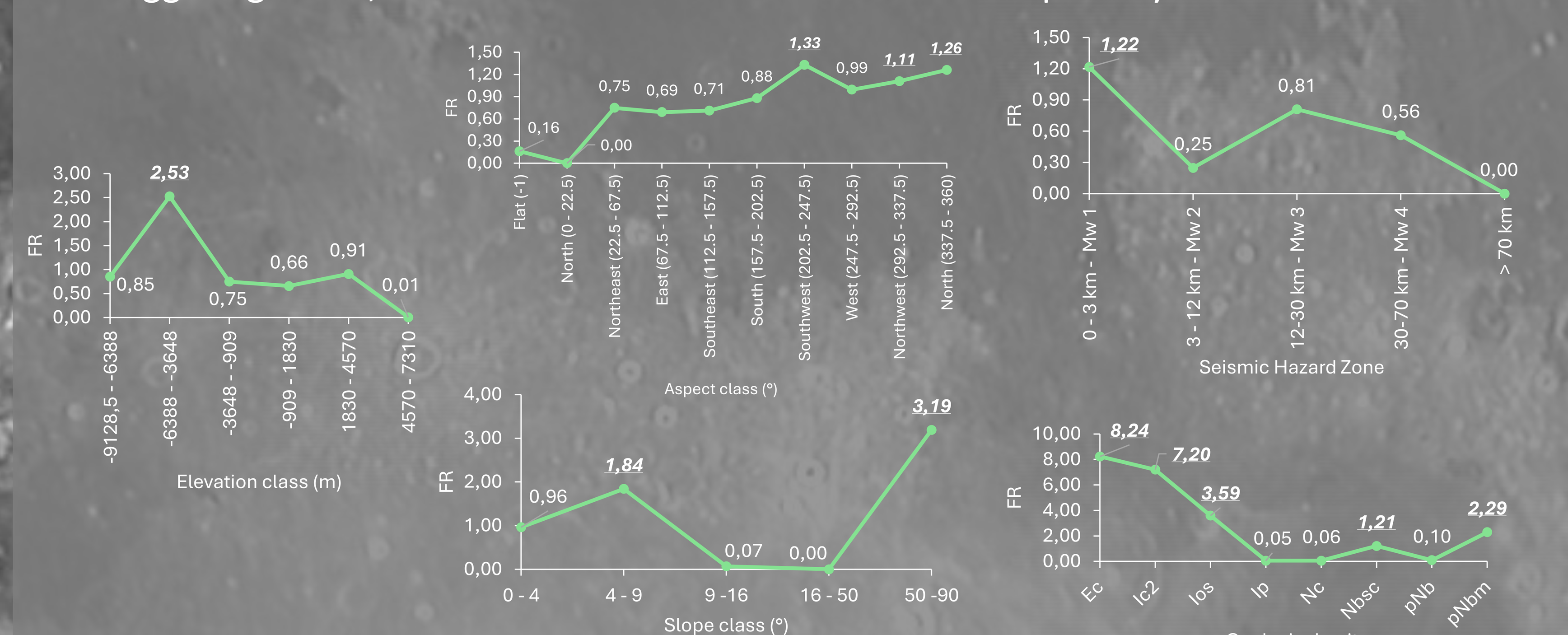
FR > 1 High Probability
FR > 1 Low Probability

$$LSM = \sum_{j=1}^{n} FR_j$$

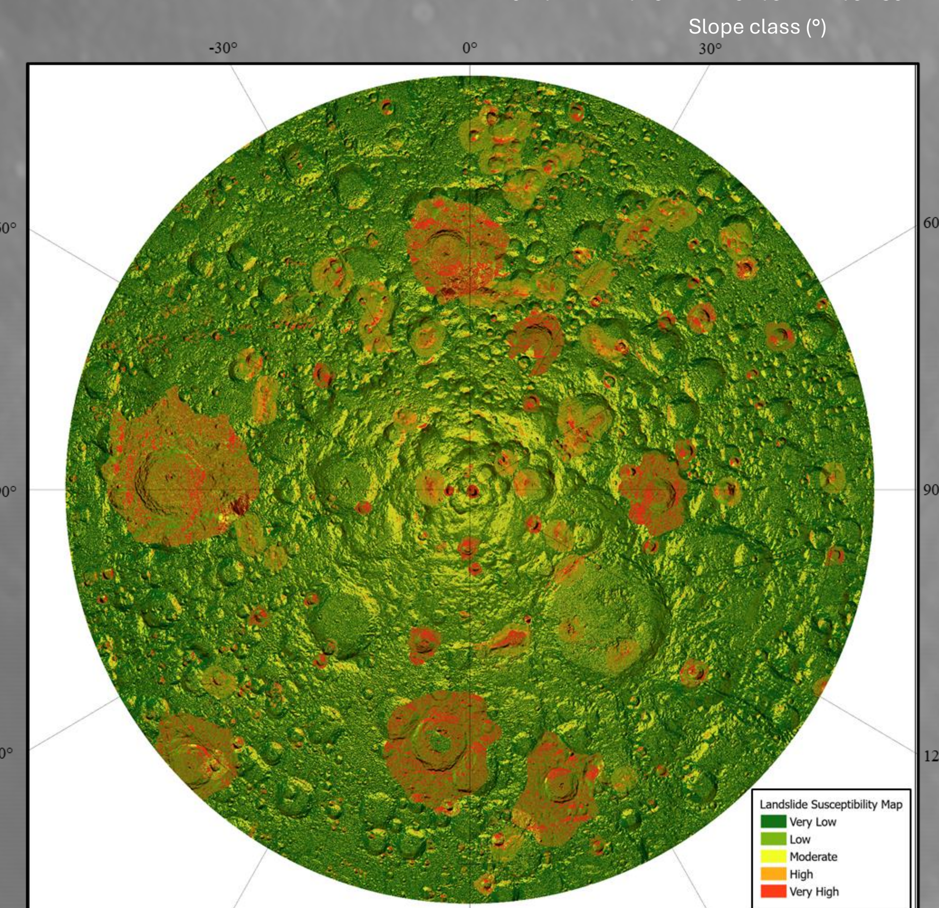
Where $N_{pix}(SX_i)$ represents the number of landslide pixels in class i of the factor X; $N_{pix}(X_j)$ is the total number of pixels within factor X_j; m is the number of classes in factor X_i; and n is the total number of factors.

RESULTS

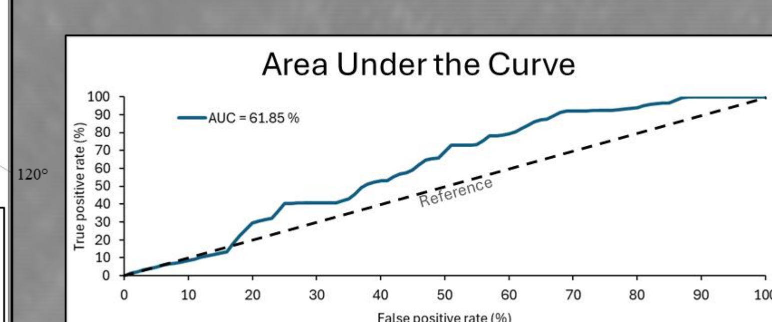
Using the FR model, it was possible to specifically identify the classes, within each causative and triggering factor, that could influence the landslide susceptibility.



LANDSLIDE SUSCEPTIBILITY MAP

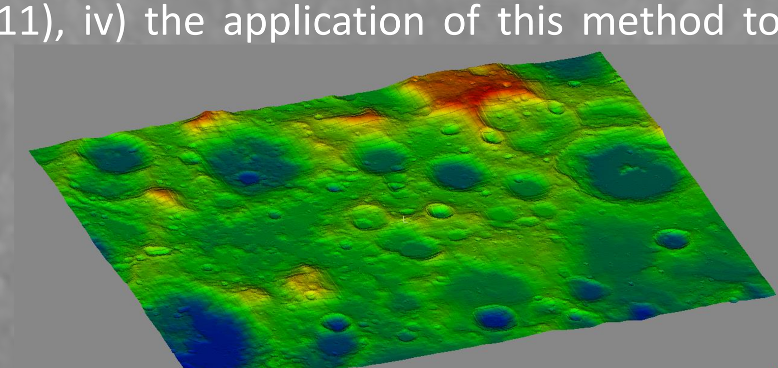


Susceptibility	Area (km²)	%
Very Low	229.31	29
Low	226.54	29
Moderate	227.77	29
High	58.18	7
Very High	42.31	5



CONCLUSION AND FUTURE DEVELOPMENT

The study of landslide susceptibility has allowed for a detailed identification of the classes to the causative and triggering factors that are most susceptible to seismic-induced landslides. This has enabled the evaluation of safety conditions, not only for the sites chosen for the Artemis lunar mission landing but also for future missions. Future developments of this work will involve: i) the integration of additional information, such as temperature variations in permanently shadowed areas; ii) the use of more accurate predictive models (ex. Weight of Evidence, Random Forest) to enhance the comprehensiveness of landslide susceptibility mapping; iii) a large-scale three-dimensional slope stability analysis in LSPR using engineering-geological data provided by past missions (ex. Luna 13, Apollo 11), iv) the application of this method to other celestial bodies (ex. Mars).



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