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THE GLOBAL ENGINEERING CONFERENCE ON SUSTAINABLE DEVELOPMENT AND WORLD FEDERATION OF ENGINEERING ORGANISATIONS EXECUTIVE COMMITTEE MEETINGS.

15th - 18th October 2024, Kigali, Rwanda

Theme: Engineering Innovations for a Sustainable Future

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INSTABILITY AND PREVENTION COUNTERMEASURES OF TYPICAL LANDSLIDE IN NORTHWEST RWANDA

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CONTENTS

INTRODUCTION

Background

Landslides are common geological disasters, causing casualties, resource degradation, and infrastructures damage. North West Rwanda frequently experiences severe landslides due to its mountainous, rain nature.

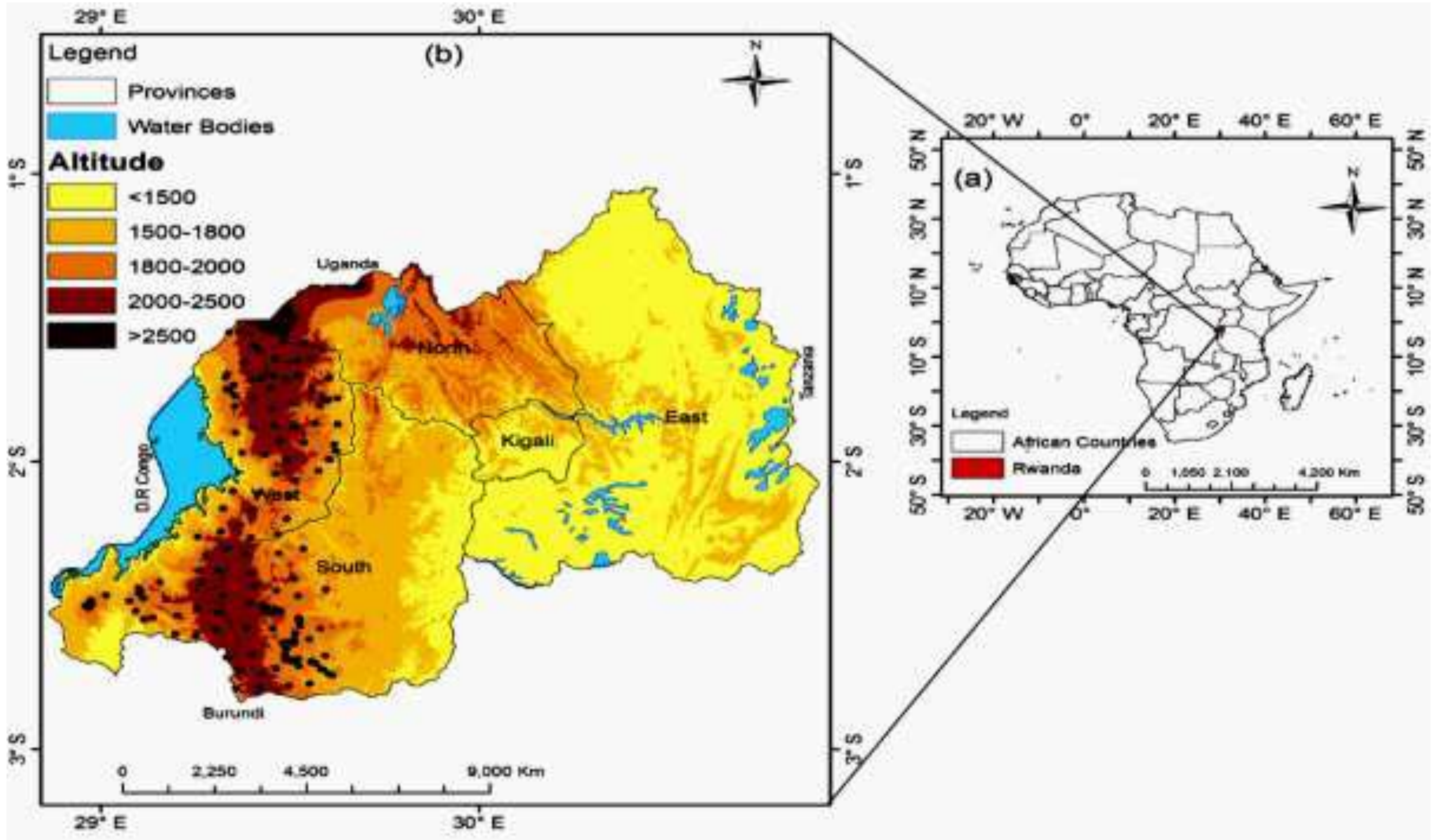
Study Objective

The study aims to analyze landslide instability and propose preventive engineering measures

LANDSLIDE CONTEXT IN RWANDA

Geographical setting

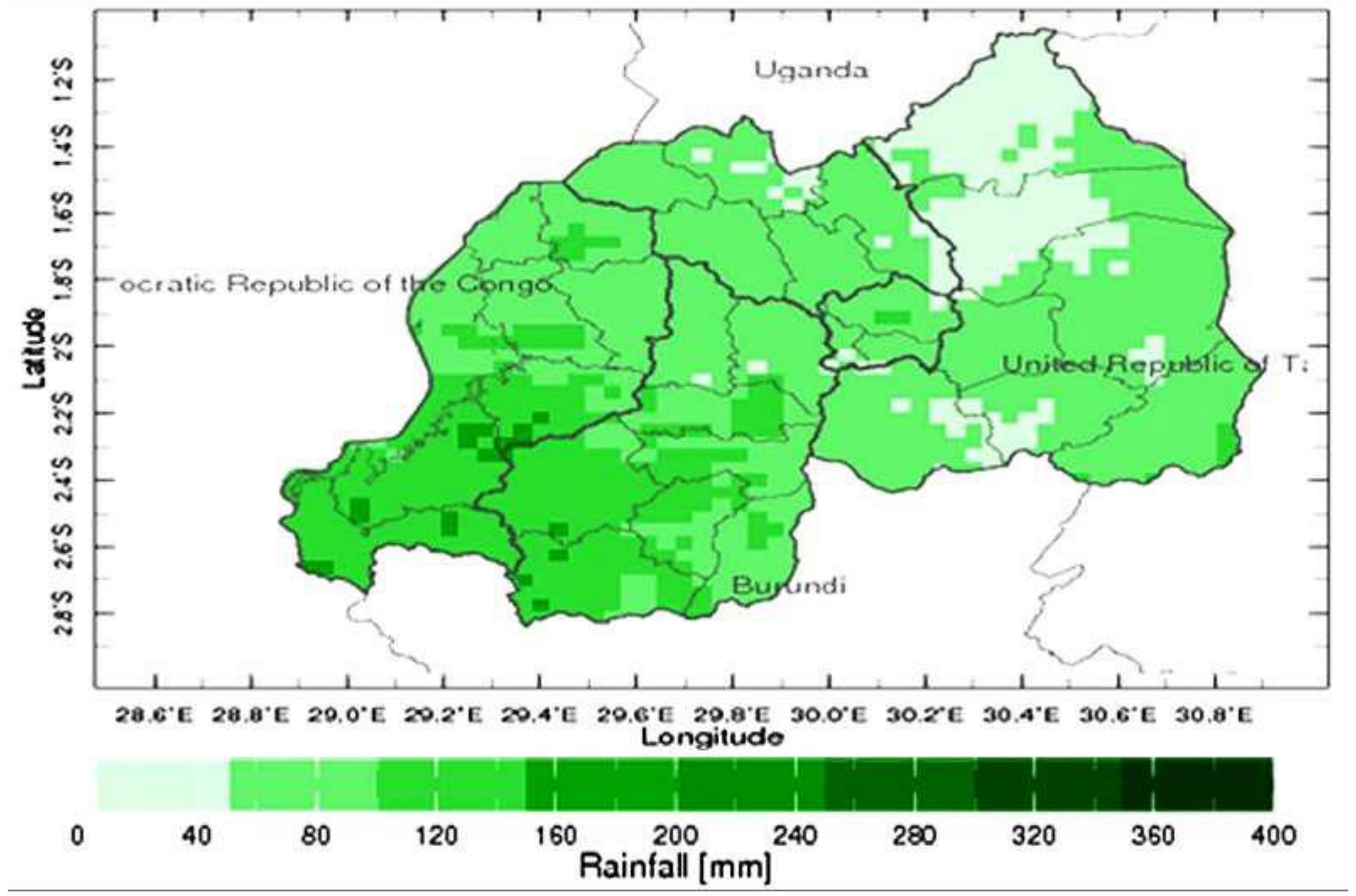
Rwanda is a high-elevation, landlocked East African country, prone to landslides due to its hilly terrain and significant rainfall



Geographical location of (a) Rwanda in Africa and (b) its landslides inventory

Climate Factors

The country has heavy annual rainfall, averaging over 500mm, with some areas receiving up to 2000mm. Combination of high rainfall, steep slopes, and human activities increases landslide risk.



Precipitation average per month

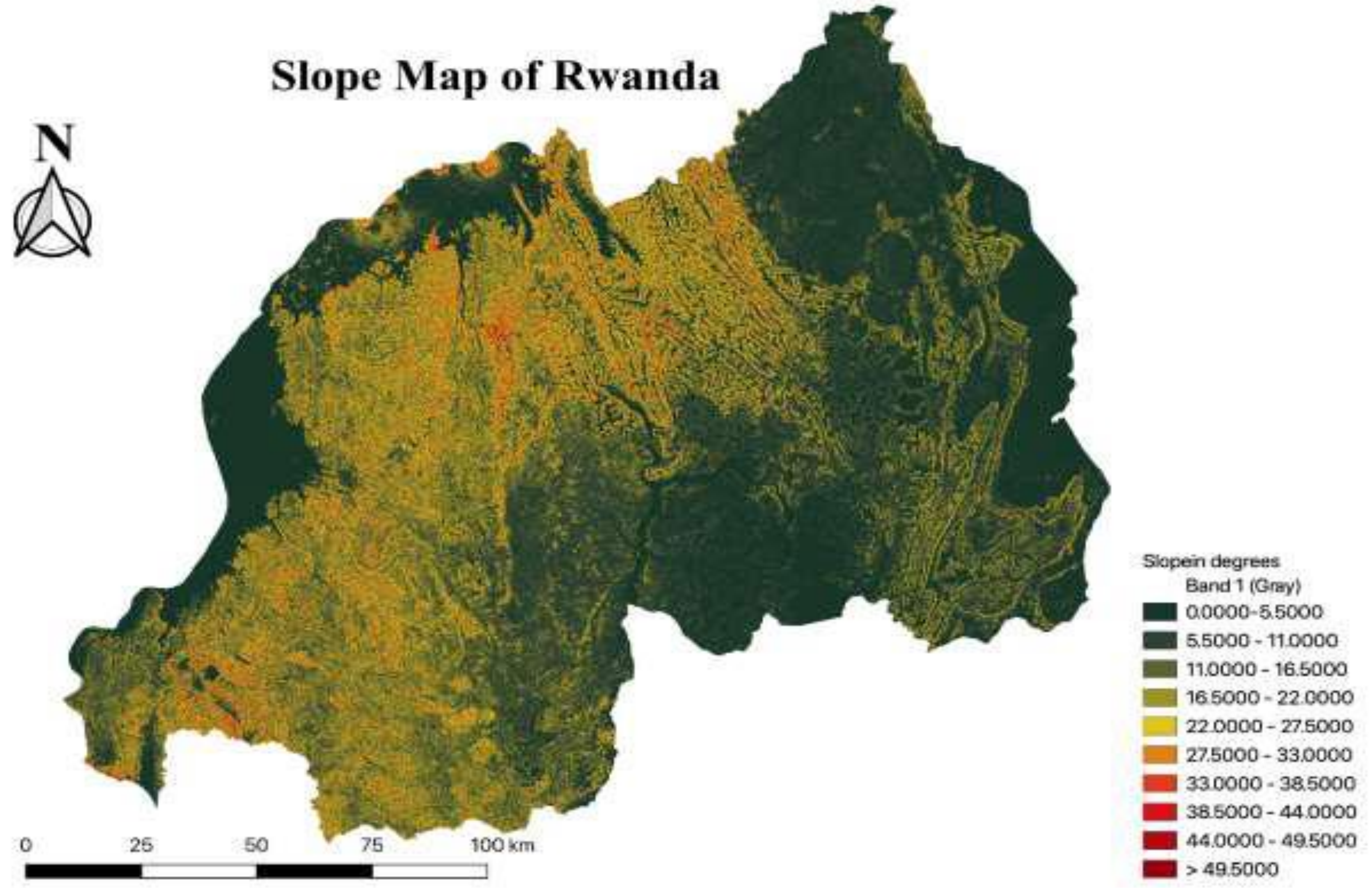
MAIN CAUSES OF LANDSLIDES IN RWANDA

Natural Causes

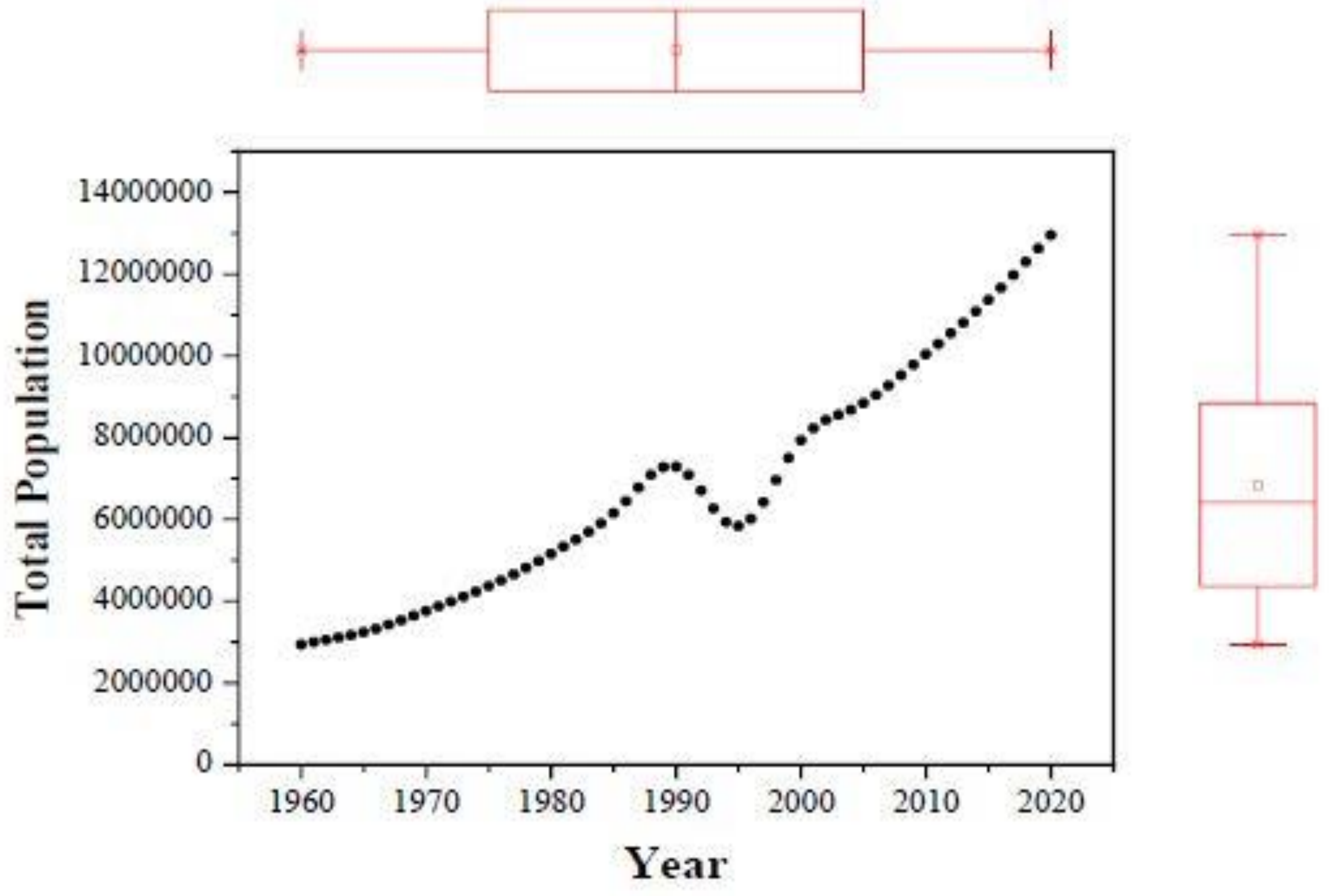
Key contributors include intense rainfall, slope steepness, and soil properties. High clay content increases water retention, leading to slope instability

Human Activities

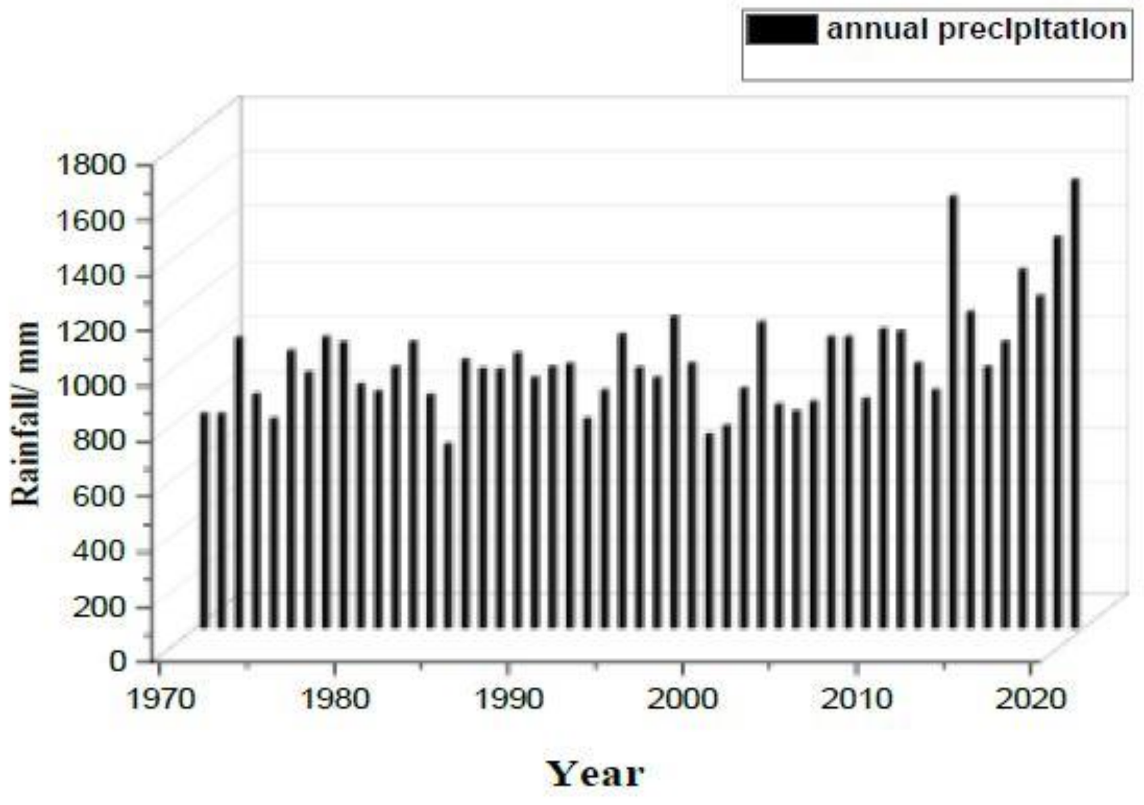
Deforestation, undercutting slopes for construction, and improper land-use practices exacerbate the risk.



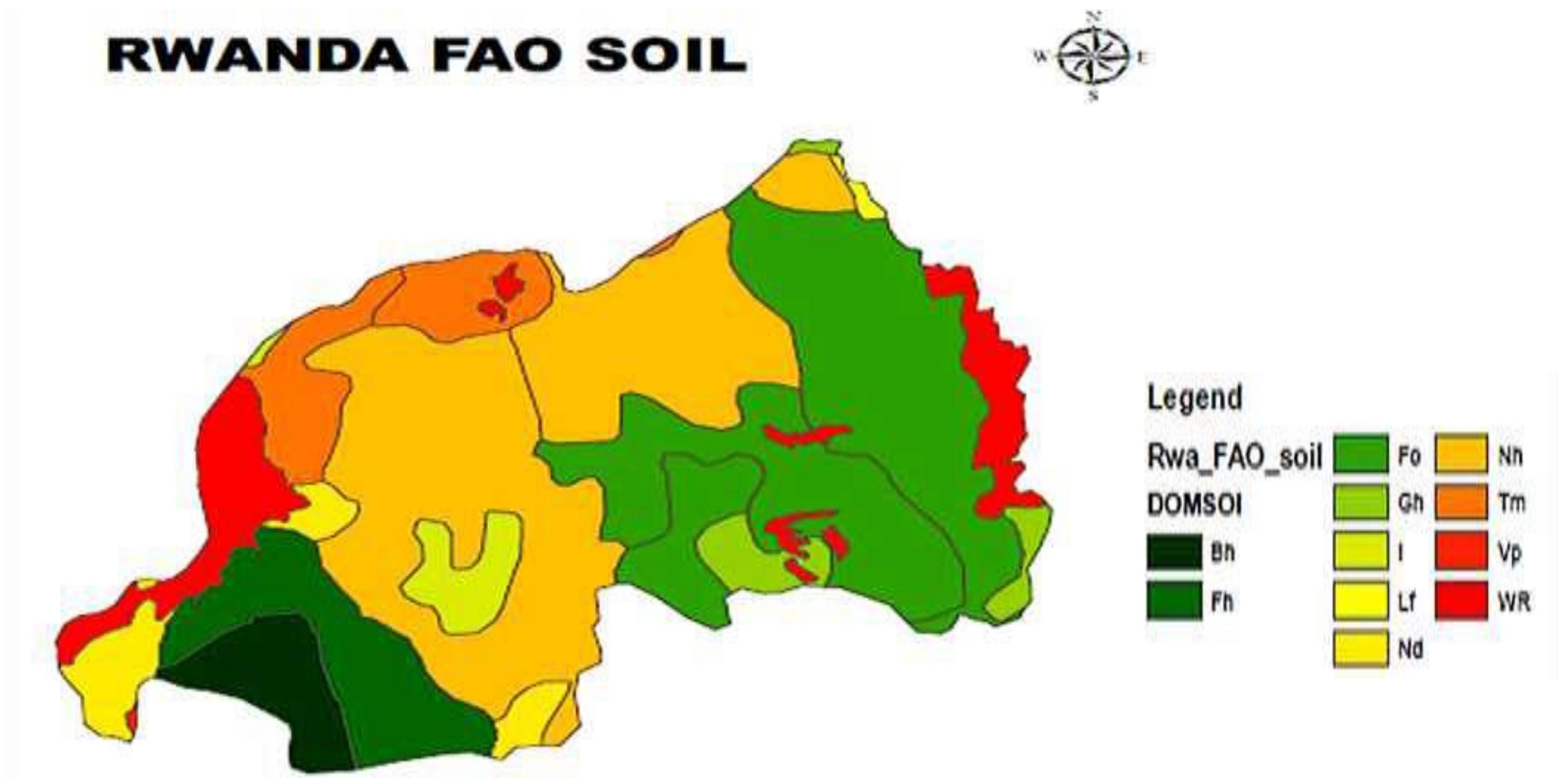
Rwanda has a steep topography with an altitude between 915m and about 4500m



Population in Rwanda form 1960 to 2020



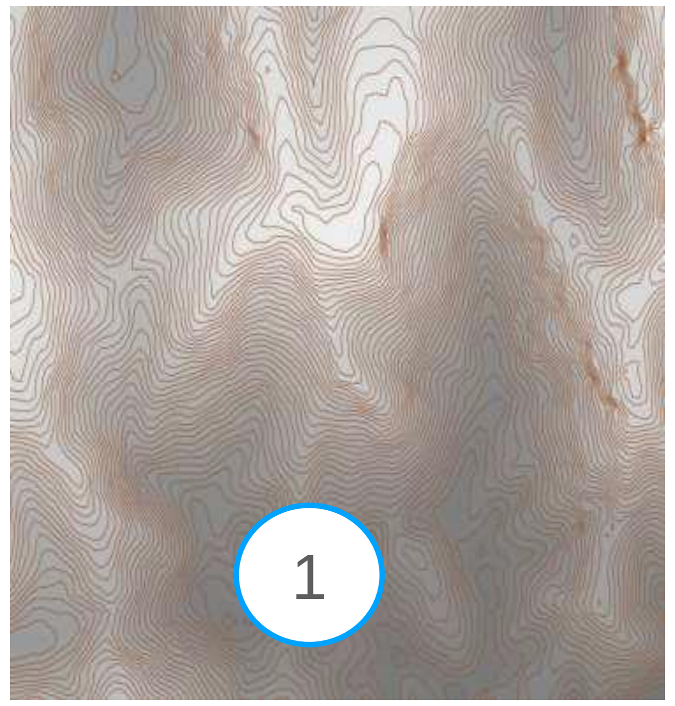
Rwandan Annual precipitation 1970-2020



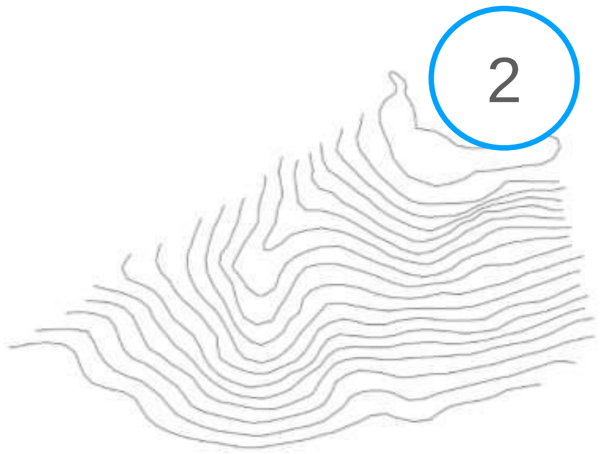
Rwanda FAO soil map

LANDSLIDE ANALYSIS AND METHODOLOGY

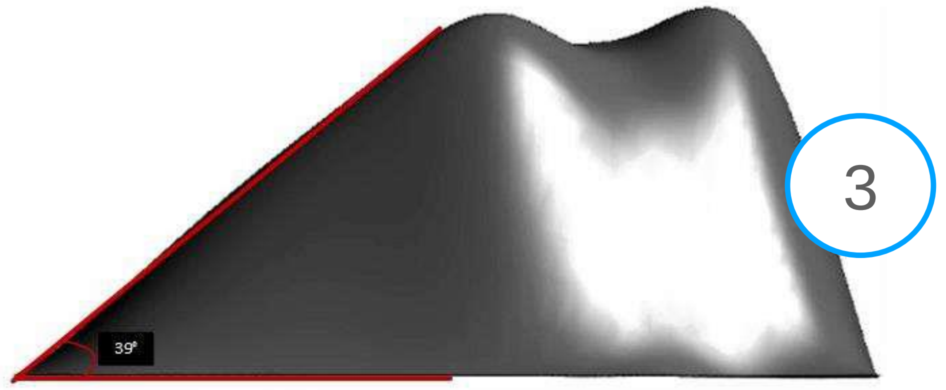
This study utilized numerical simulation methods to analyze slope instability in North West Rwanda. Tools include GTS NX Software and methods like Bishop's Simplified method and Spencer's method of slices. These methods evaluate factors of safety (FS) concerning slope gradients, rainfall impact, and soil properties under different conditions



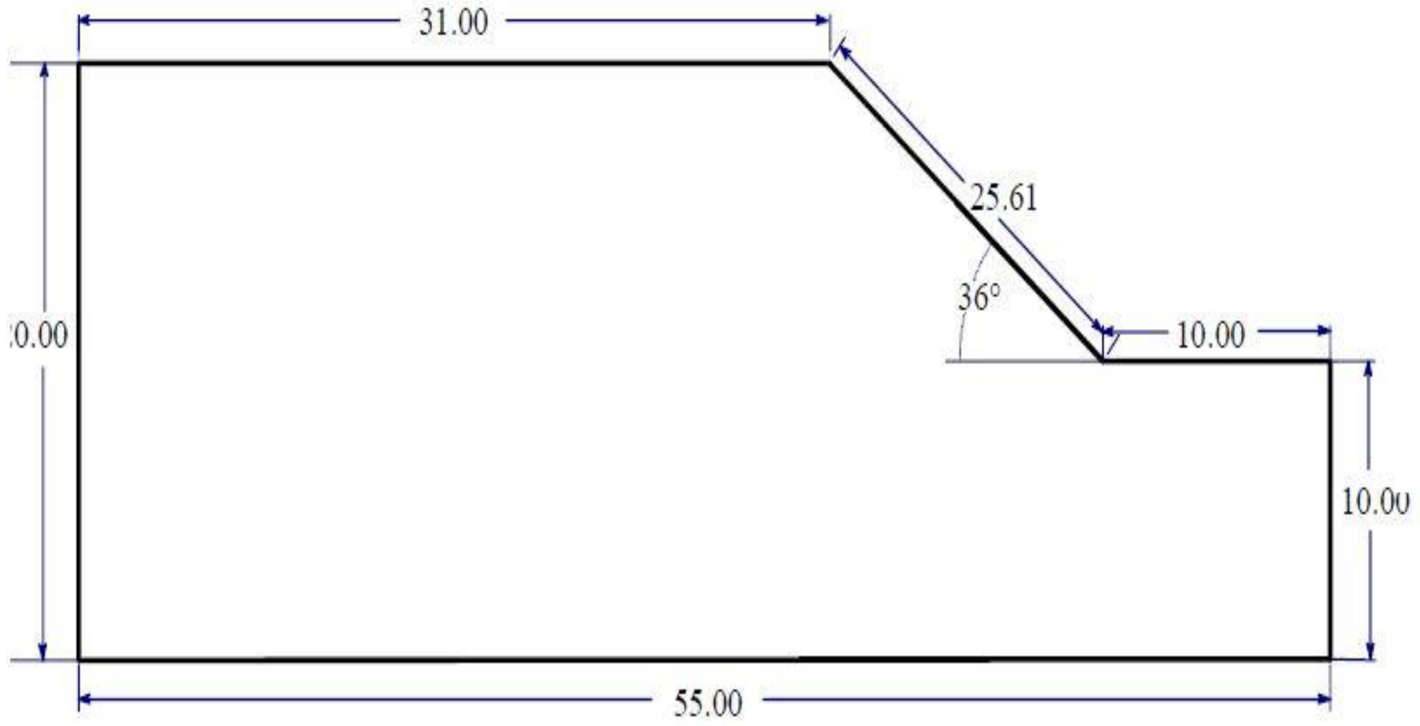
Digital elevation model (DEM) data



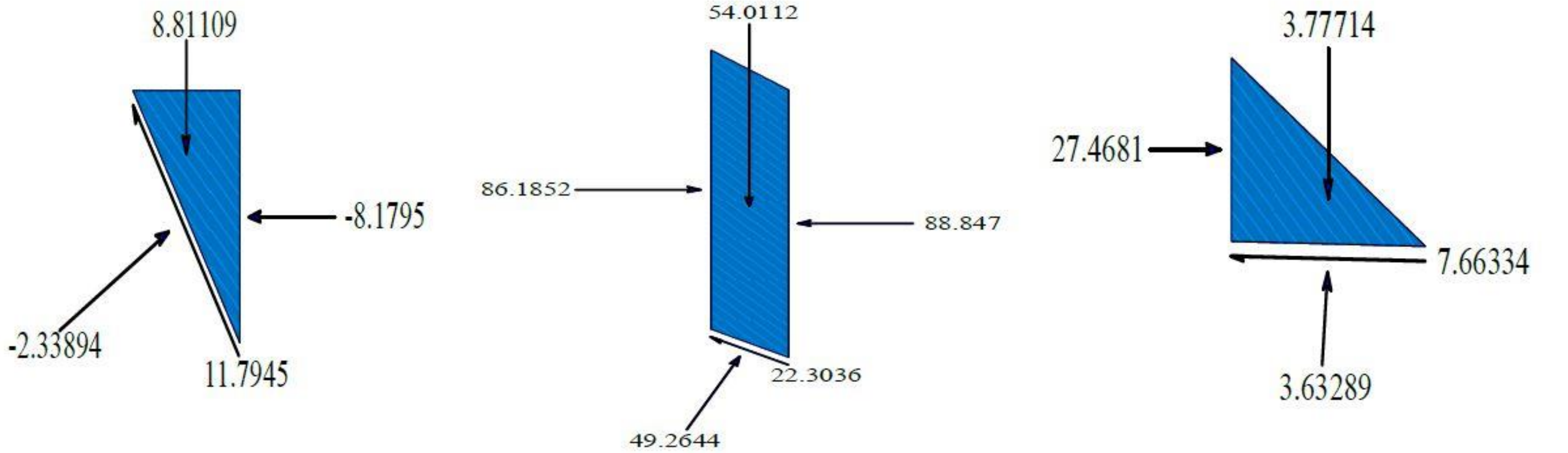
AutoCAD 3D contours generation



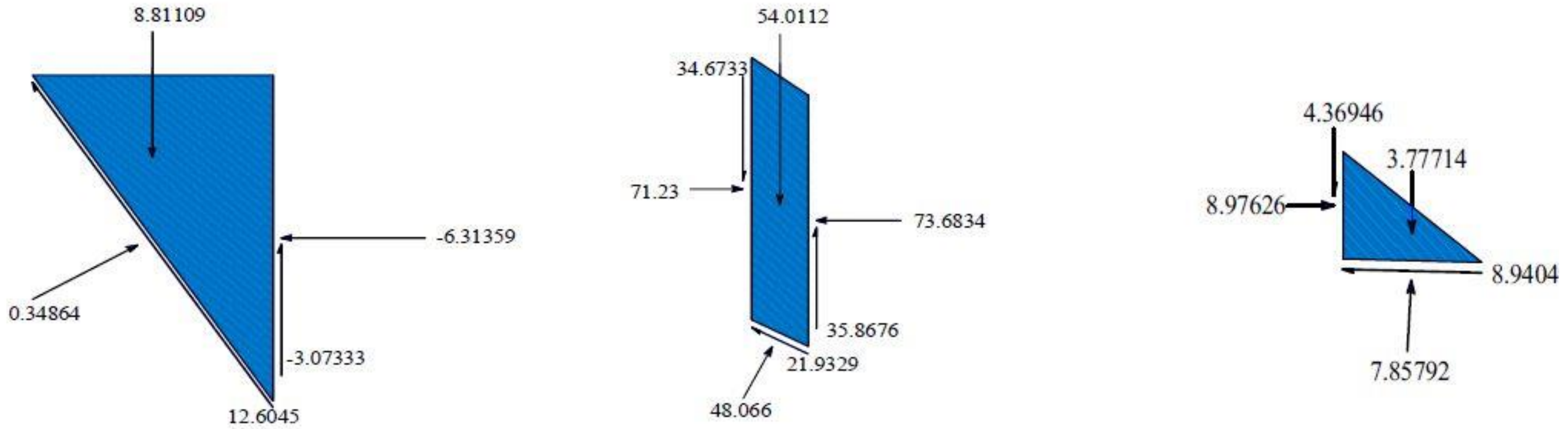
GTS NX terrain reference model



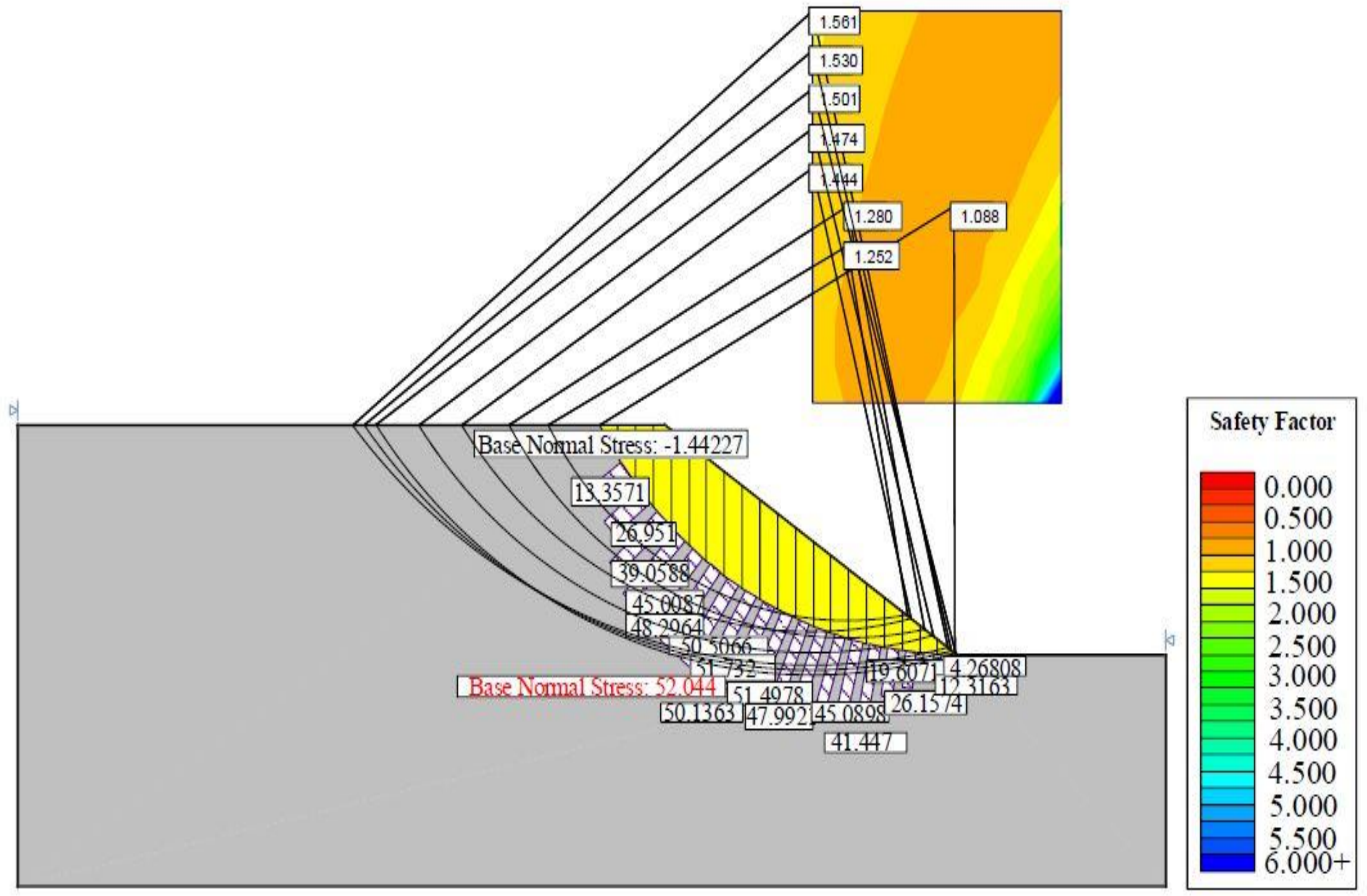
Soil modal 36 degrees



Top, Middle and Bottom slice results, Bishop Method



Minimum and maximum inter-slice results Spencer Method



Possible safety factors with base normal stress

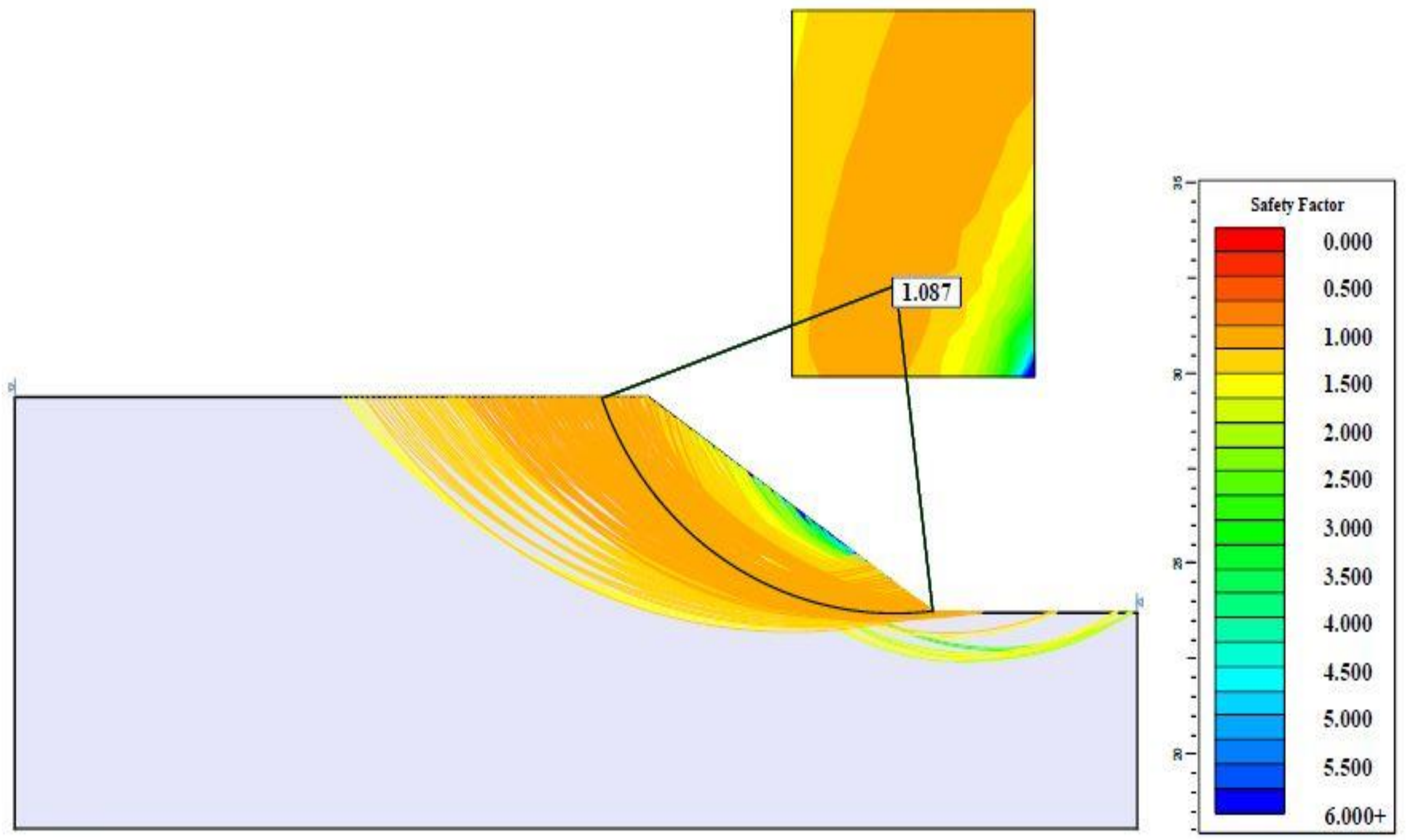
KEY FINDINGS FROM THE STUDY

Slope Impact

Slopes with gradients over 30 degrees in North West Rwanda were particularly prone to landslides, influenced significantly by rainfall and clay rich soil

Safety Factor Analysis

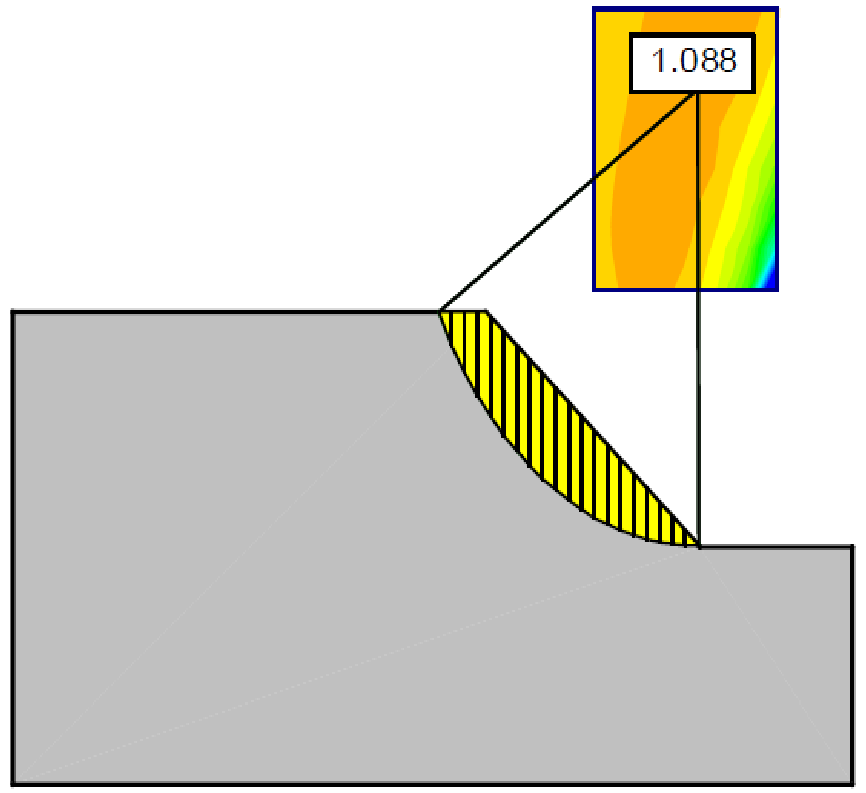
Using Bishop and Spencer methods, many slopes showed FS below the standard value of 1.35, indicating natural instability, particularly in multi-layer soil slopes and cut slope



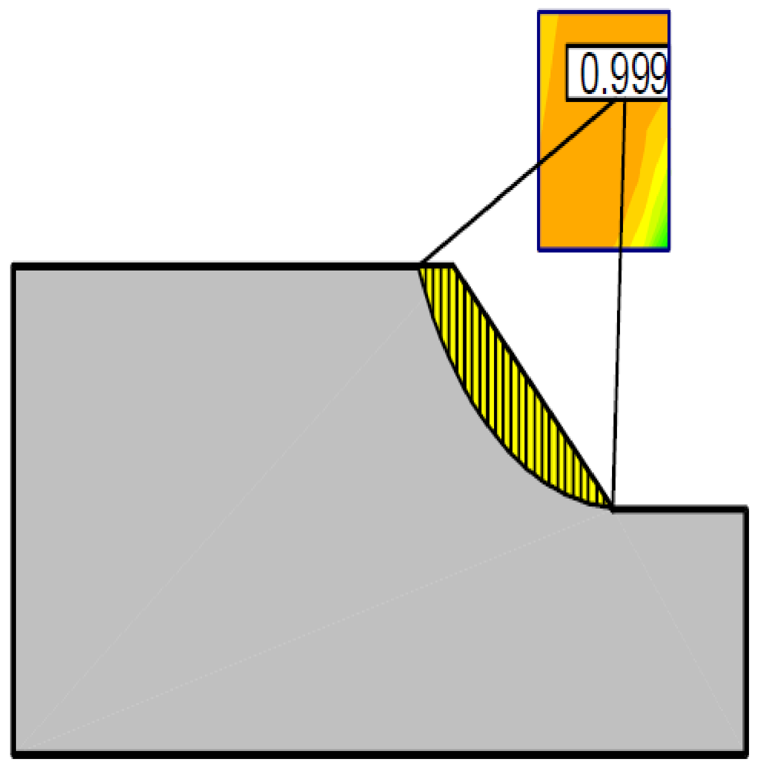
There is no big difference between the results of spencer and Bishop as shown in Figure 3-6. The *FS* using Spencer method is equal to 1.087090 as shown in Figure 3-6. The value of center

and radius are (43.156, 25.252), and 15.325, respectively with the left and right slip surface endpoint equal to (28.759, 20.000) and (44.954, 10.033), respectively.

The resisting moment equals 6383.79 kN-m with a driving moment equals to 5872.35kN-m

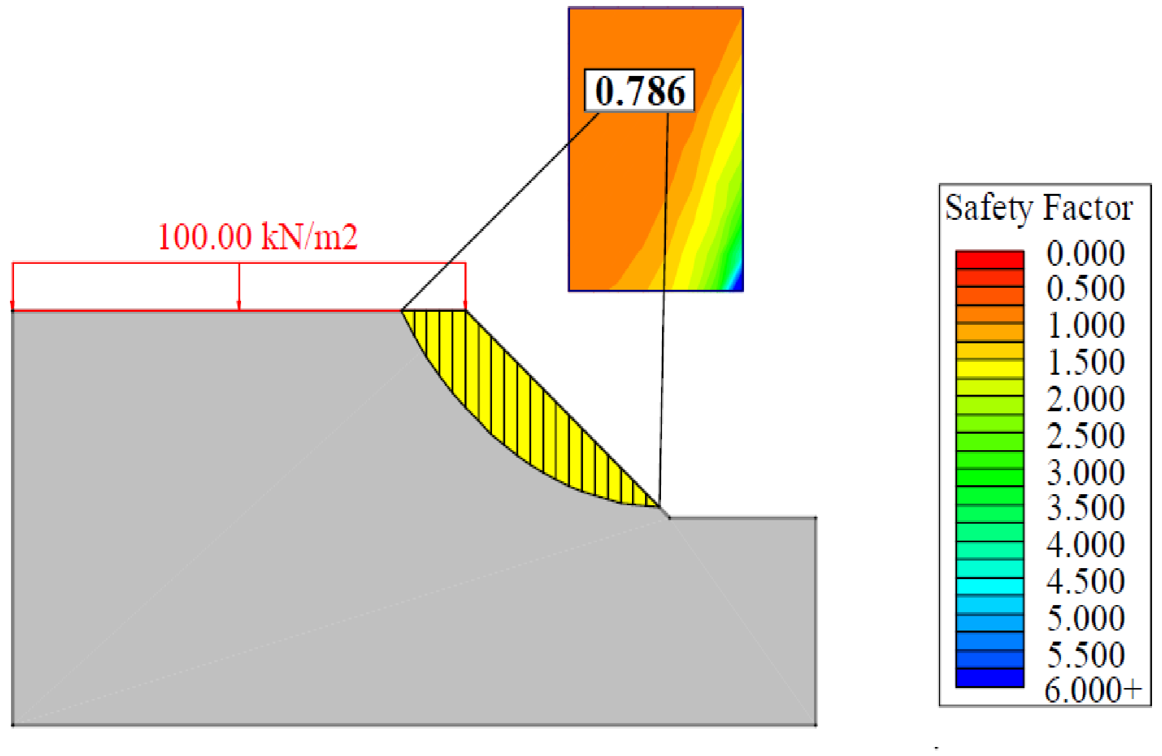


(a) safety of factor at 36 degrees

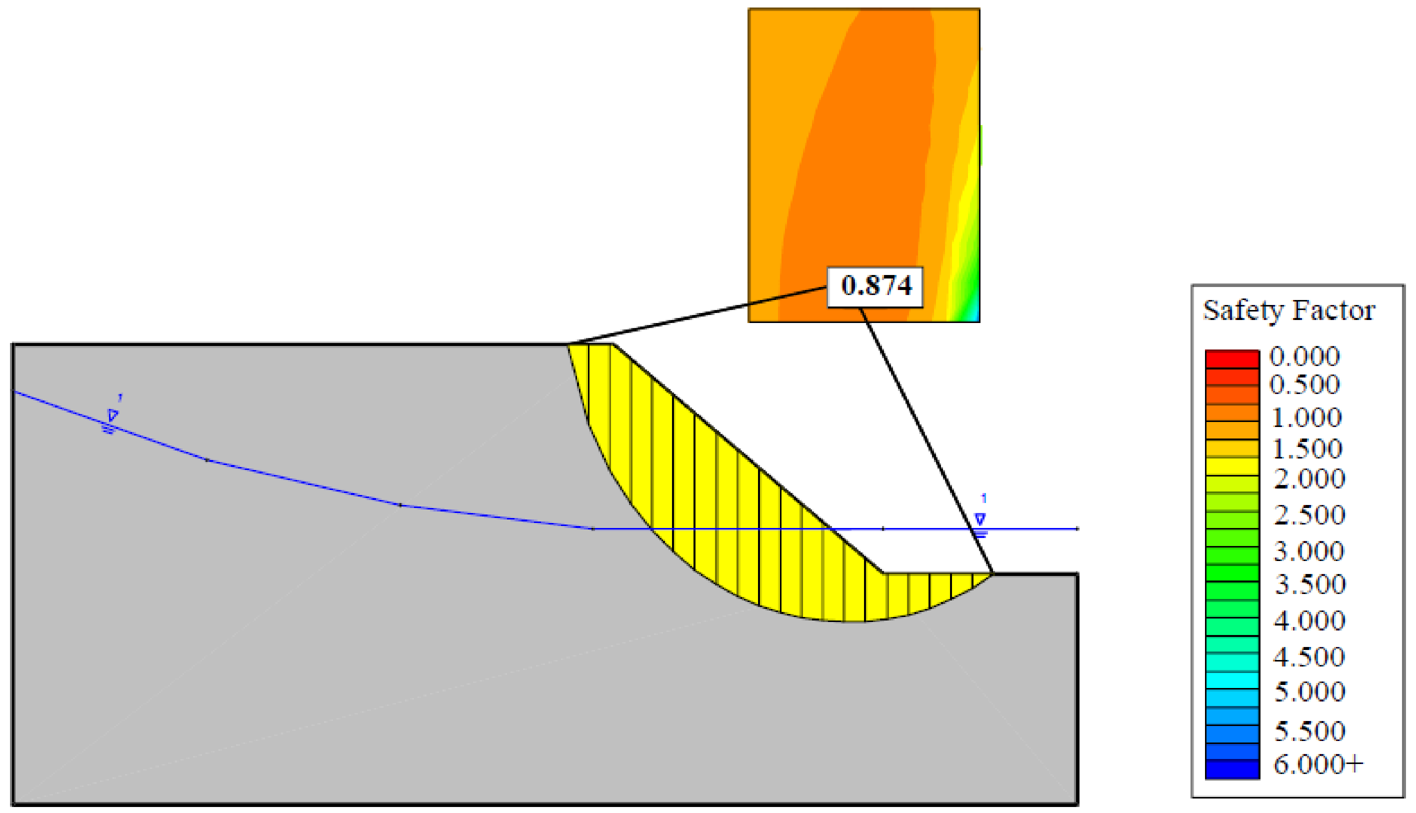


(b) safety factor at 40 degrees

Slope failure due to the angle of inclination



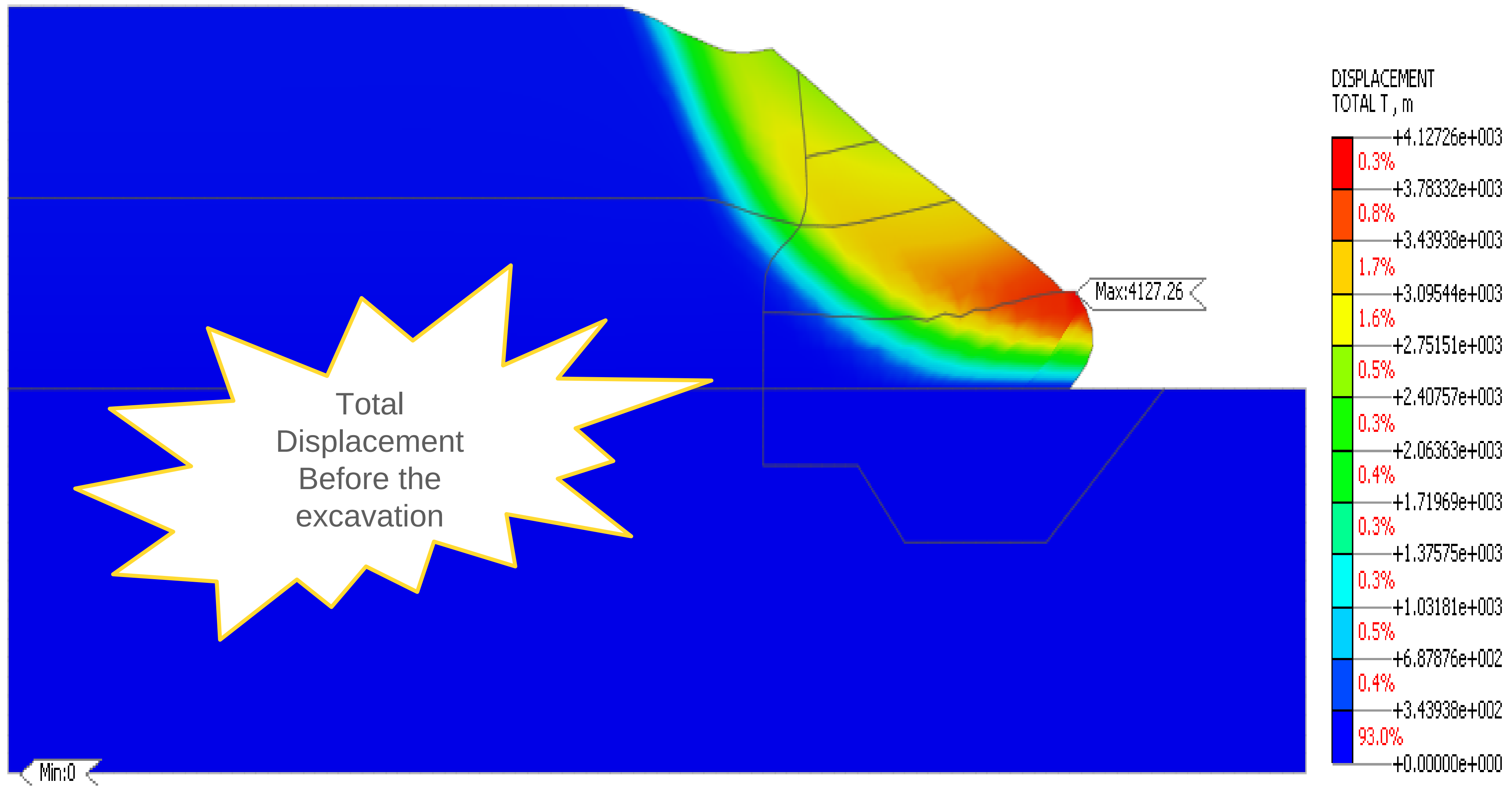
Bishop Result of external load applied to the top surface area

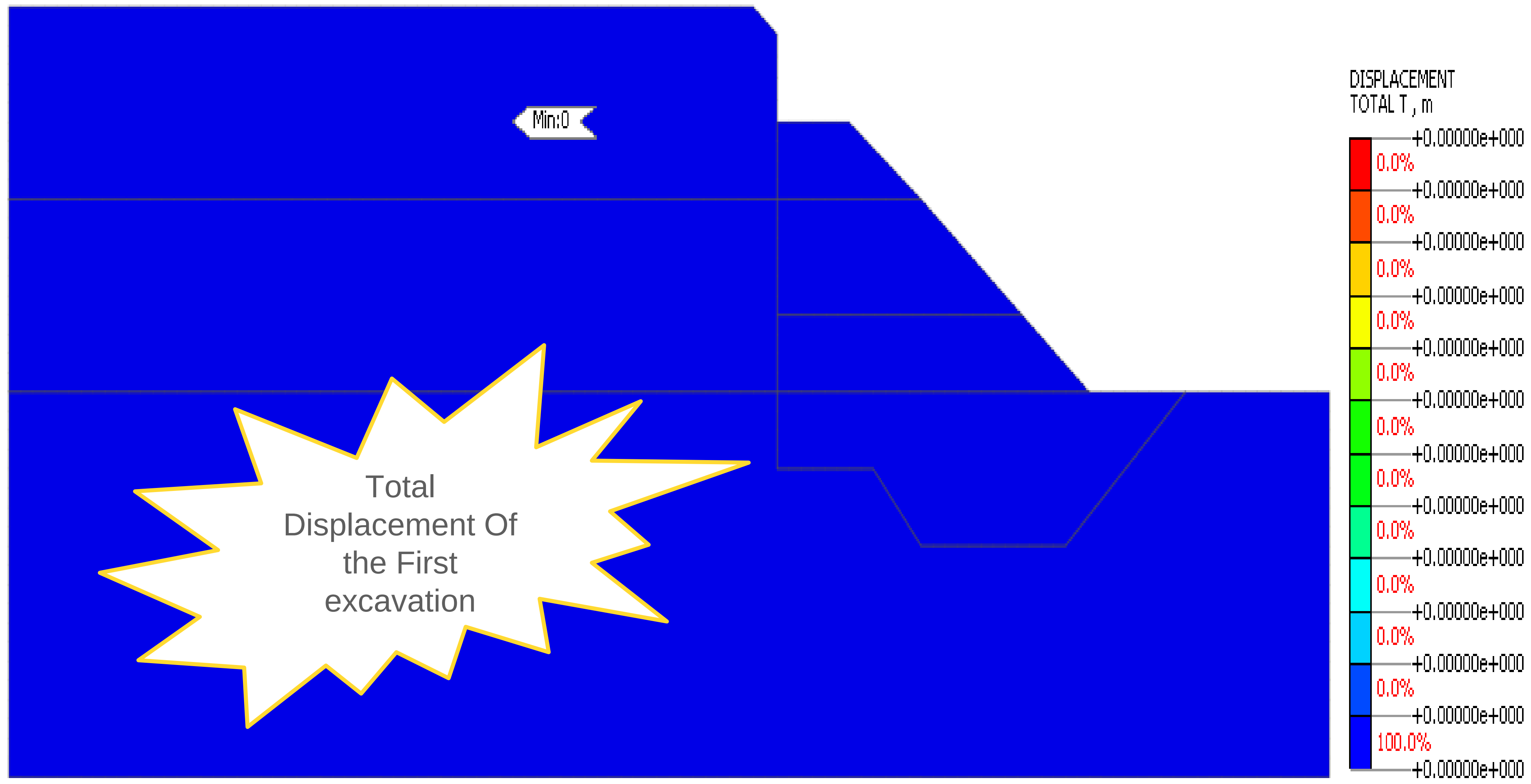


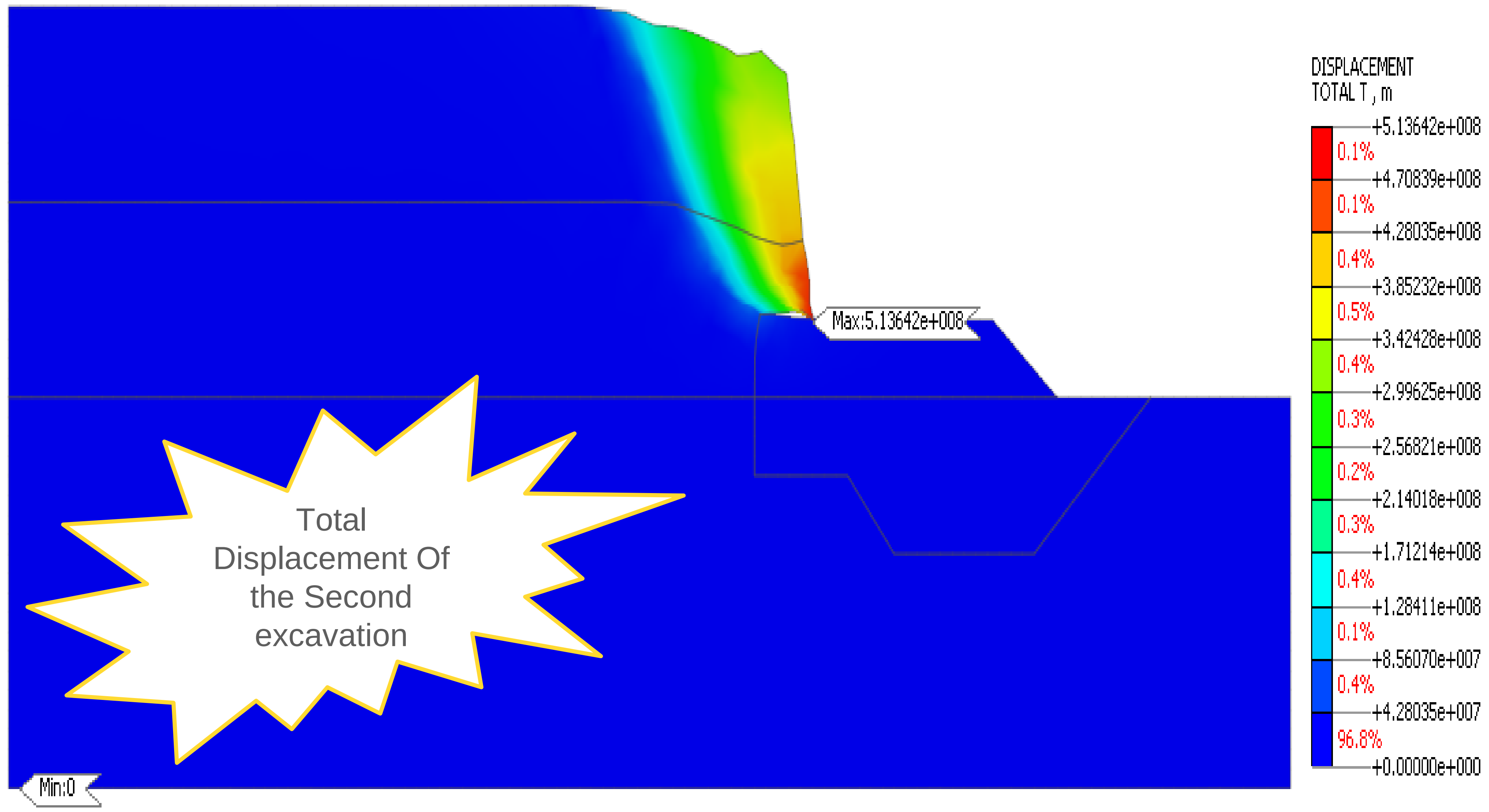
Water effect on slope stability bishop method result

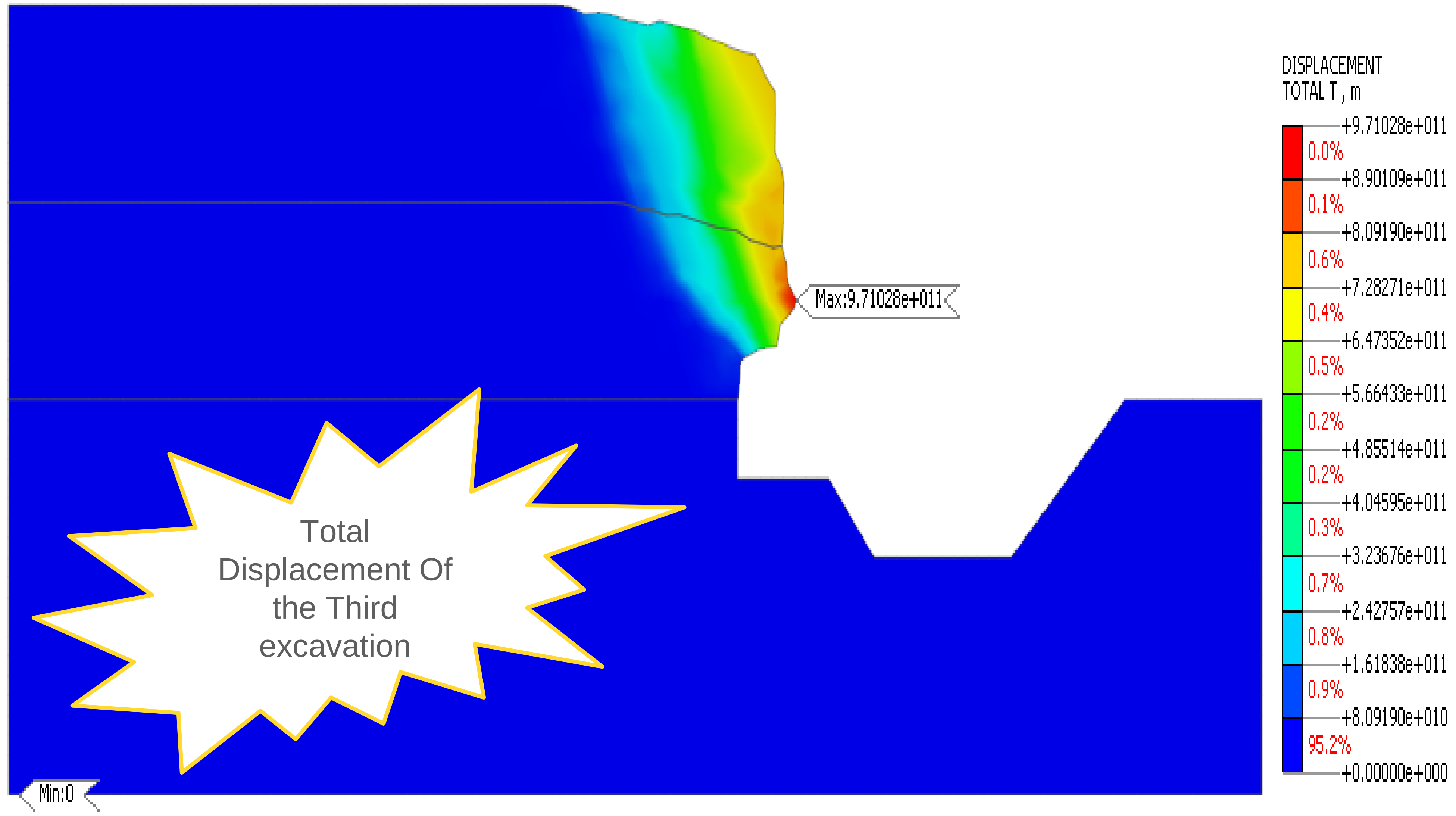
KEY FINDINGS FROM THE STUDY

Evaluation of slope stability of the excavation





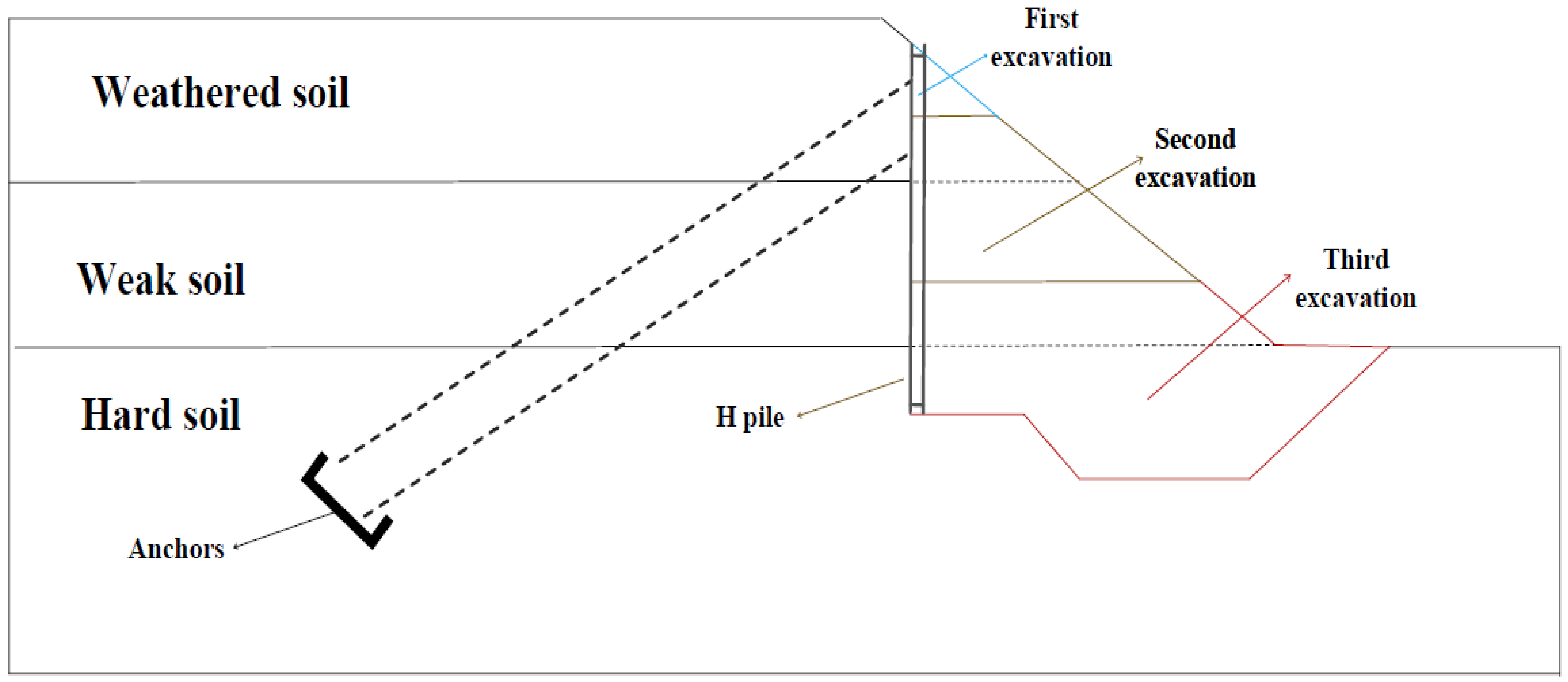




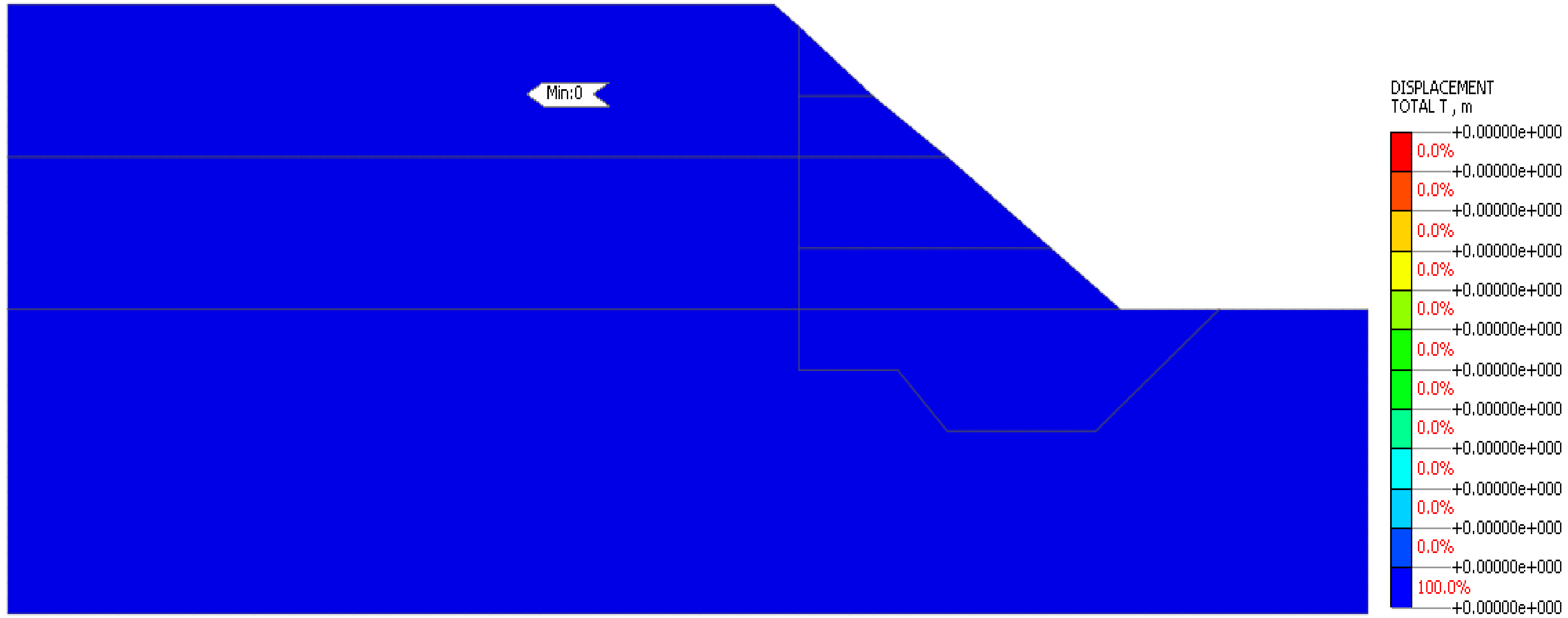
KEY FINDINGS FROM THE STUDY Cont’

Reinforcement Feasibility

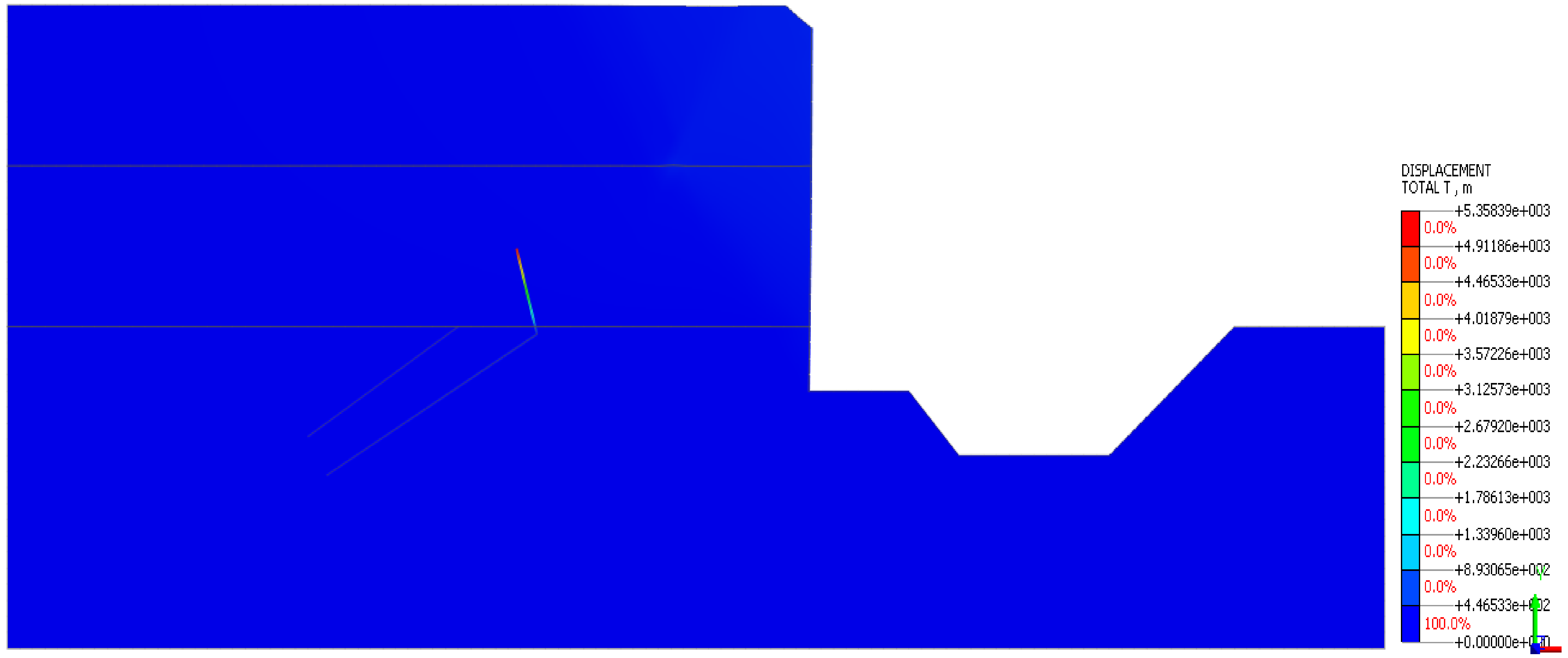
Evaluations of anchor rods and H-Type piles showed potential effectiveness in reinforcing unstable slopes in Rwanda



Material	H-pile (Beam)	Anchors (Truss)
Elastic Modulus E (kN/m2)	205000	205000
Poisson’s ratio (υ)	0.3	0.3
Dry Unity weight (kN/m3)	75	75



No deformation after using H-piles and Anchors

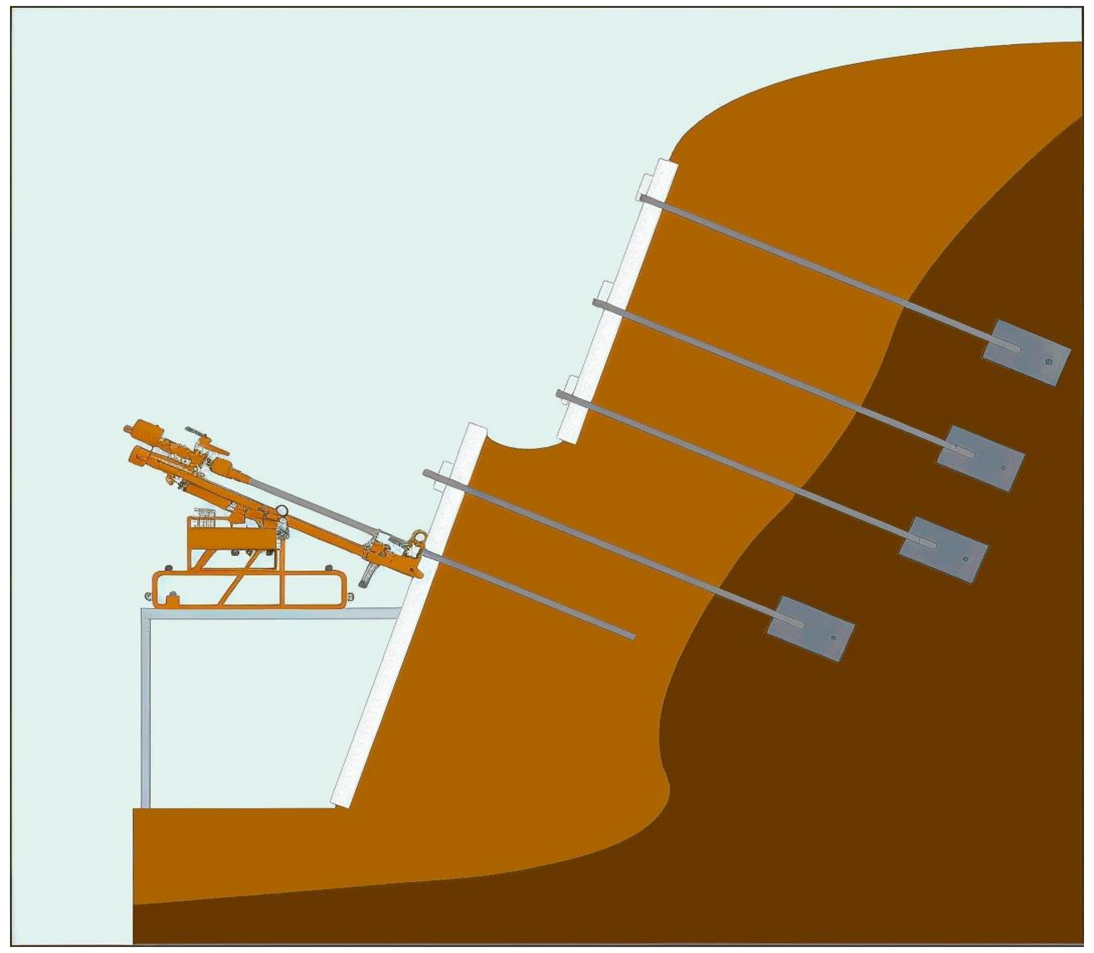


No deformation after using H-piles and Anchors after the third excavation

PREVENTIVE MEASURES AND RECOMMENDATIONS

Engineering Solutions

Proposed countermeasures include reinforcing slopes using anchor rods, and H-Piles and constructing Soil nails to improve slope stability

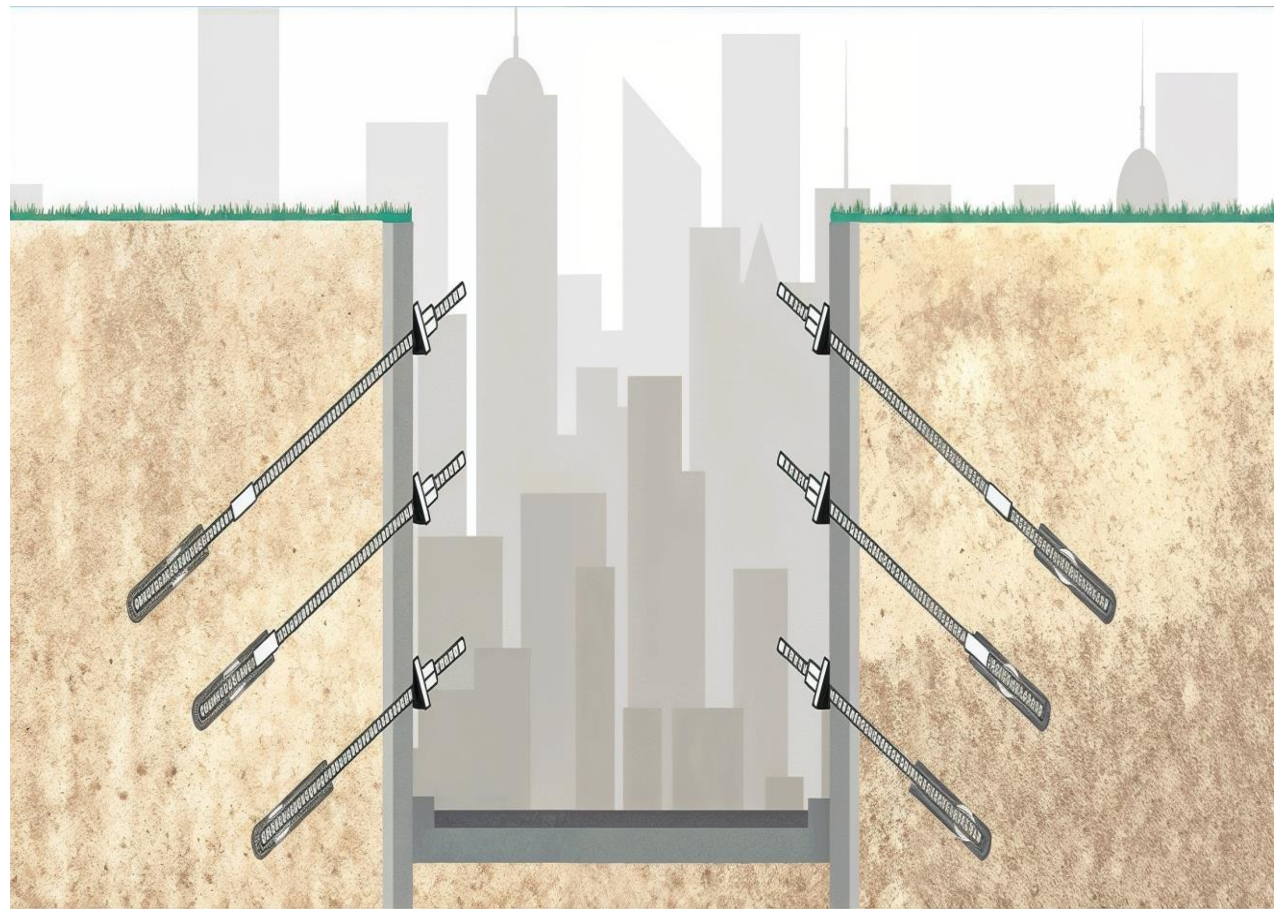


Management Strategies

To manage risks, further deforestation prevention, controlled construction practices, and detailed landslide risk assessment are recommended.

Policy Recommendations

Government policies should support sustainable landslide management and community awareness programs to mitigate landslide lisks.



CONCLUSION

Summary of Findings

Identified primary causes, analyzed slope stability using simulations, and proposed engineering and policy measures.

Future Recommendations

Continuous monitoring, adopting preventative engineering practices, and incorporating findings into national disaster management plans.

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