

# Landslide Related Road Failures in Ethiopia

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# Questions

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- i. What is the scale of road damage due to rainfall triggered landslides in Ethiopia?
- ii. What are the main failure mechanisms?
- iii. What should be done to address landslide problems?



# Outline of the Presentation

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1. Introduction
2. Types and failure mechanisms of landslides
3. Effects of landslides
4. Efforts made to mitigate landslides
5. Mitigation Options: Approaches
  - Site investigation
  - Design considerations
6. Concluding remark

# 1. Introduction

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- Road development is one of the major investments in Ethiopia.
- Over 700 landslide sites recorded in Ethiopia; mostly affecting rural communities.
- Infrastructures, farm lands, dwelling houses, etc are frequently affected by landslides.
- This study focuses on evaluation of 54 sites (road sections) which are affected by landslides in Ethiopia.



# 2. Locations, Types and Failure Mechanisms

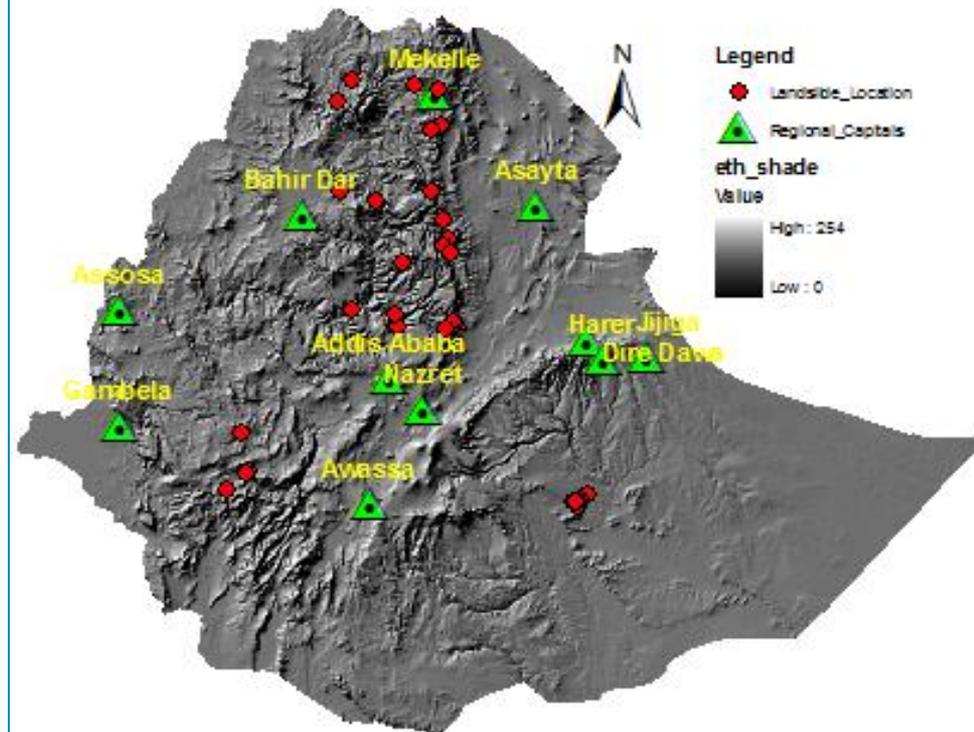
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## 2.1 Locations

- Landslides are common in many parts of the highlands and rift escarpment of Ethiopia.
- 54 sites in different parts of Ethiopia are considered in this study.

## 2.2 Types of landslides

- Rockfalls: 4
- Rockslides: 6
- Debris/earth slides: 40
- Debris/earth flows: 4

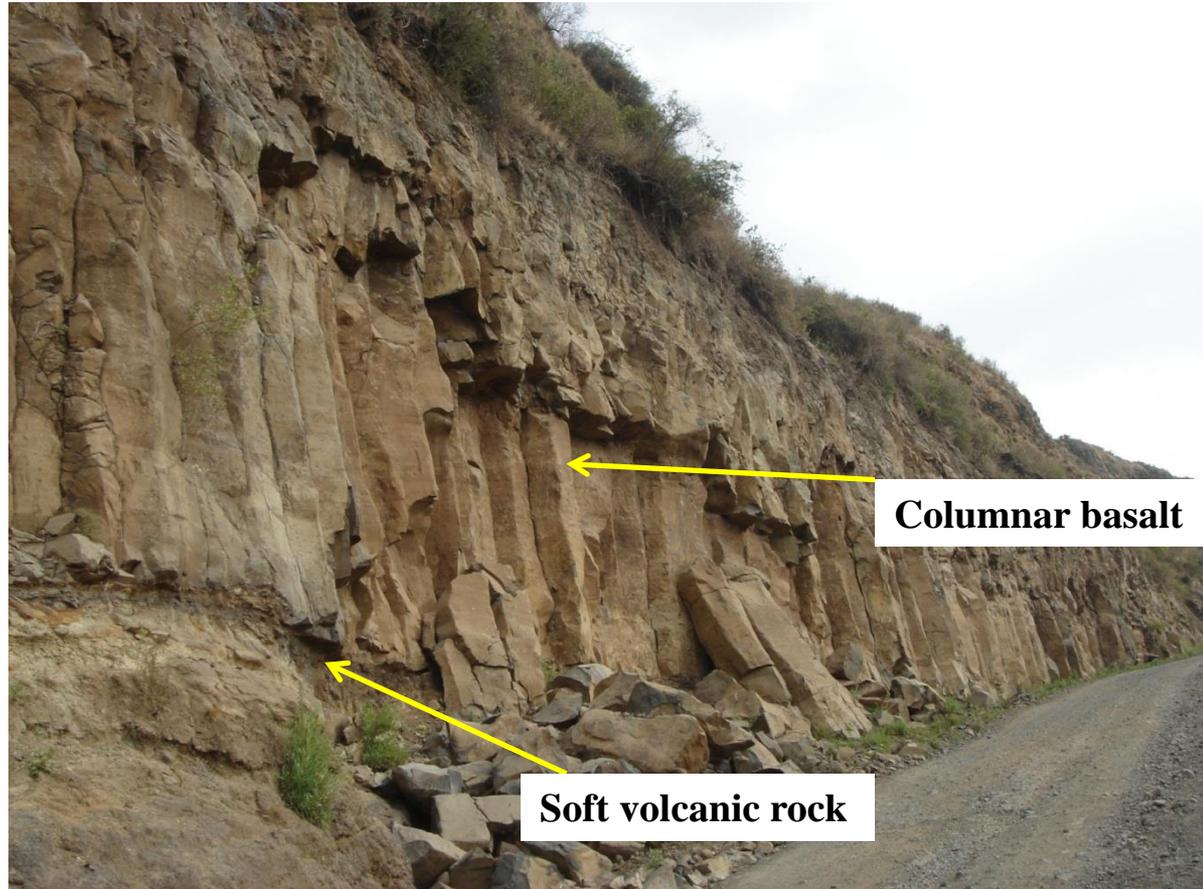


## 2.3 Failure Mechanisms

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### 2.3.1 Rockfalls:

- On steep slopes: volcanic as well as sedimentary terrains.
- Presence of soft, erodible materials contributes to instability.



*Along Lemi-Alem Ketema route*

## 2.3.2 Rockslides

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- Sliding of limestone and shale intercalating slope mass, leading to failure of retaining structure.
- Presence of shale material contributes to instability.



- Rockslide controlled by discontinuities (that daylight on the slope), leading to failure of masonry retaining structure.



*Along Shire-May Tsebri road*

## 2.3.3 Debris/earth slides/flows

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Failure took place at the interface between soil (colluvial/earth material) and the underlying bedrock.

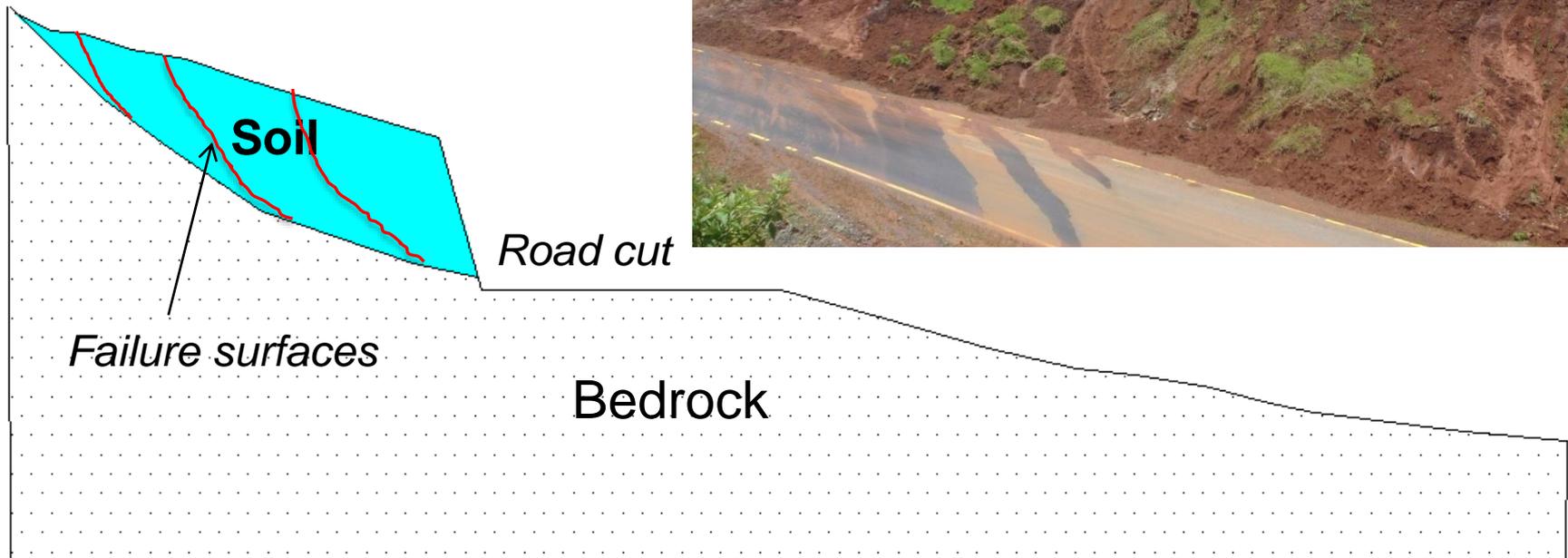
- ***Water pressure developed*** at the interface between soil and bedrock.
- Over 60% of the failures are associated with stream/river incisions or with gully development from water from culverts.
- Failure characteristics can be categorized into ***four Models***.



*Earth slide along Jimma-Agaro road*

***Model 1: Road (including subgrade) is stable; upslope side is sliding***

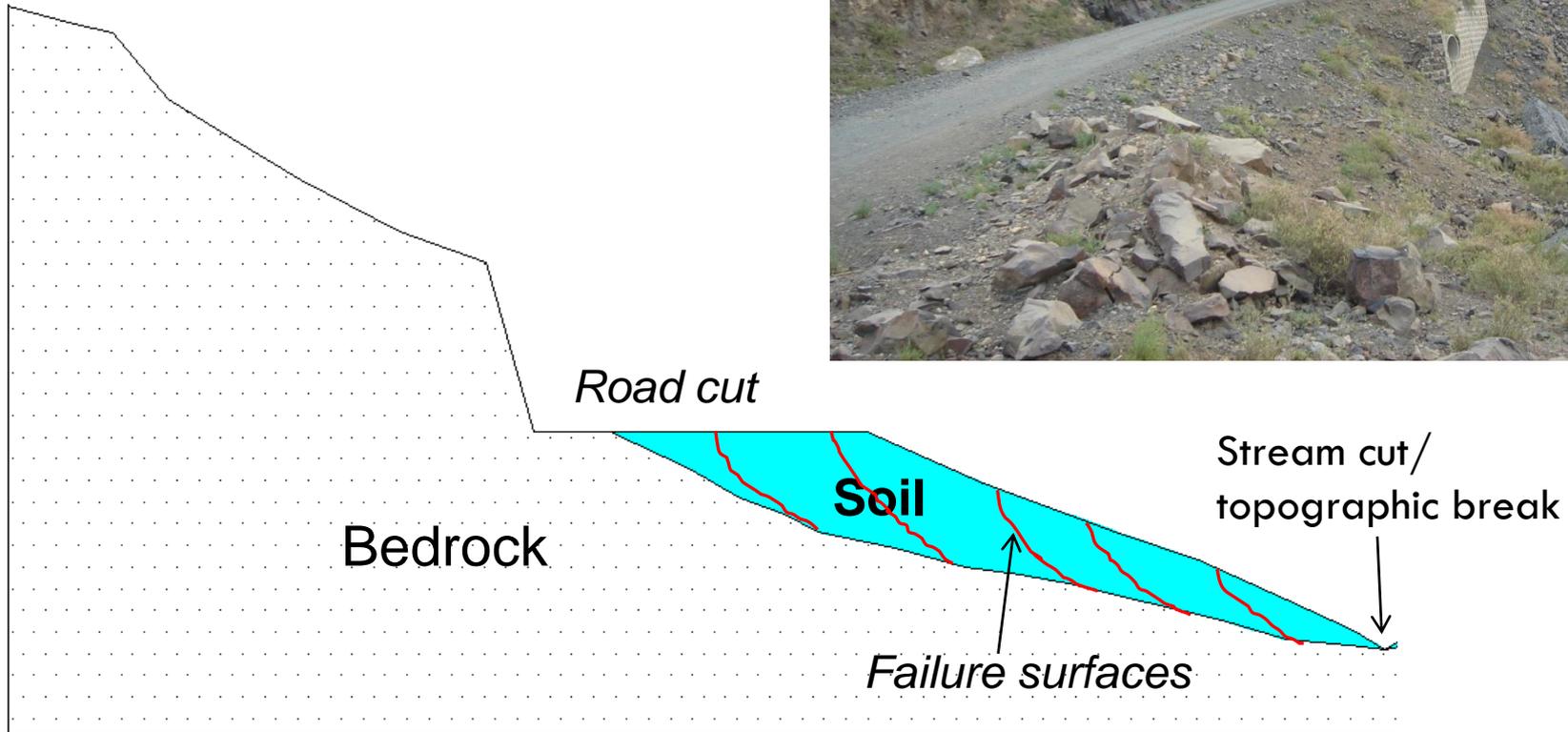
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- *Removal of support due to road excavation has initiated instability of the upslope.*
- *Provision of proper retaining structure coupled with drainage systems (surface and sub-surface) is the solution.*

**Model 2: Upslope side is stable; downslope side is sliding**

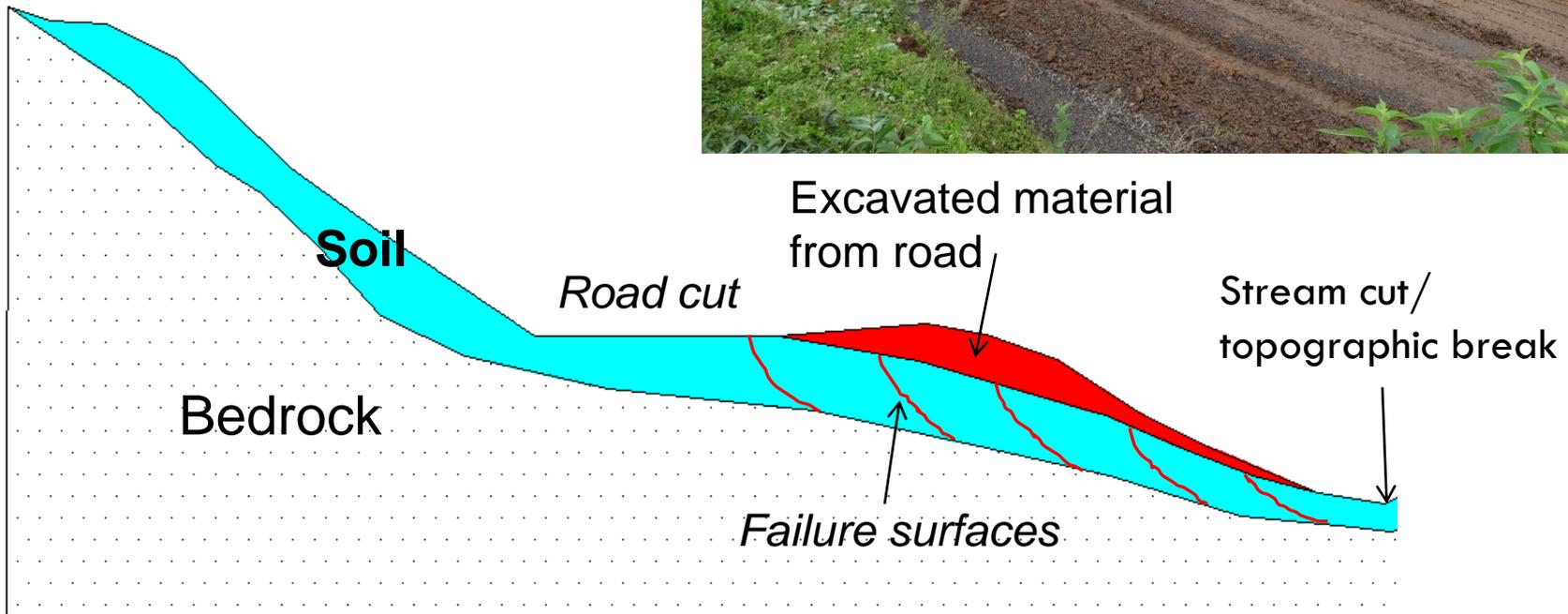
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- *Additional load (due to road construction) on a slope which was already unstable or on marginally stable state is initiating instability of slopes.*

## ***Model 3: Placement of excavated material on marginally stable slope***

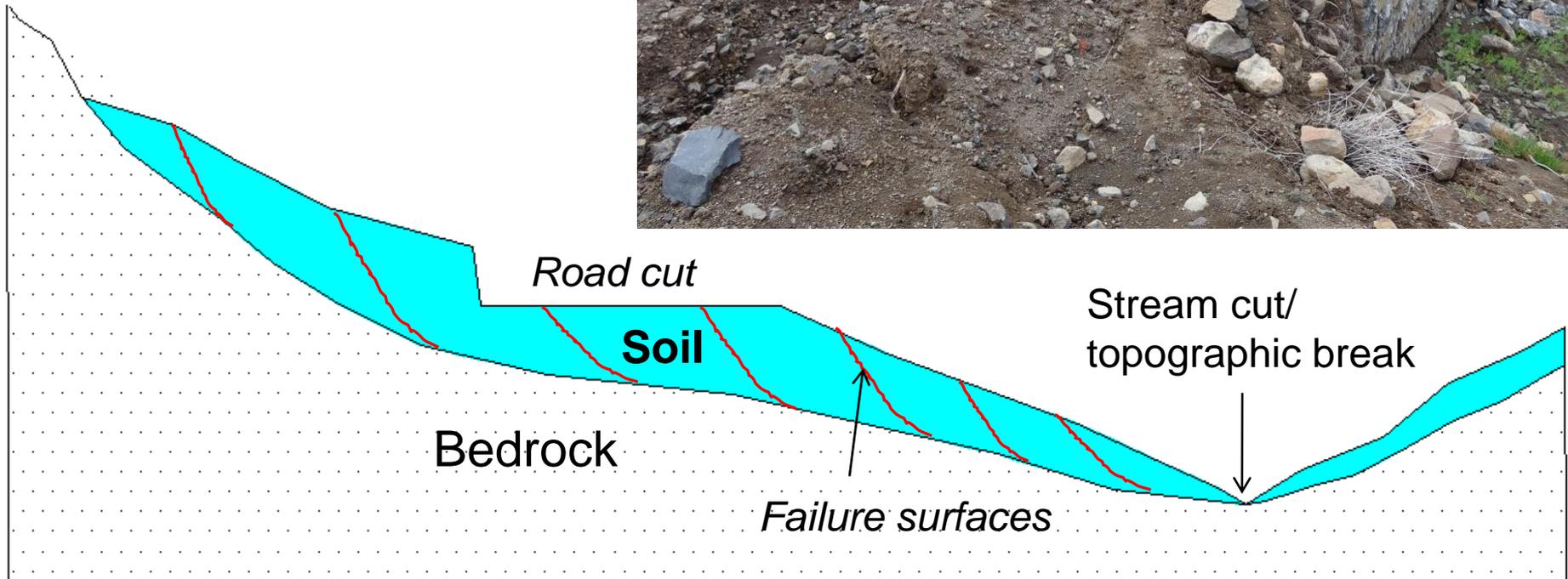
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- *Placing excavated material from roads on marginally stable slopes or on unstable slopes is initiating instability of slopes.*

## Model 4: Whole road section is on a sliding mass

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- Excavation and placement of additional load (road) on already unstable slope or on marginally stable slope is initiating instability of slopes.

# 3. Effects of landslides

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- Damage on roads (asphalt and gravel).
- Hamper traffic.
- Rarely car accidents.
- Damage on other infrastructures like power lines, etc.
- Repeated failures leading to repeated maintenance costs.



*Damaged asphalt road  
in Tarmaber area*

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## **Effects of landslides in Ethiopia: 1985-2012 (Woldearegay et al, 2012):**

- Damaged dry weather road
- Damaged asphalt road.
- Damage on other facilities like mini-hydropower, mills, schools.
- Environmental health problems: ponding of water causing spread of malaria.
- Damage on the natural environment.

*Landslide in Abay Gorge*



# 4. Efforts made to mitigate landslides

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Different efforts have been done but many of them remain less effective.

Some of them:

- Construction of retaining structures over a sliding mass.
- Construction of retaining structures not able to overcome loads from upslope.
- Lack of proper design for drainage systems.
- Backfilling over sliding mass roads affected by landslides.





*View of a large-scale landslide: affecting roads, power lines and farm lands along Bonga-Mizan road.*



*View of a large-scale landslide: affecting roads, power lines and farm lands along Bonga-Mizan road (arrow indicates direction of movement).*

Main Power line damaged by a landslide is shifted but still endangered by the same landslide along Bonga-Mizan road







*Landslide related road failure along Kombolcha area (head of the slide).*

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Backfilling and construction of retaining wall over a sliding mass.

- Could this be effective while the landslide extends upto about 800m downstream?

*Downslope view of the landslide along Kombolcha area.*



*Landslide in Dessie town;  
affecting retaining structures.*

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*Gabion retaining wall under  
construction over a sliding  
mass along Bonga-Mizan road.*



# Summary: findings of this study

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- For 60% of the sites, mitigation measures implemented could not achieve the intended purpose.
  - In many cases, the mitigation measures implemented had contributed to further instability of the slopes.
- In 50% of the sites, road maintenance have been carried out up to 4 times in 5 years.
- There is shortage of knowledge/ capacity to design appropriate mitigation measures of landslides.

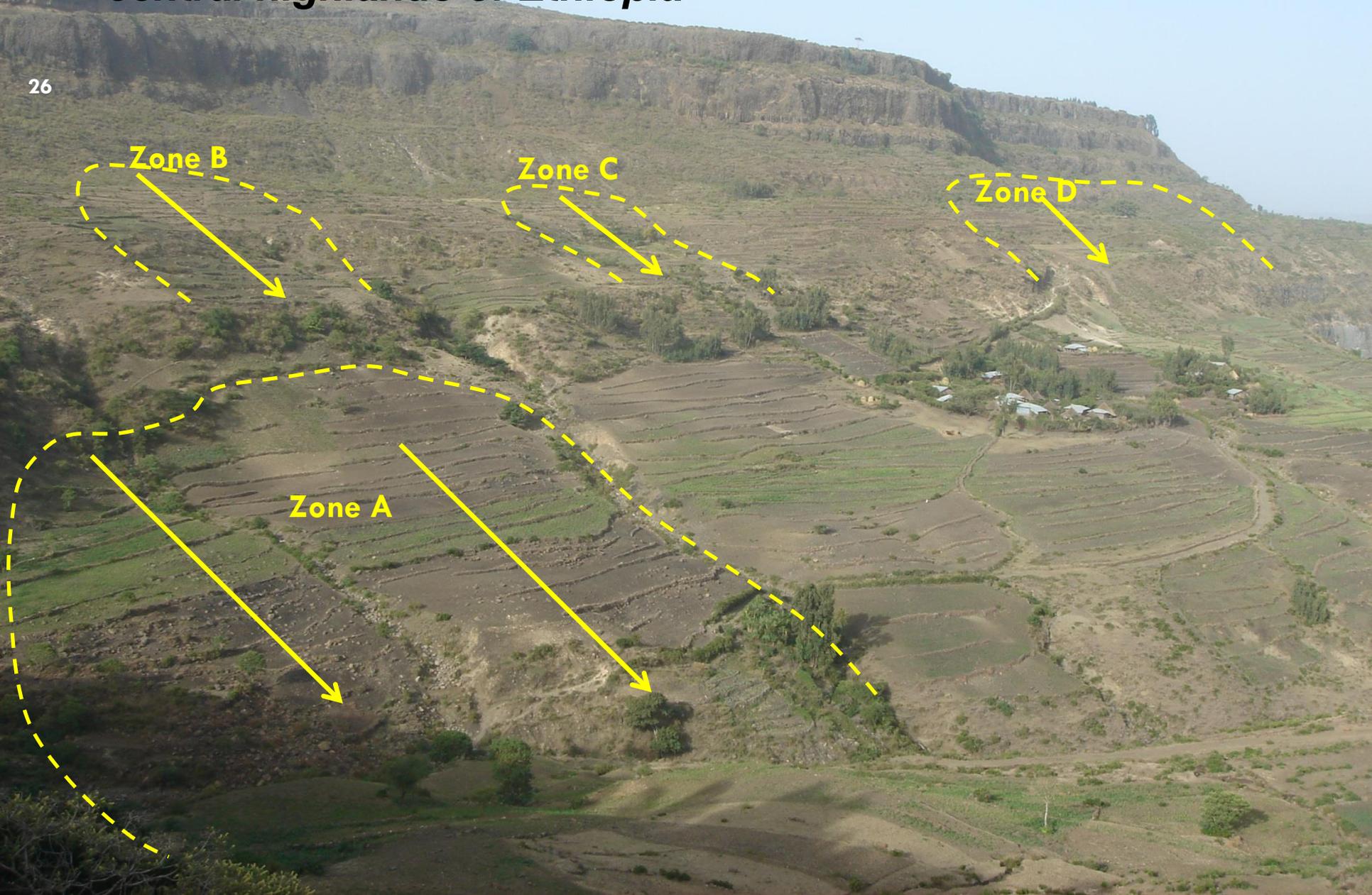


- There is little coordinated research done in understanding landslides and their mitigation measures.
- ***This call for more collaborative research and capacity building to address landslides and landslide-generated road failures in Ethiopia.***
- ***There should be clear standards, guidelines and accountability.***



# ***Challenges of road design and construction in Lemi area, central highlands of Ethiopia***

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*Zone B: Debris/earth slide affecting farm land in Lemi area,*

# 5. Mitigation Options

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## 5.1 Site Investigation

- Proper understanding of the *type, and geometry of failure* should be the requirement to design any engineering solution.
- Most of the landslide related road failures are associated with old landslides; hence the need to understand the history of the site and its interaction with the engineering environment *beyond the road corridor*.
- Parameters like depth of failure, distribution of soils/rocks, water pressure, and geotechnical design parameters need to be obtained.



## 5.2 Design Considerations

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- All designs and constructions of landslide mitigation measures should be based on clear understanding of the **geometry of failures**, **surface and sub-surface water**, and **geotechnical design parameters**.
- Proper **stability analysis** of slopes is critical for the design of landslide mitigation measures.
- Provision of **retaining structures** requires proper keying to stable stratum, with clear understanding of the **magnitude of the stresses**.
- **Drainage** (surface and subsurface) need to be integrated as part of the solution.



*Drainage based water harvesting is an option to be considered.*

*Example from the Blue Nile Gorge.*



## 6. Implications for research and development

- The hilly terrains of the highlands of Ethiopia remain highly fragile environments in terms of slope stability.
  - It is, therefore, advisable to undertake proper landslide hazard assessment and risk analysis prior to development planning and constructions.
- Landslide hazards are affecting many of the roads in the country .
  - Landslide investigations and design of mitigation measures require clear understanding of the processes and factors leading to slope failures based on multi-disciplinary approach.
- Ethiopia is embarking massive road and railroad construction which links the different Kebeles in the country. Many of these road pass through potentially unstable areas.
  - There is a strong need to evaluate the landslide condition of these routes.

- As part of the on-going massive natural resources management effort in the country, soil and water conservation practice is being implemented in Ethiopia.
  - A number of landslides have started to be initiated as a result of enhanced groundwater recharge, especially in the central highlands of Ethiopia.
  - As a mitigation measure, it is advisable ***to integrate soil and water conservation works with water harvesting (drainage) for multi-purpose use.***
  
- For a successful landslide risk management program, there need to be policies, legislation and guidelines related to, among others:
  - Building codes on excavation, construction and grading, and
  - Land-use regulations and management of landslide-prone areas.

# 7. Concluding remarks

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- Considering the hilly nature of our country, landslides will continue to challenge road and other infrastructural development ***unless properly addressed.***
- Study, design and construction of roads and other infrastructures requires a clear understanding of present and potential landslides beyond the road corridor.
- It is possible to avoid or at least reduce costs related landslides through proper site investigation at all stages (starting from feasibility studies to construction phases).
- Capacity building and research on landslides need to be strengthened.



# 8. Acknowledgement

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***Thank You***

