Landslide Related Road Failures in Ethiopia

By: Kifle Woldearegay (PhD) (Mekelle University, Ethiopia)

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Questions

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

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

- 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.

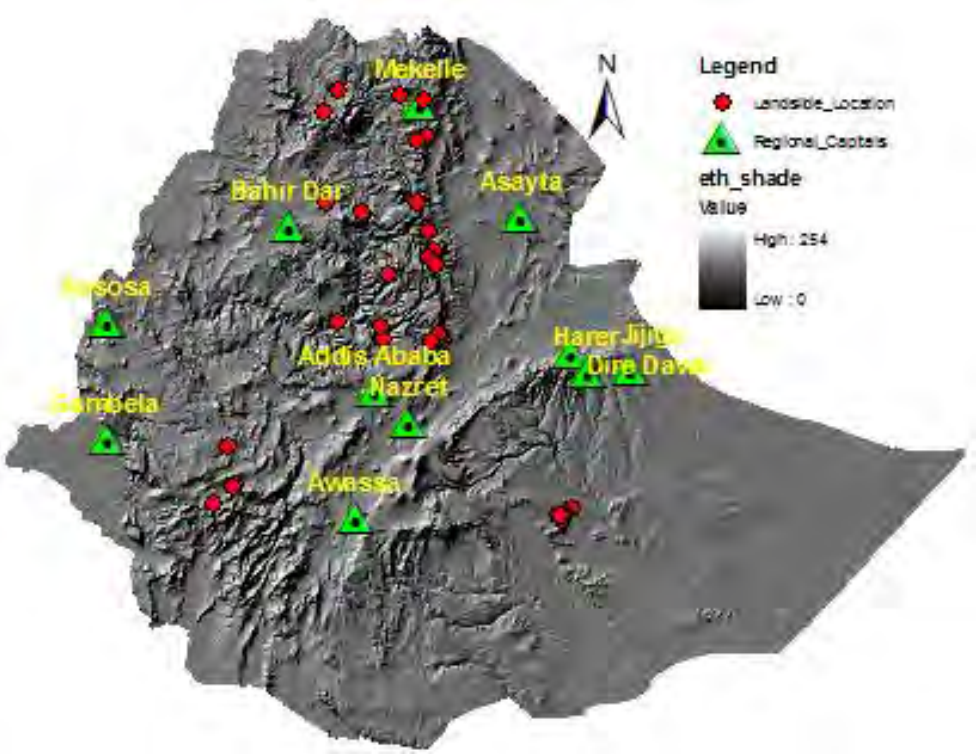
2. Locations, Types and Failure Mechanisms

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

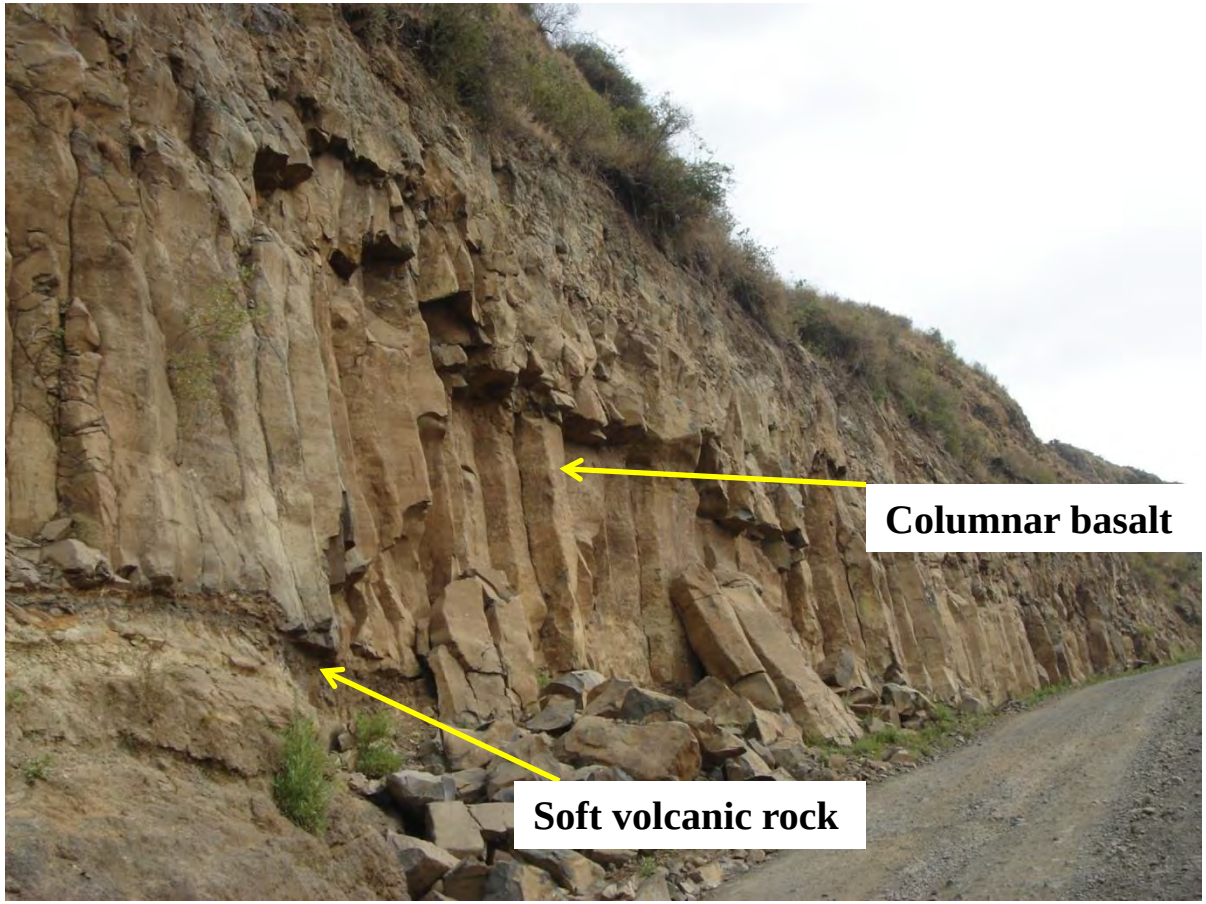
- Rockfalls: 4
- Rockslides: 6
- Debris/earth slides: 40
- Debris/earth flows: 4



2.3 Failure Mechanisms

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

- 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

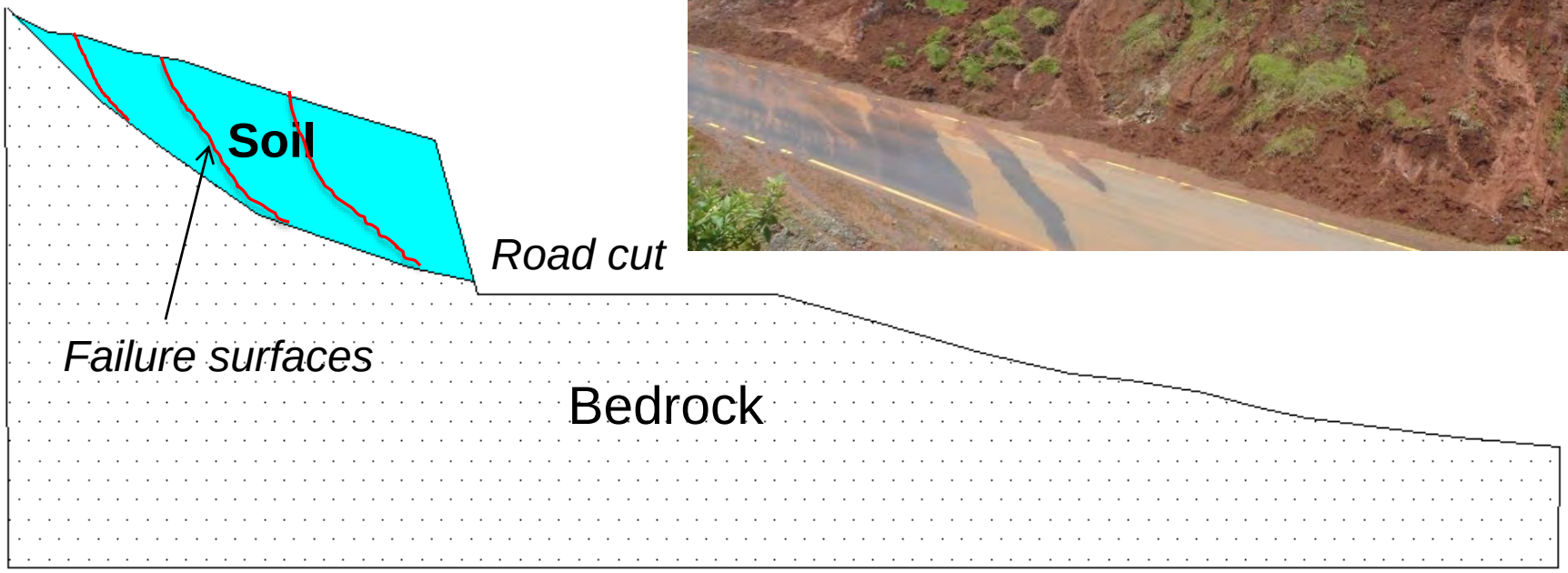
2.3.3 Debris/earth slides/flows

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***.

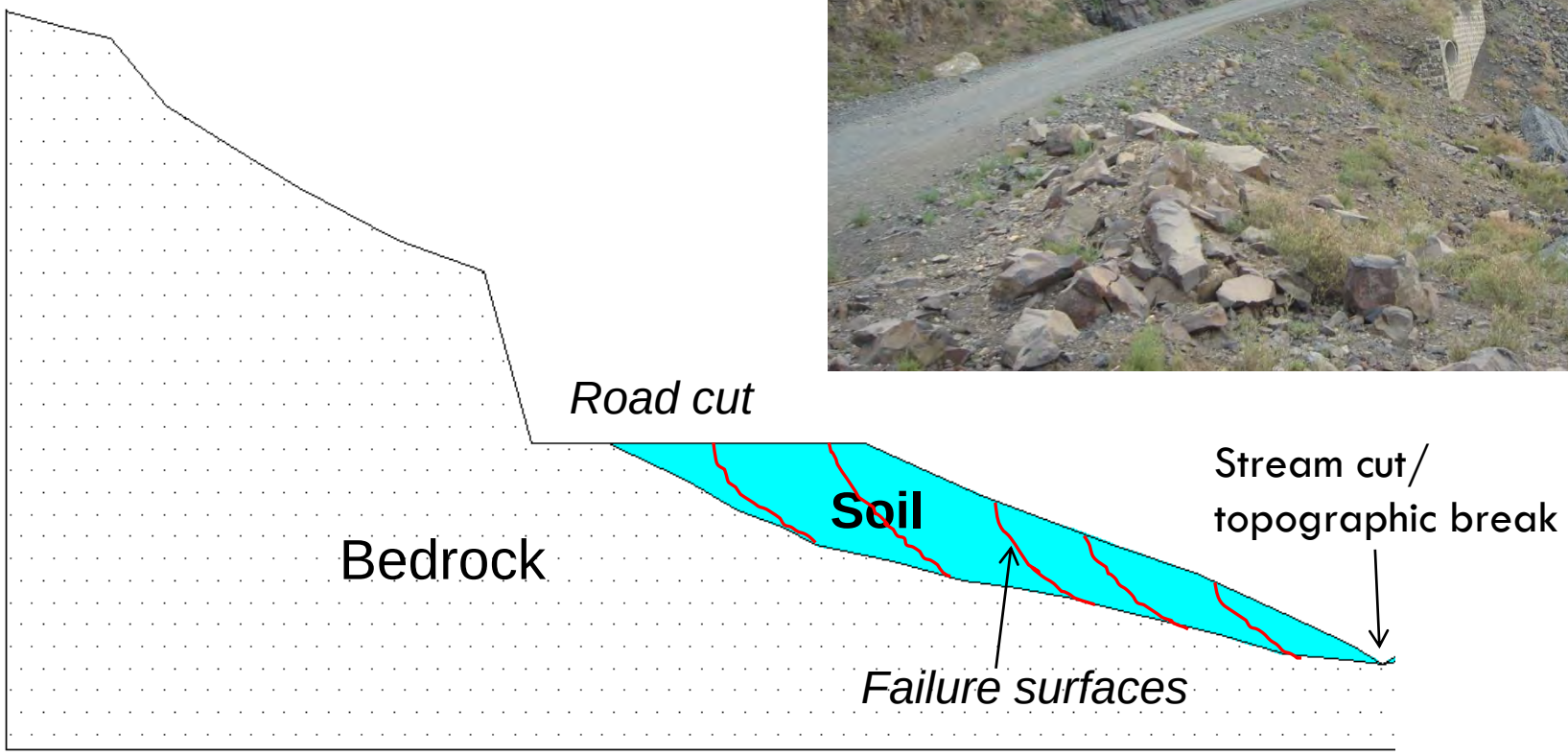
Earth slide along Jimma-Agaro road

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



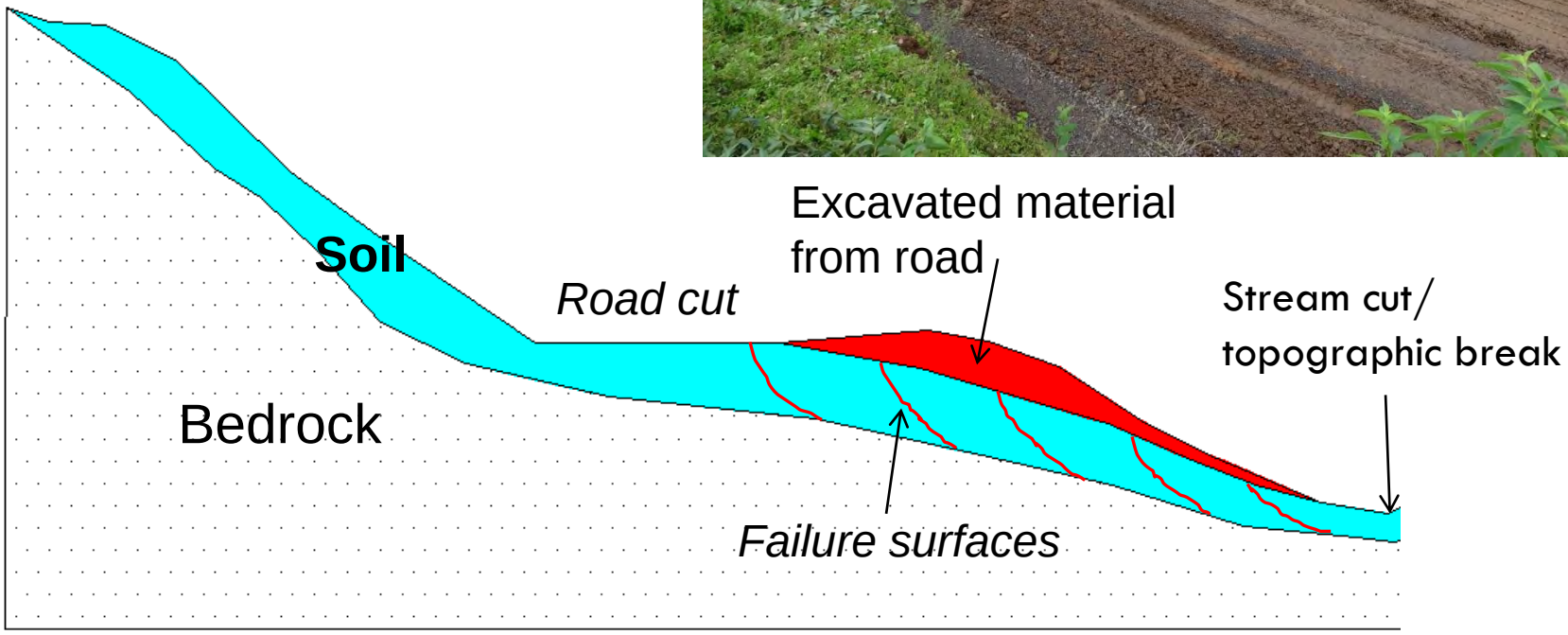
- *Removal of support due to road excavation has initiated instability of the upslope.*
- *Provision of proper retaining structure coupled with drainage systems (surface and sub-surface) is the solution.*

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



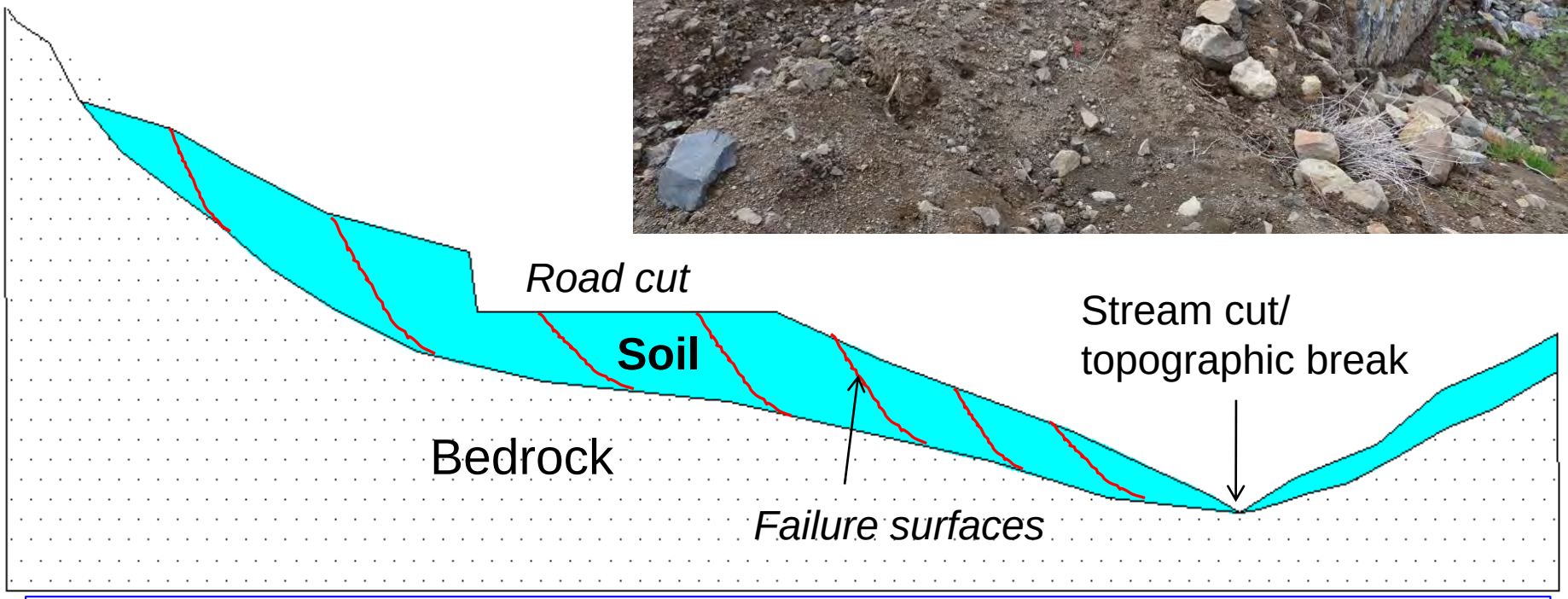
- *Additional load (due to road construction) on a slope which was already unstable or on marginally stable state is initiating instability of slopes.*

Model 3: Placement of excavated material on marginally stable slope



- *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



- *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

- 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

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

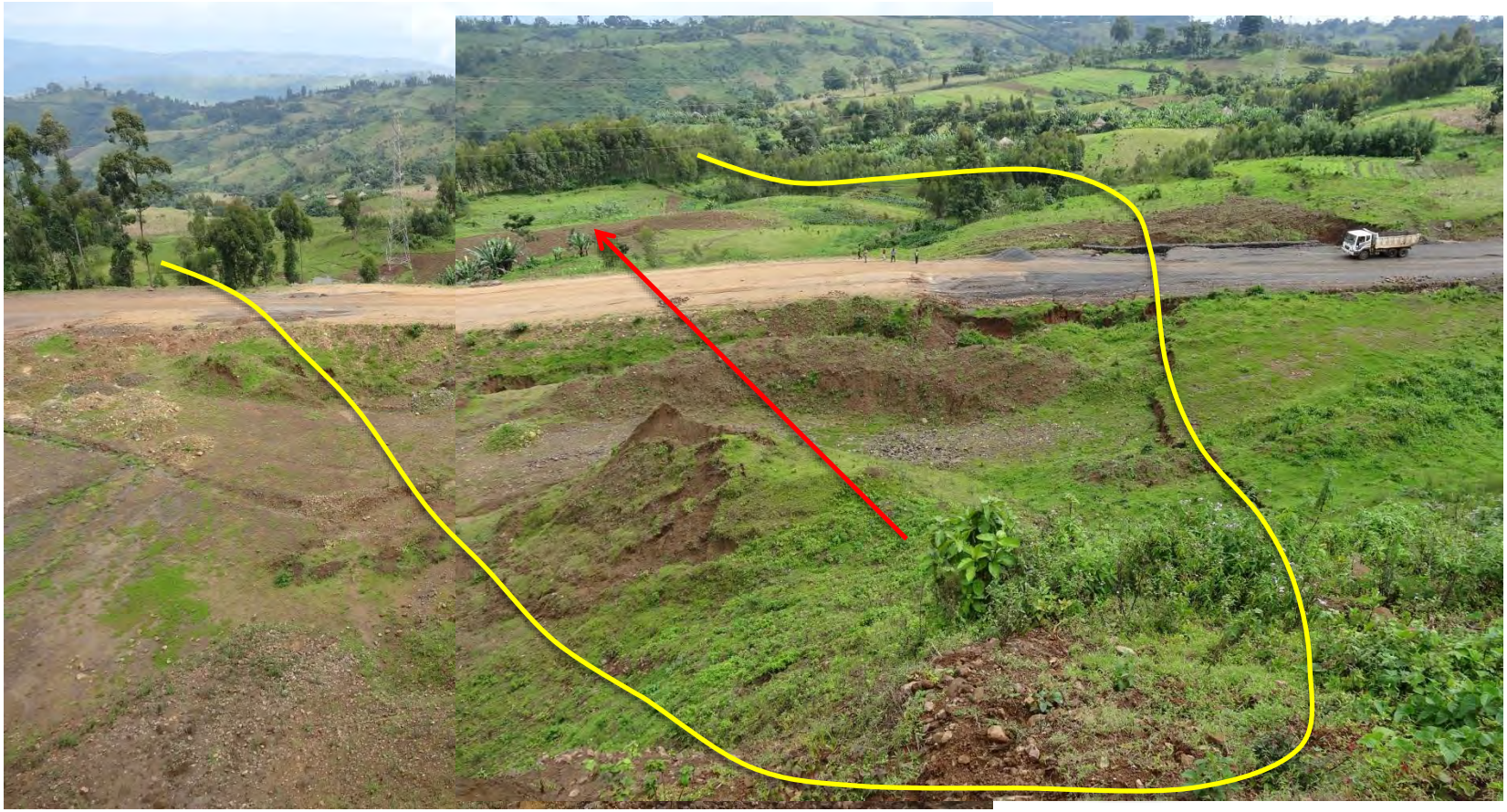
4. Efforts made to mitigate landslides

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).

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.

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

Summary: findings of this study

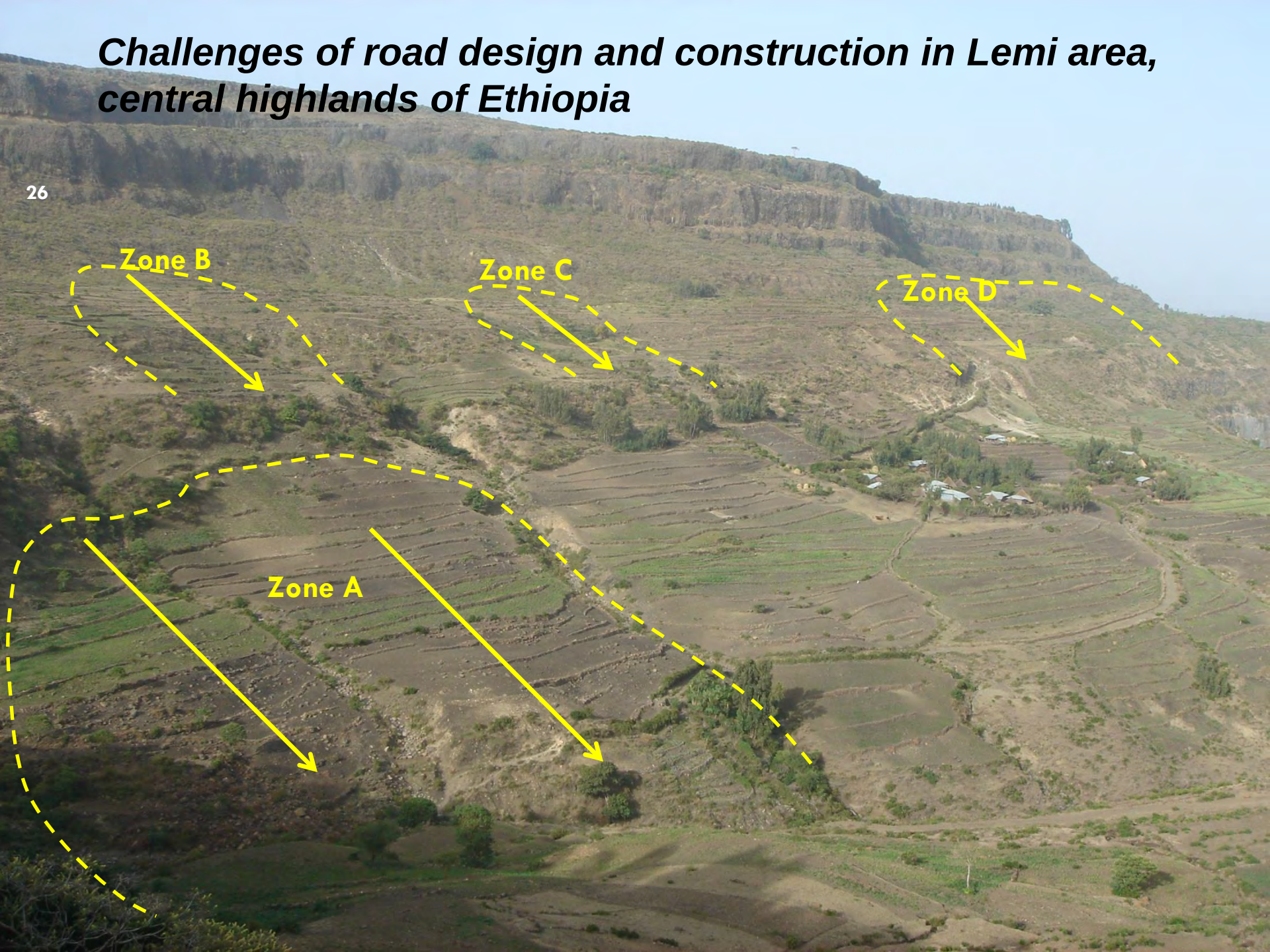
- For 60% of the sites, mitigation measures implemented could not achieve the intended purpose.
  - ➢ In many cases, the mitigation measures implemented had contributed to further instability of the slopes.
- In 50% of the sites, road maintenance have been carried out up to 4 times in 5 years.
- There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

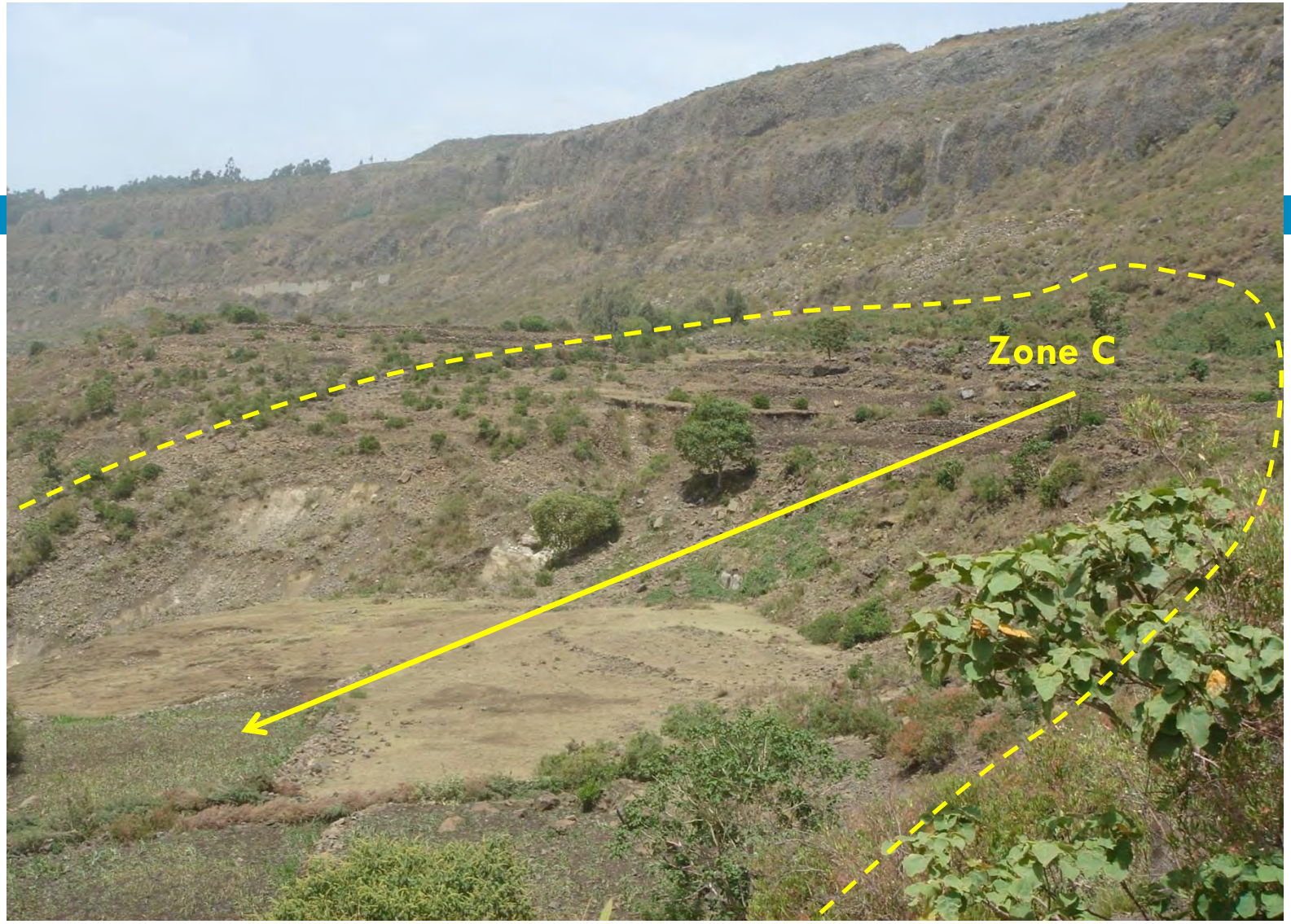
- There is little coordinated research done in understanding landslides and their mitigation measures.

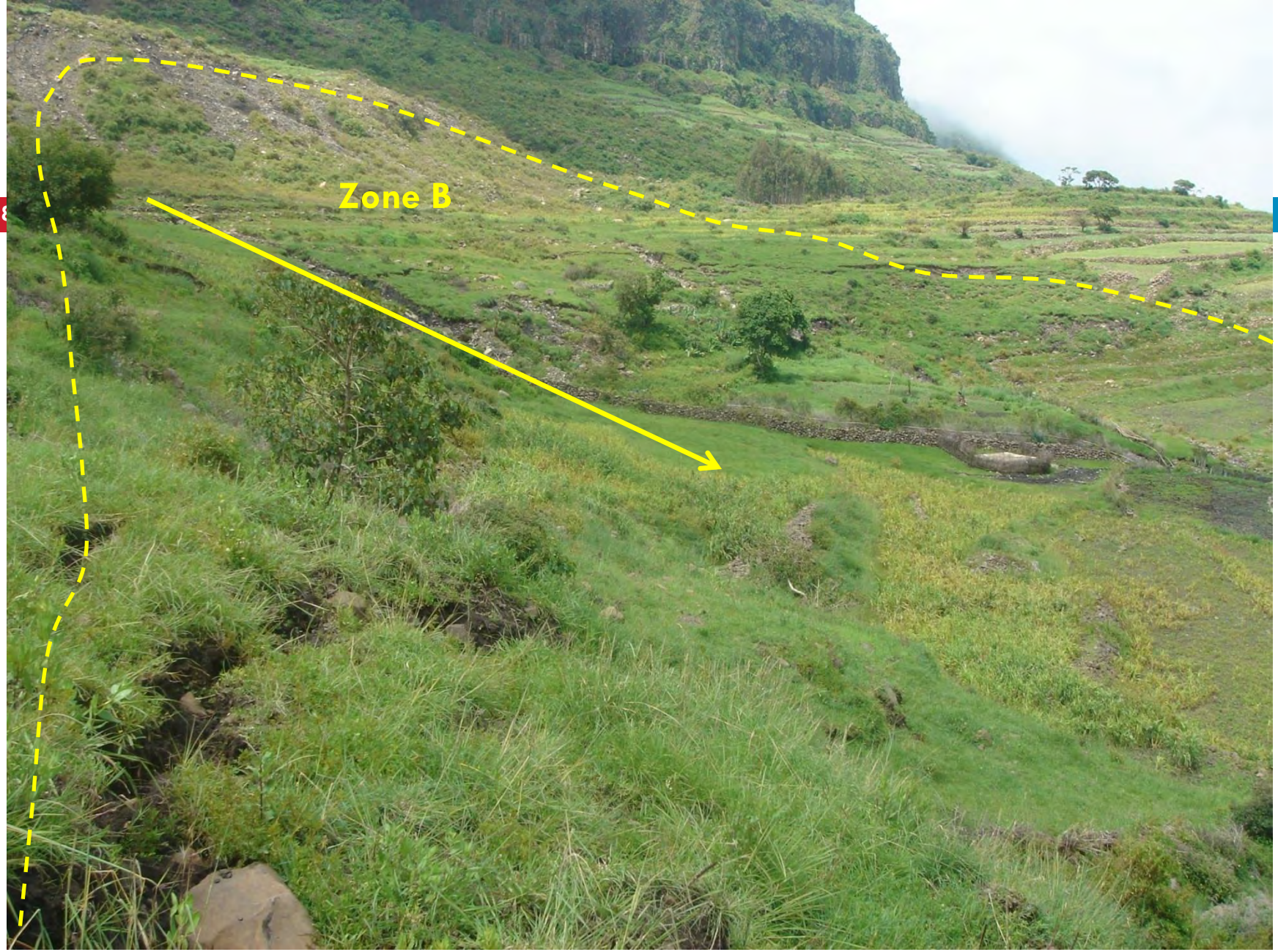
➢ ***This call for more collaborative research and capacity building to address landslides and landslide-generated road failures in Ethiopia.***

➢ ***There should be clear standards, guidelines and accountability.***

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




Zone C



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

5. Mitigation Options

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

- 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

- 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