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Multi-temporal analysis of scarp expansion in the Kamitokitozawa landslide: insights from tree-ring, UAV data, and Google Earth imagery

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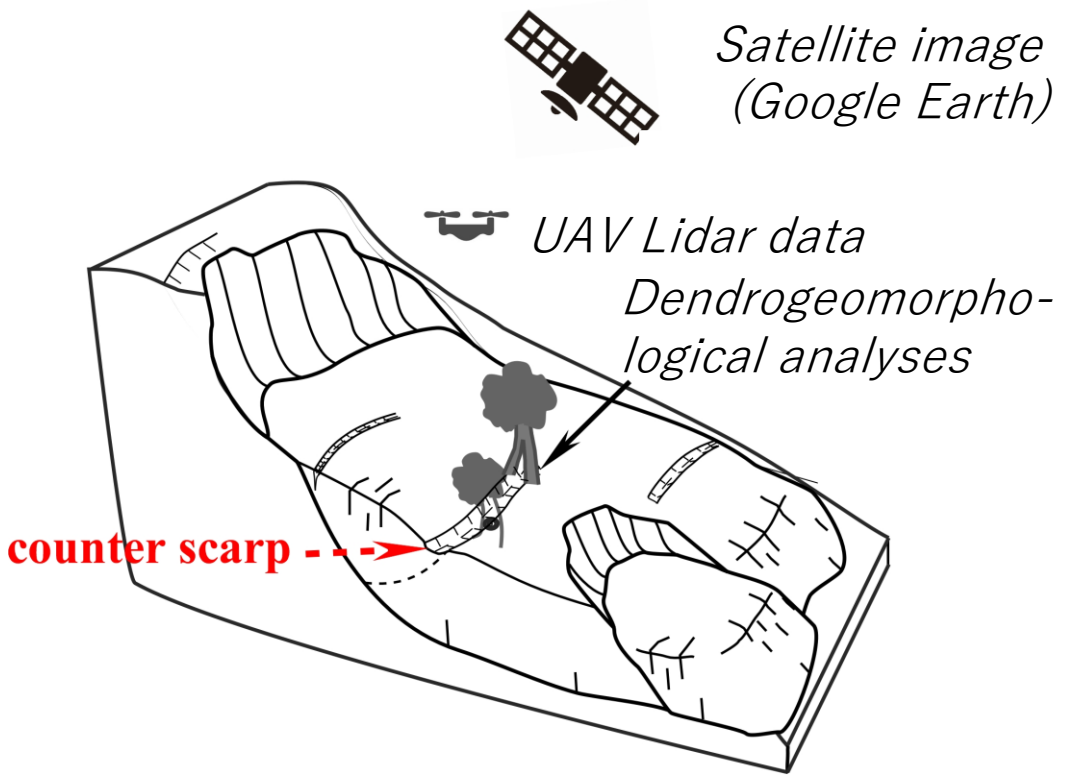
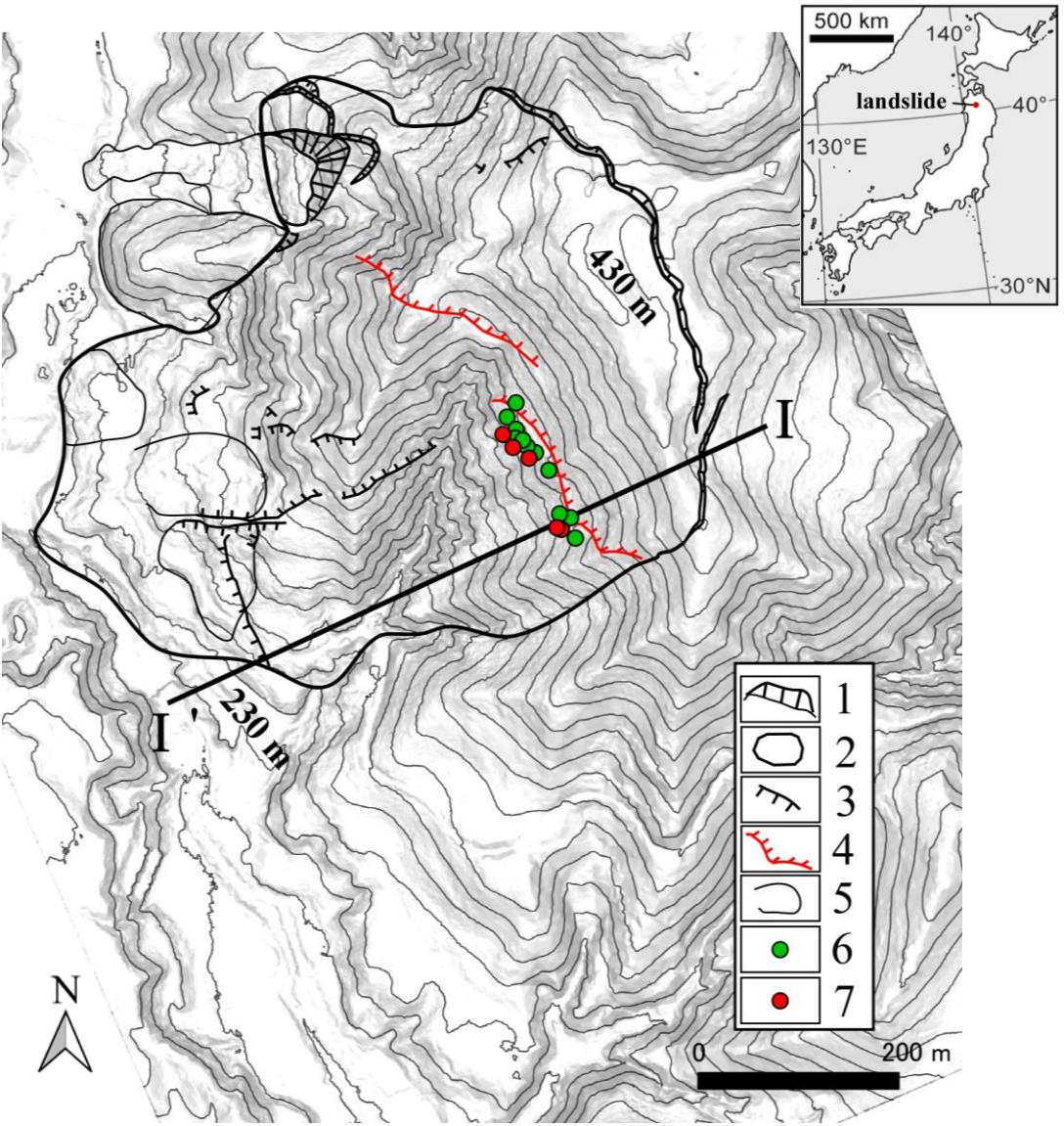
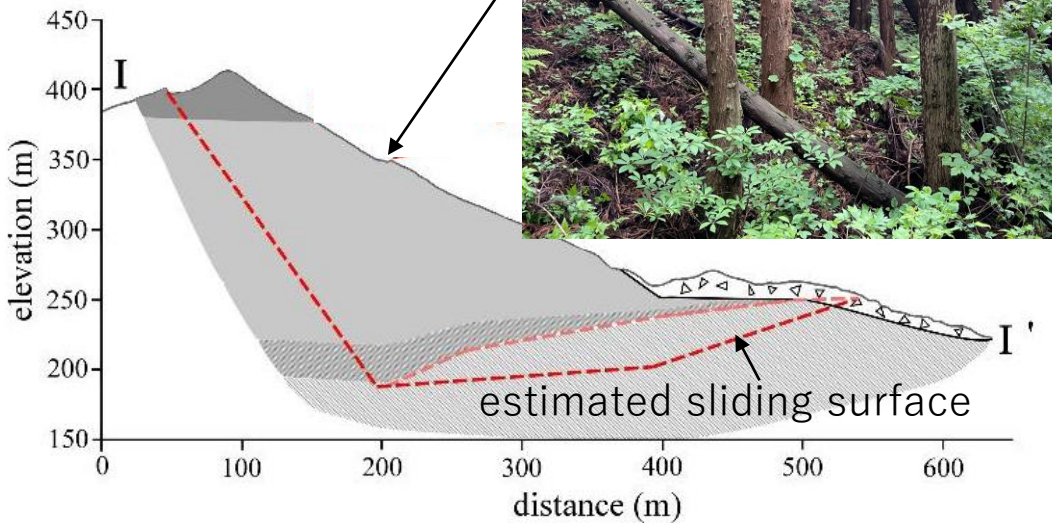


1. Introduction



Counter scarp (up to ~3 m high)

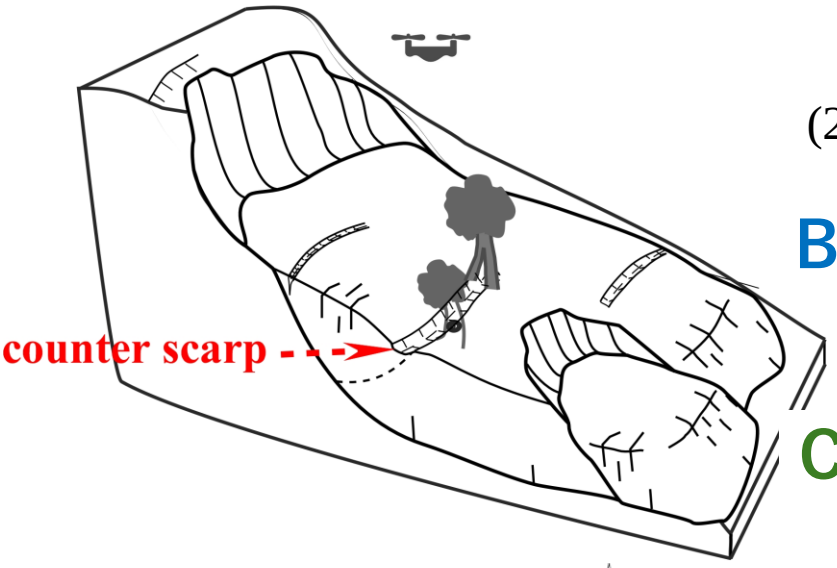


Tension cracks, step-like terrain, and other signs of landslide reactivation are prominent in the study area, highlighting the need to study their temporal changes.

This study aims to reveal the temporal development of a NW-SE trending counter scarp, using multiple methods.

1. scarp 2. landslide body 3. crack **4. counter scarp**
5. failure 6. disc sampled trees 7. sampled shade-intlerant trees

2. Methods



A. Satellite image (Google Earth imagery)

multi-temporal imagery in the period 2010-2024

(2010.06.09; 2012.09.17; 2014.11.12; 2016.10.19; 2017.09.05; 2020.10.09; 2024.09.01)

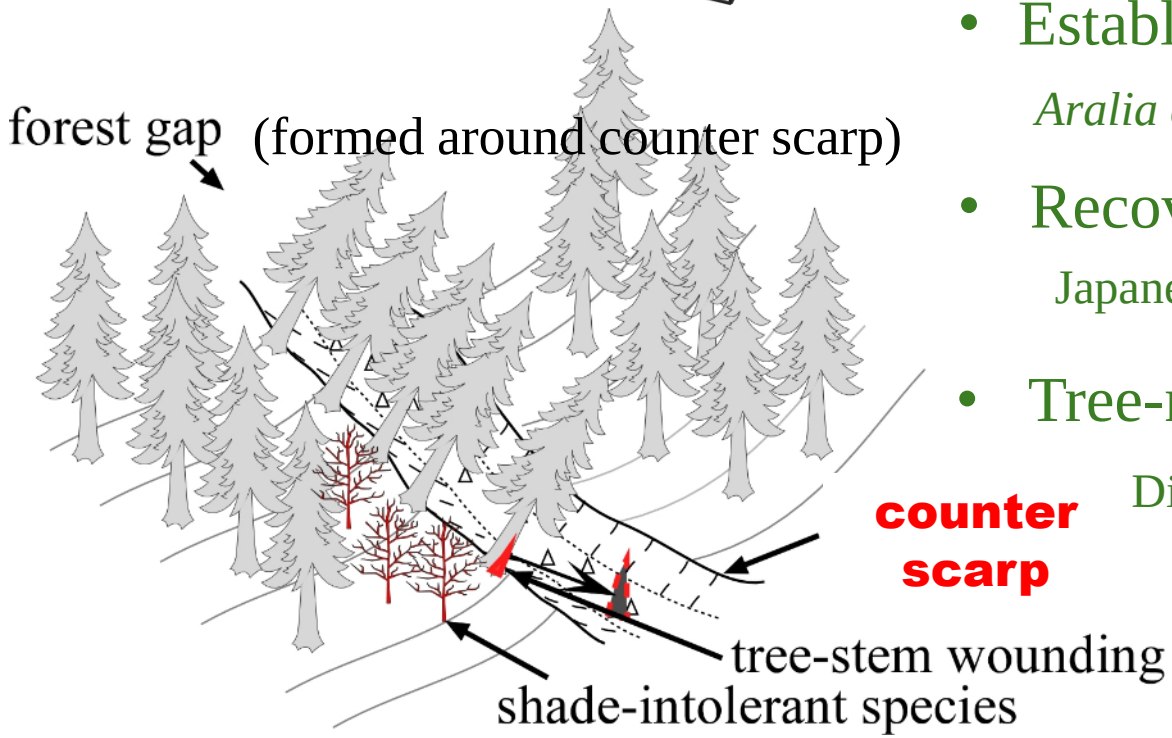
B. UAV Lidar data

multi-temporal data in the period 2008-2023

Resolution: 50 cm mesh (2008; 2019; 2021; 2022.05; 2022.11; 2023)

C. Dendrogeomorphological analyses

Sample year: 2024

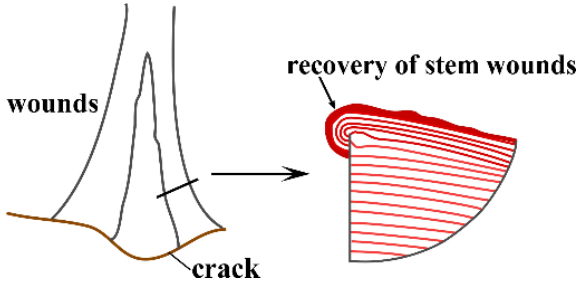


- Establishment year of shade-intolerant trees

  Aralia elata (2) and *Clerodendrum trichotomum* (3)

- Recovery age of stem wounds

  Japanese ceder *Cryptomeria japonica* (2)



- Tree-ring eccentricity analysis

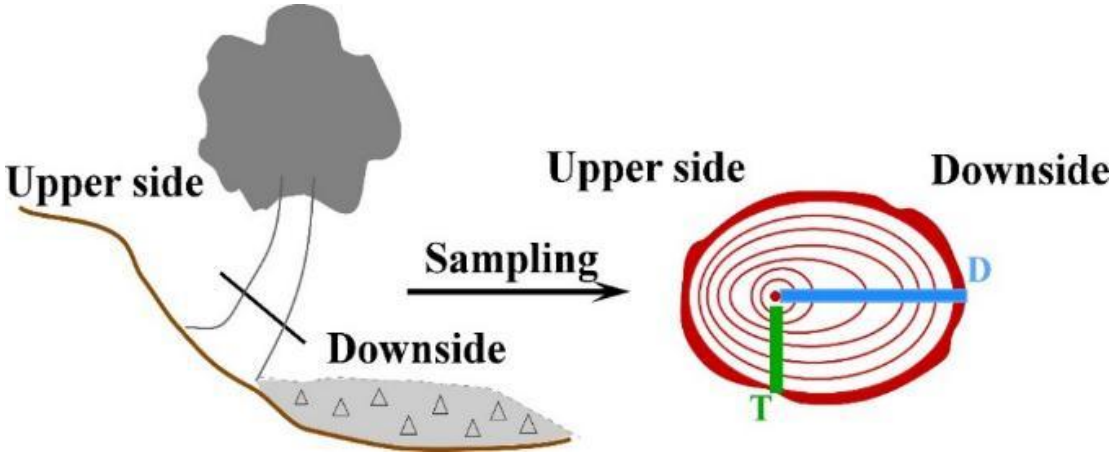
  Disc samples taken from Japanese ceder *Cryptomeria japonica* (11)

* ( ): numbers of samples

3. Methods: Dendrogeomorphological analyses

➢ Tree-ring eccentricity analysis (Šilhán et al., 2024)

- to extract the landslide-induced tree Growth Disturbance (referred to as GD here)



$$e = \frac{D - T}{D + T}$$

e: tree-ring eccentricity value
D: lower tree-ring width
T: lateral side tree-ring width

- to constrain the timing of counter scarp formation using threshold values of GD and landslide response index (I_t)

$$GD \geq 2 \;\&\; I_t \geq 18\%$$

** values set based on a eyewitness account of counter scarp activity in 2022*

$$I_t(\%) = \frac{\sum R_t}{\sum N_t} \times 100$$

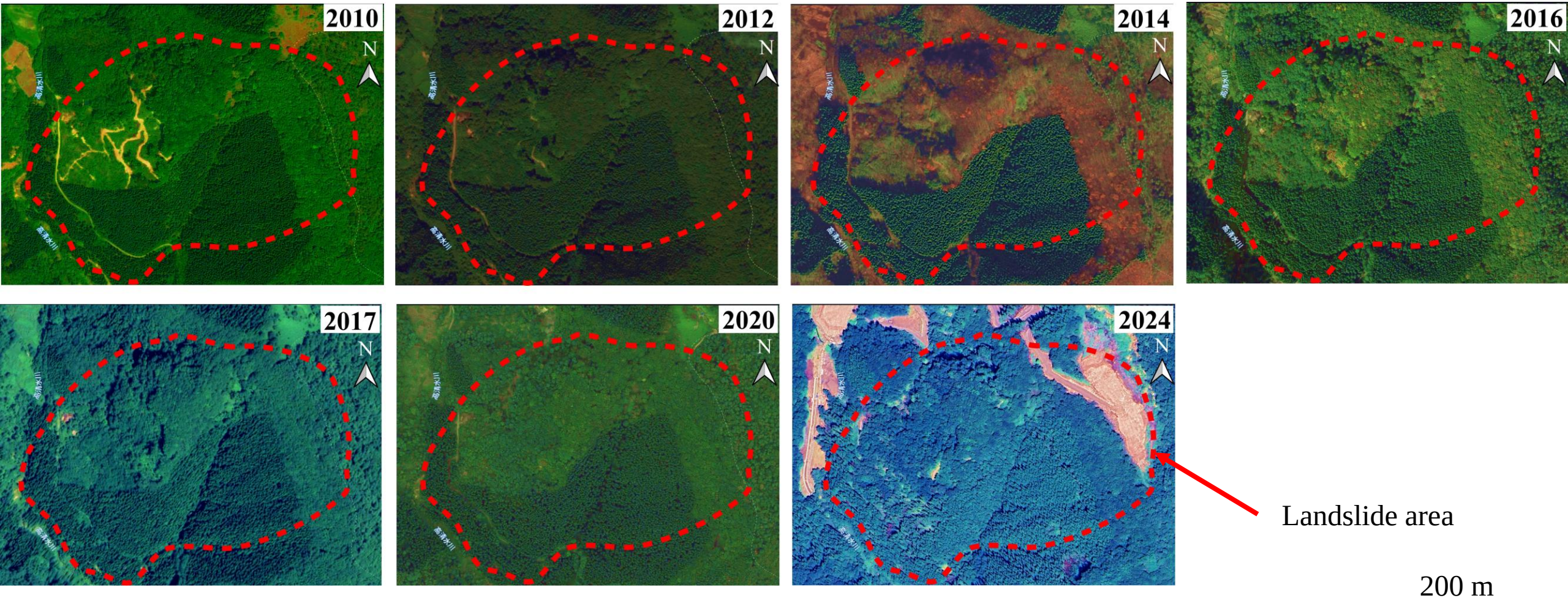
Shroder (1978)

I_t : Landslide response index
R_t : Number of trees showing GD as a response to landslide in year t
N_t : Number of disturbed trees alive in year *t*

4. Result and Discussion:

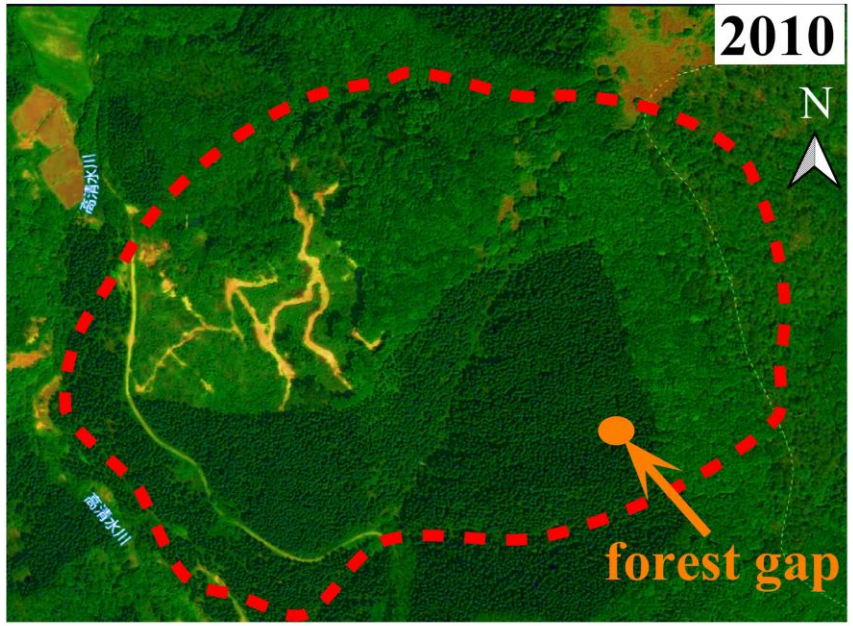
A. Satellite image (Google Earth imagery)

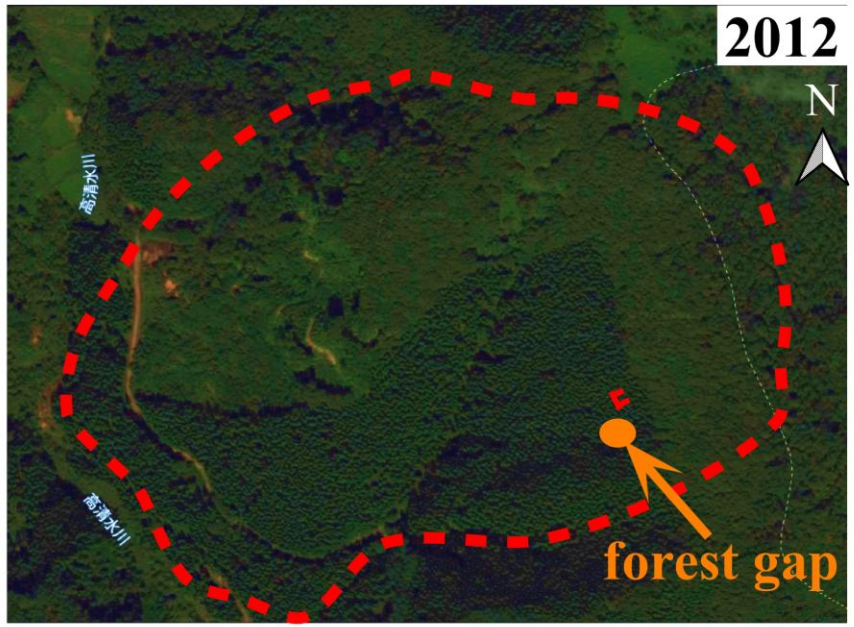
multi-temporal imagery in the period 2010-2024

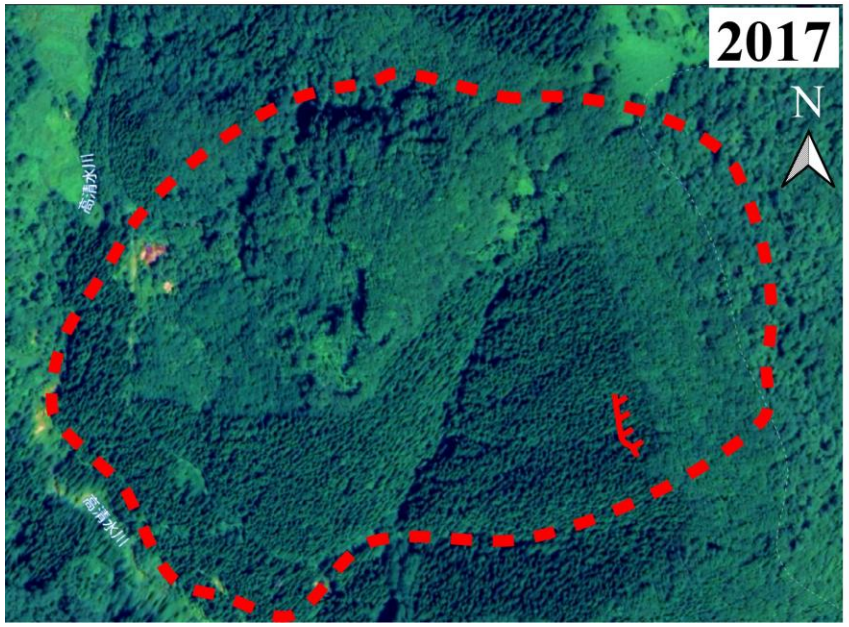


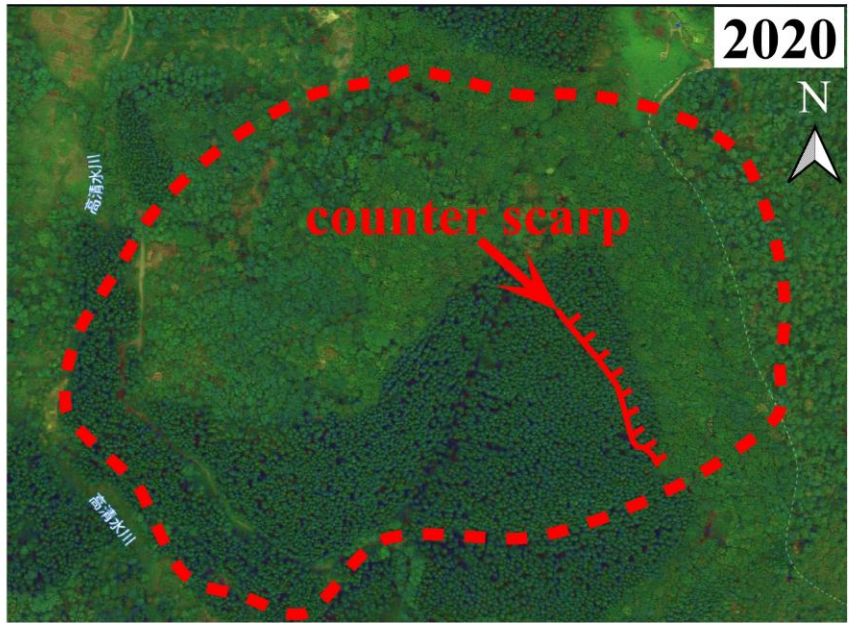
4. Result and Discussion:

A. Satellite image (Google Earth imagery)









Example cases of interpretation of forest gap and counter scarp:

2010: forest gap near counter scarp

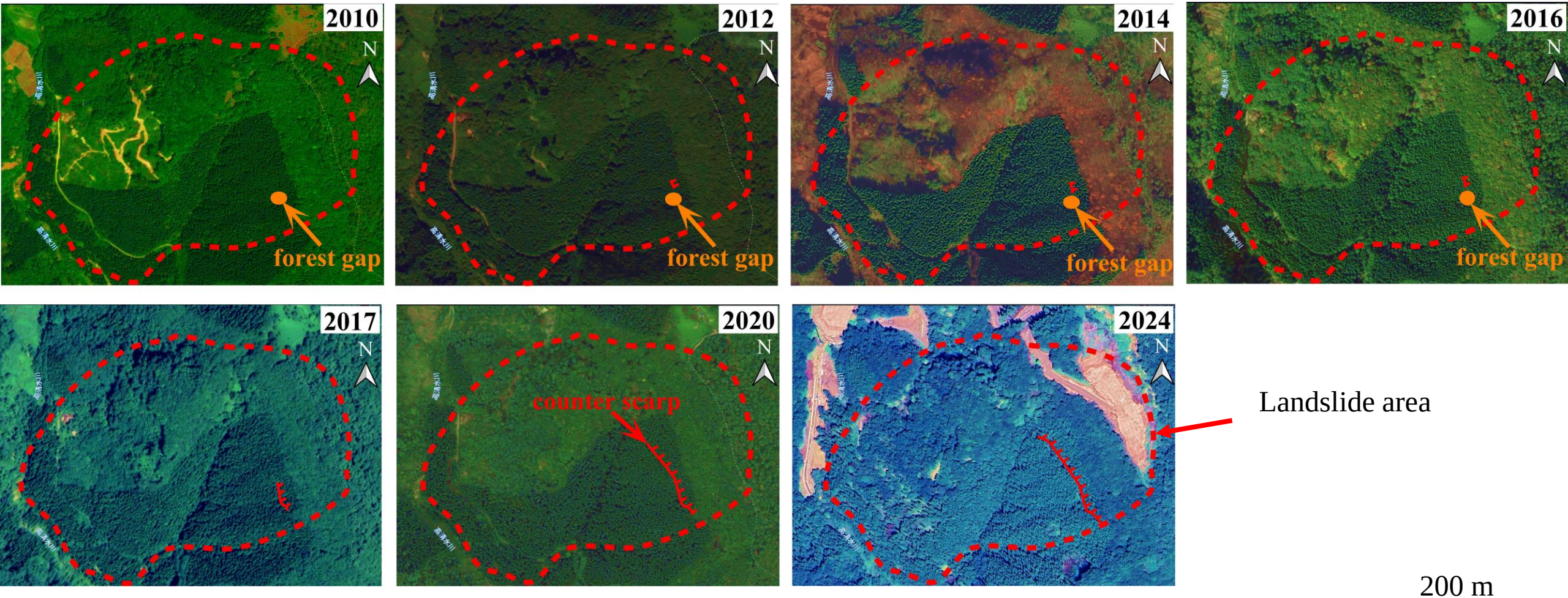
2012–: gradual development of counter scarp

2020: significant development of counter scarp

200 m

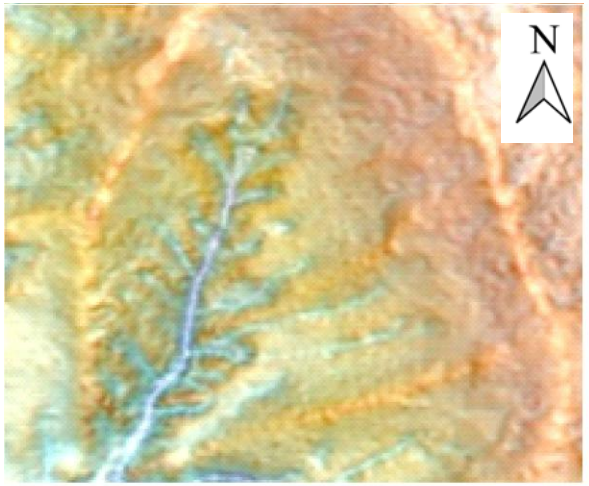
4. Result and Discussion: A. Satellite image (Google Earth imagery)

2010: forest gap near counter scarp
2012–2024: gradual development of counter scarp
2020: significant development of counter scarp

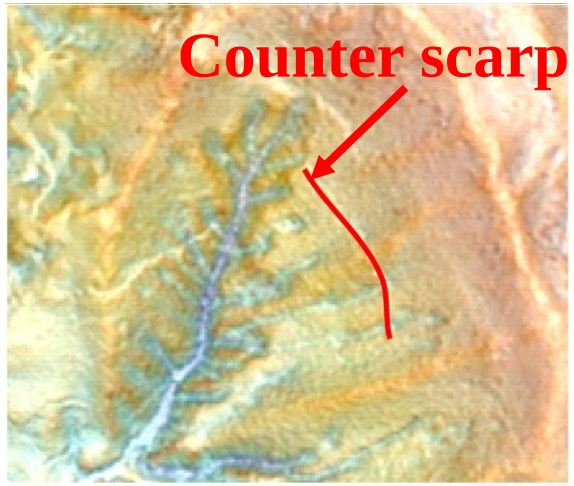


4. Result and Discussion:

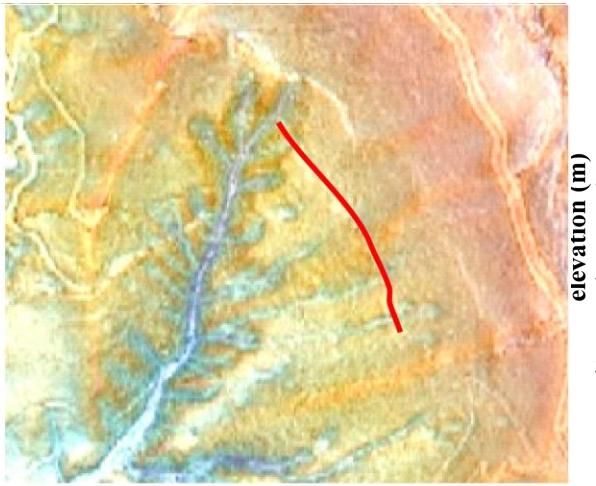
B. UAV Lidar data



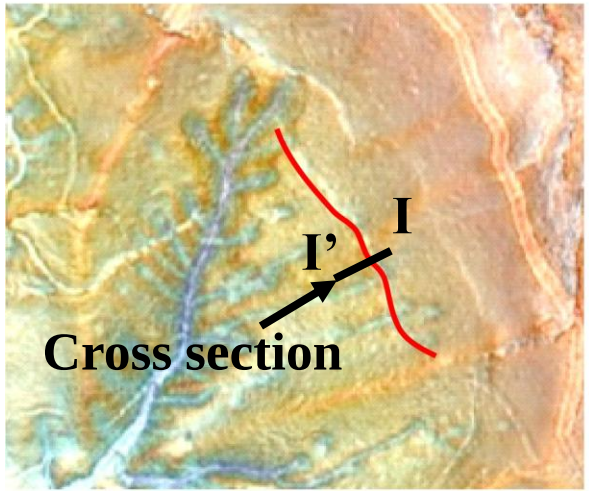
2008 (Not observed)



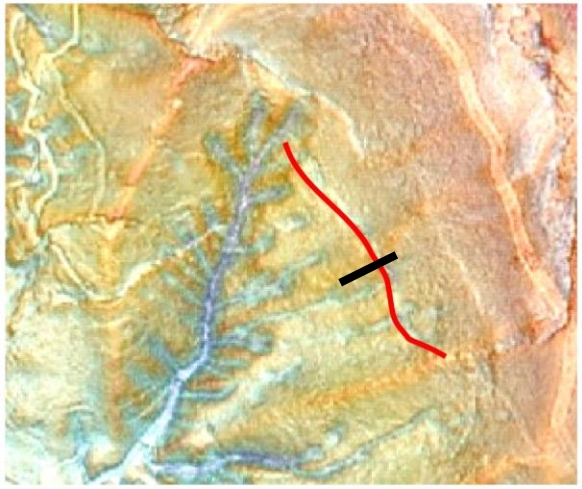
2019



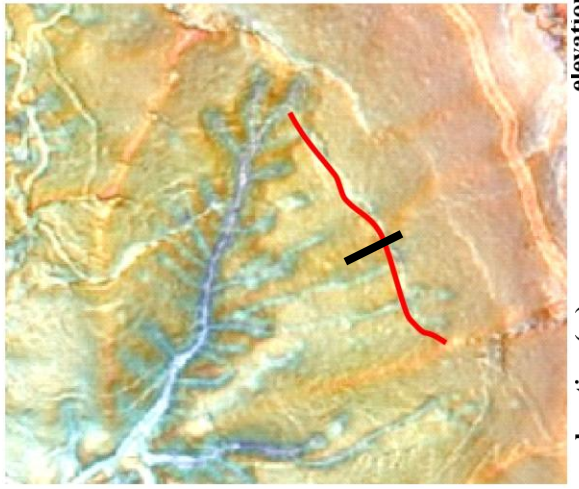
2021



May, 2022



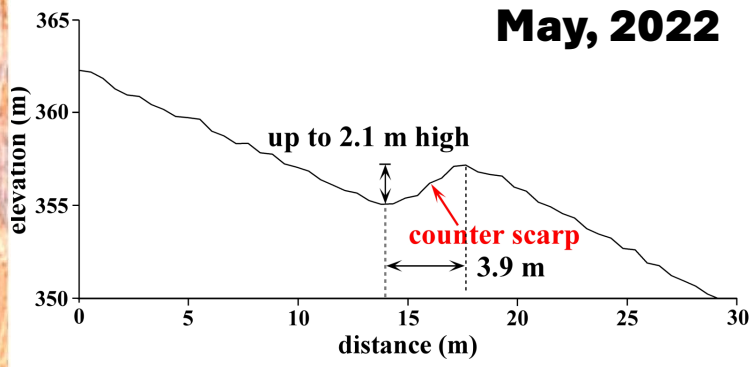
Nov., 2022

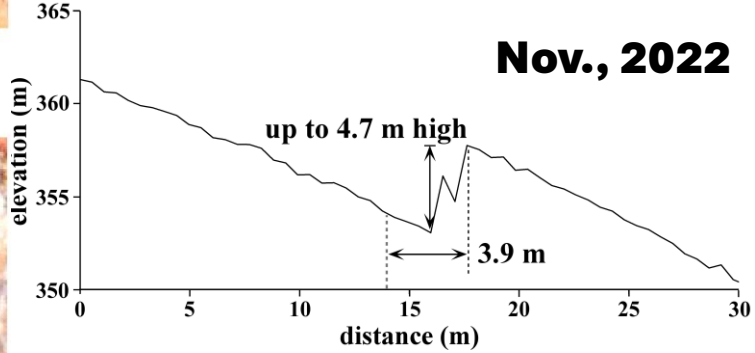


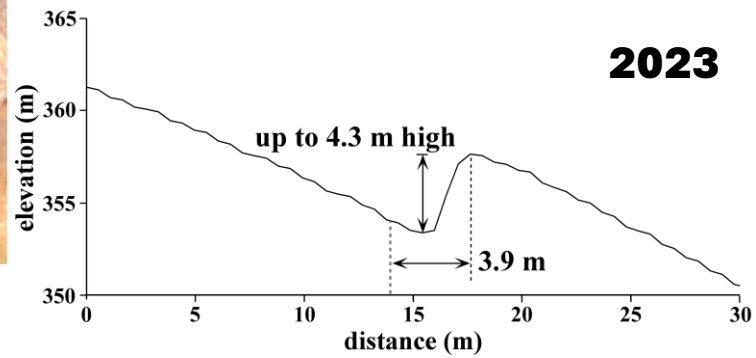
2023

200 m

■ Cross section (I—I')







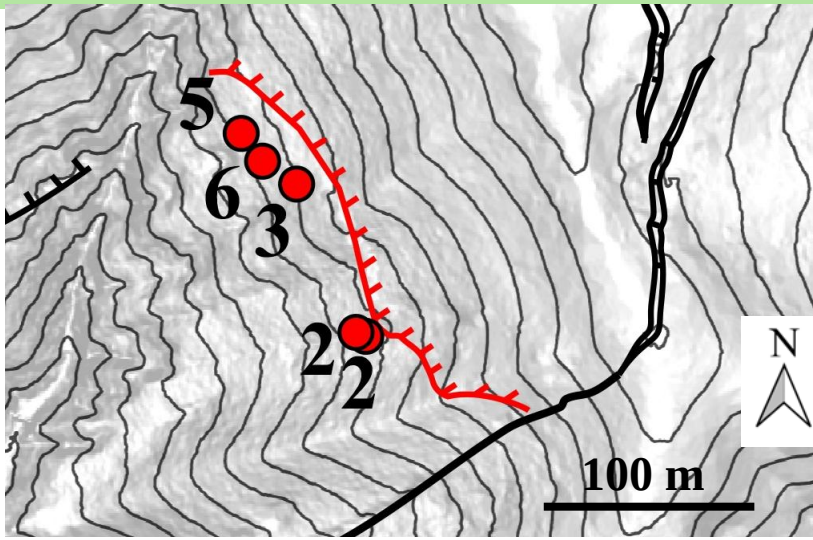
4. Result and Discussion ：

C. Dendrogeomorphological analyses

- Establishment year of shade-intolerant trees

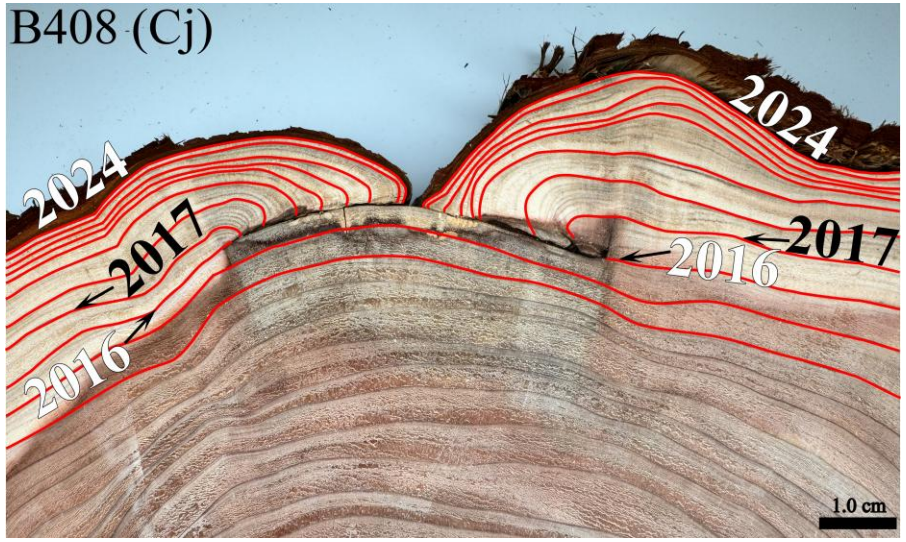
tree ages: 2–6 years old (establishment years: 2019–2023)

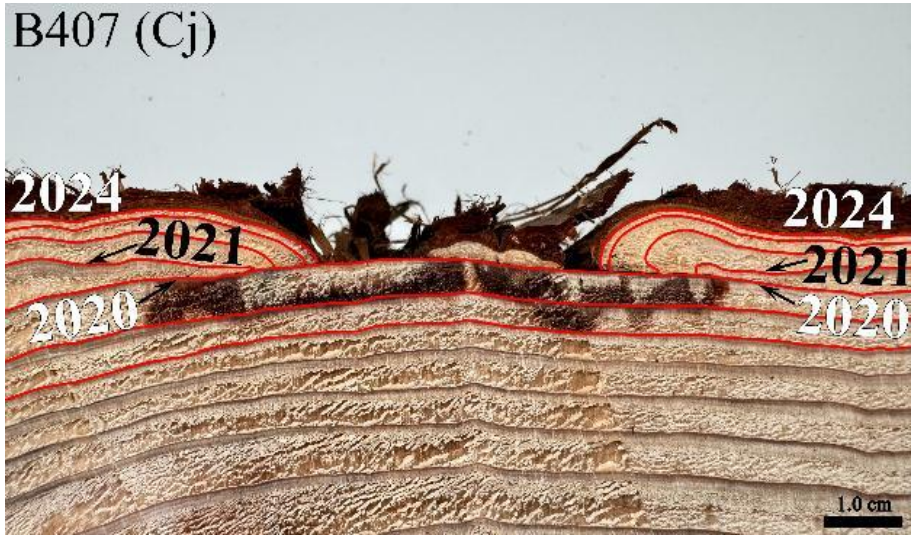
☞ **timing of counter scarp enlargement (2019–2023)**

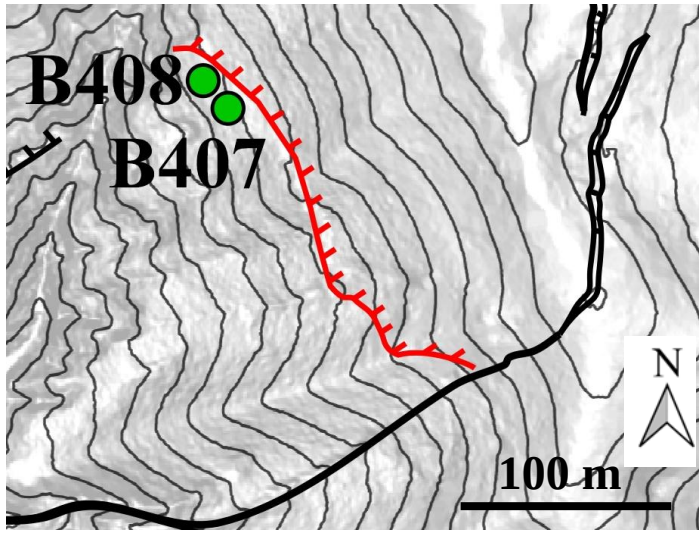


Numbers of shade-intolerant trees ages

- Recovery age of stem wounds





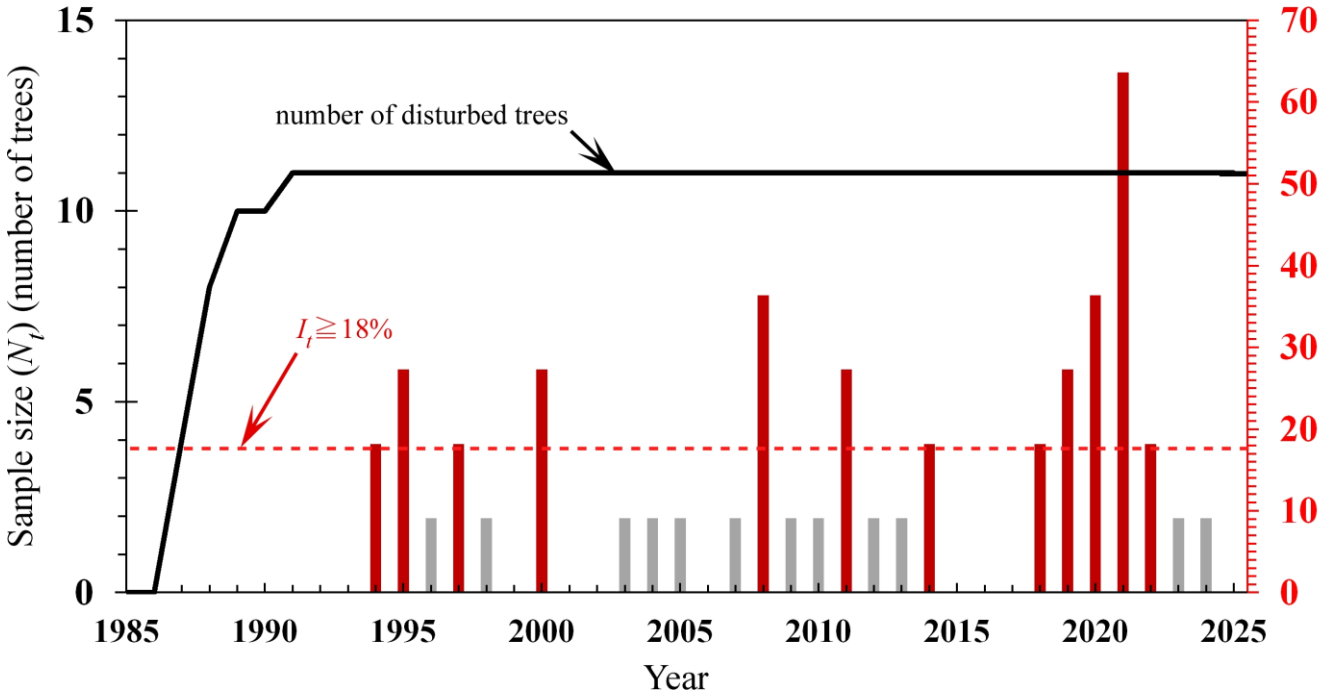


☞ **timing of counter scarp enlargement (**2016 or 2017; 2020 or 2021)

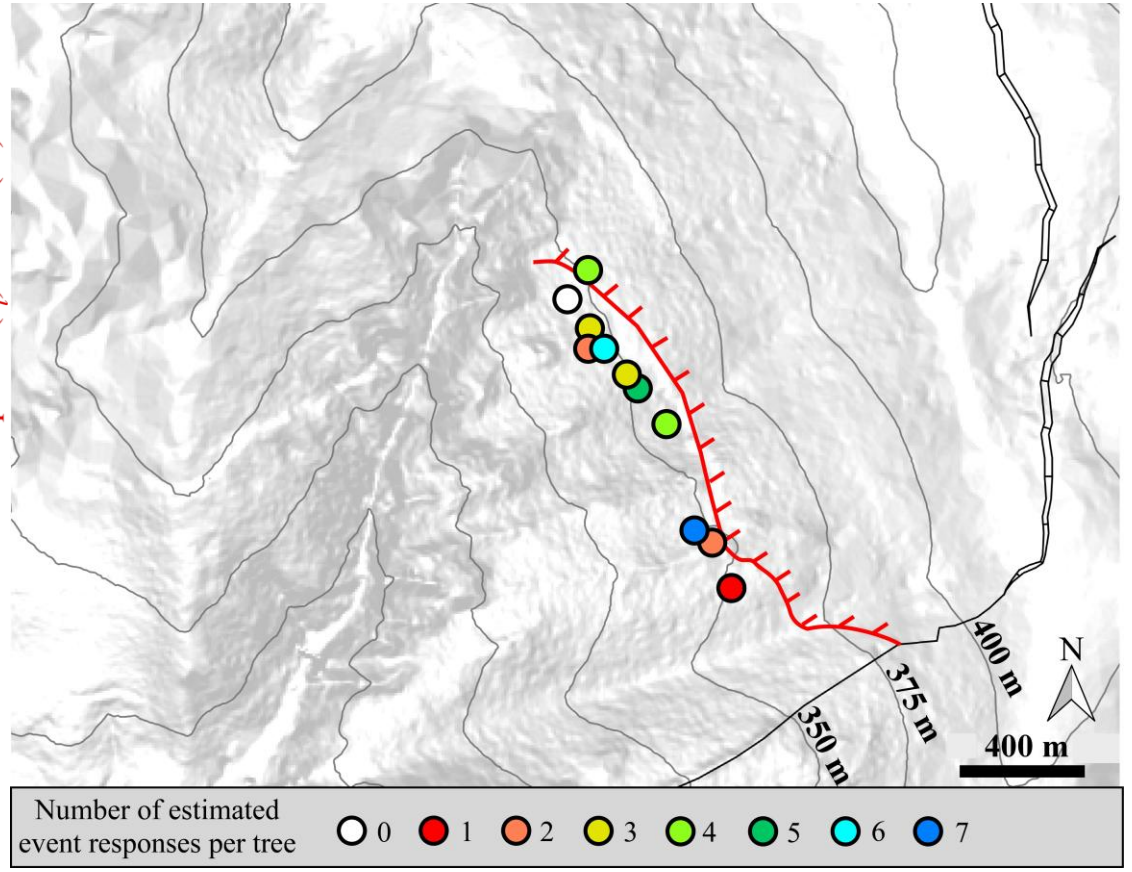
4. Result and Discussion: C. Dendrogeomorphological analyses

➢ Estimated timing of counter scarp enlargement event years

①1994, ②1995, ③1997, ④2000, ⑤2008, ⑥2011, ⑦2014, ⑧2018, ⑨2019, ⑩2020, ⑪2021, ⑫2022



Dendrochronological investigations of past counter scarp events, based on the I_t index and number of trees displaying GD.
Red columns represent the reconstructed counter scarp events that met threshold values (GD ≥ 2 and I_t ≥ 18%).

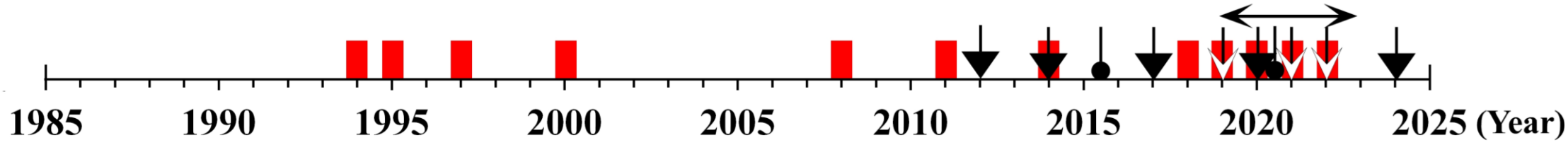


Number of estimated event responses per tree

5. Conclusion

This study examined the temporal development of a NW-SE trending counter scarp, using tree-ring samples, UAV data, and Google Earth imagery for constraints.

- The counter scarp has evolved over time, likely beginning in 1994.
- The scarp develops periodically and shows reactive activity between 2019 and 2022.
- This period of increased activity suggests a significant phase of enlargement, with notable changes in the terrain.
- The continuous evolution of the scarp underscores dynamic processes driven by both environmental and geological factors, the details of which are still under investigation.



timing of counter scarp enlargement constrained by:

A. Google Earth imagery: ↓ B. UAV Lidar data: ↓

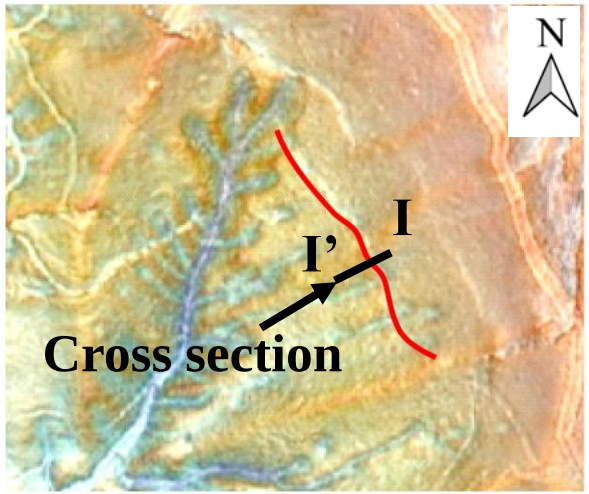
C. Dendrogeomorphological analyses: ▮ counter scarp events estimated by GD and I_t

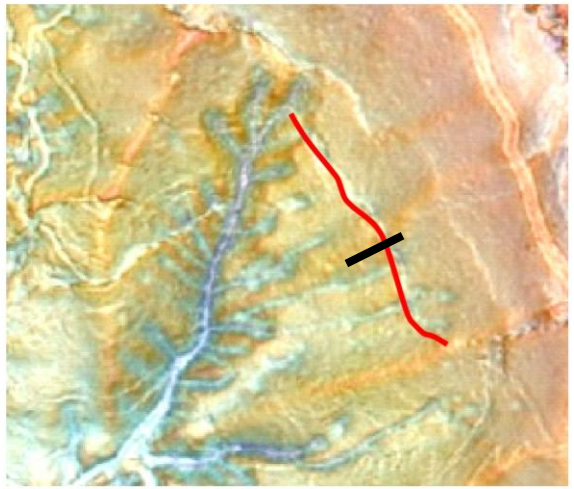
↔ establishment ages of shade-intolerant tree species ┃ recovery age of tree-stem wounds

Thank you for listening

4. Result and Discussion:

B. UAV Lidar data





May, 2022 **Nov., 2022** **2023**

200 m

■ **Cross section (I—I')**