Supplymentary materials

Long-term effectiveness and socioeconomic impact of Eco-DRR measures in Nepal

：lessons from JICA's projects

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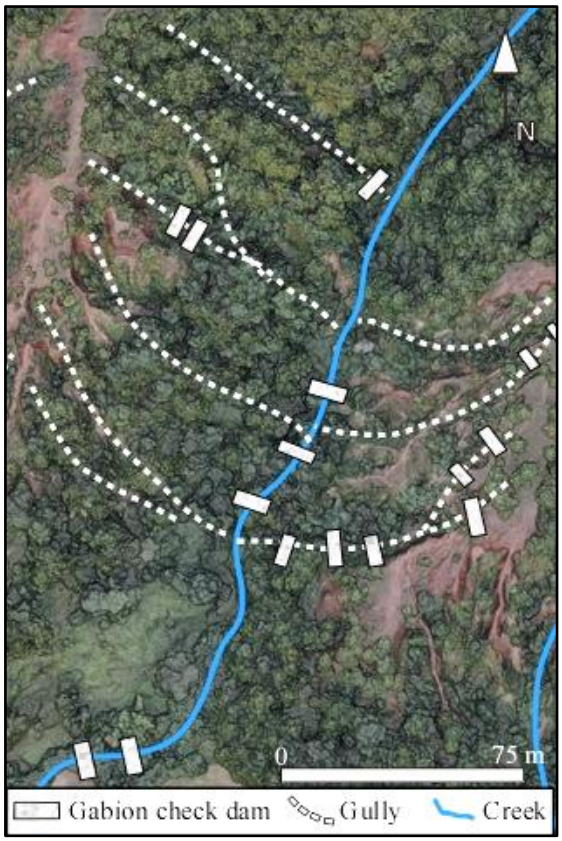
Supplementary materials 1

1. Outline of study area (Upper Pipaltar)

Model site for gully and surface erosion control (1993-2003)

Location	On the slopes of a river terrace
Elevation	500 m - 600 m
Average Slope	About 20 degrees
Geological feature	The upper layer：laterite layer (5-8 m) The lower layer：fluvial sand and gravel deposits (more than 50 m) ⇒most plants hardly grow due to less content of carbon and acid condtion of the laterite (DPTC, 1999)
Past condition (1960's)	Deforestation and overgrazing, Road construction ⇒formation of gully and surface erosion
JICA project	Plantation (tree, bamboo, grasses), Construction (Gabion check dam, Catch drain, PNC panel)

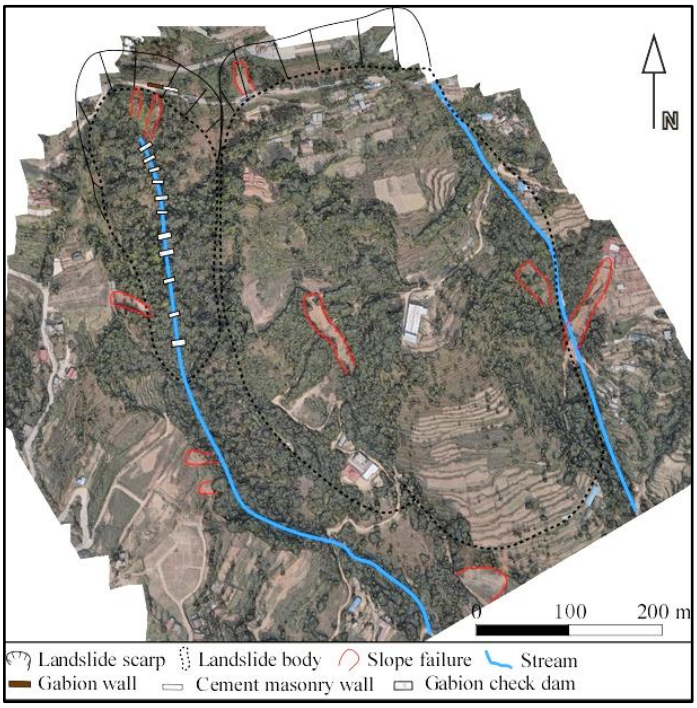


Supplementary Fig.1. Overview of Pipaltar model site (Upper)

2. Outline of study area (Dahachowk)

Model site for Sabo (1999-2004)

Elevation	1400 m - 1870 m
Average Slope	About 30 degrees
Geological feature	Phyllite, limestone, metasandstone (Rana et al., 1984) ⇒Fragile geological condition
Past condition	deforestation, overgrazing, development of infrastructures ⇒cause of landslide
JICA project	Plantation (tree, bamboo, grasses) , Vegetation net(Jute, Straw, Nursery), Construction (Gabion check dam, Retaining wall, Catch drain, Bamboo fencing, Spur dyke, Revetment work) Education for disaster prevention

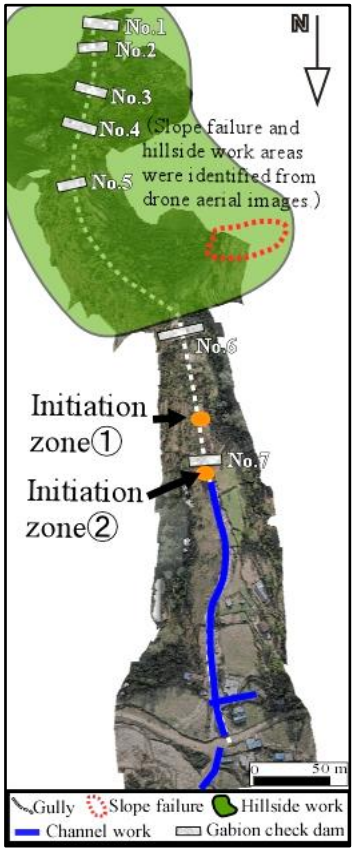


Supplementary Fig.2. Overview of Dahachowk model site

3. Outline of study area (Nallu Khola)

Model site for countermeasures against sediment run-off after debris flow (1992-1999)

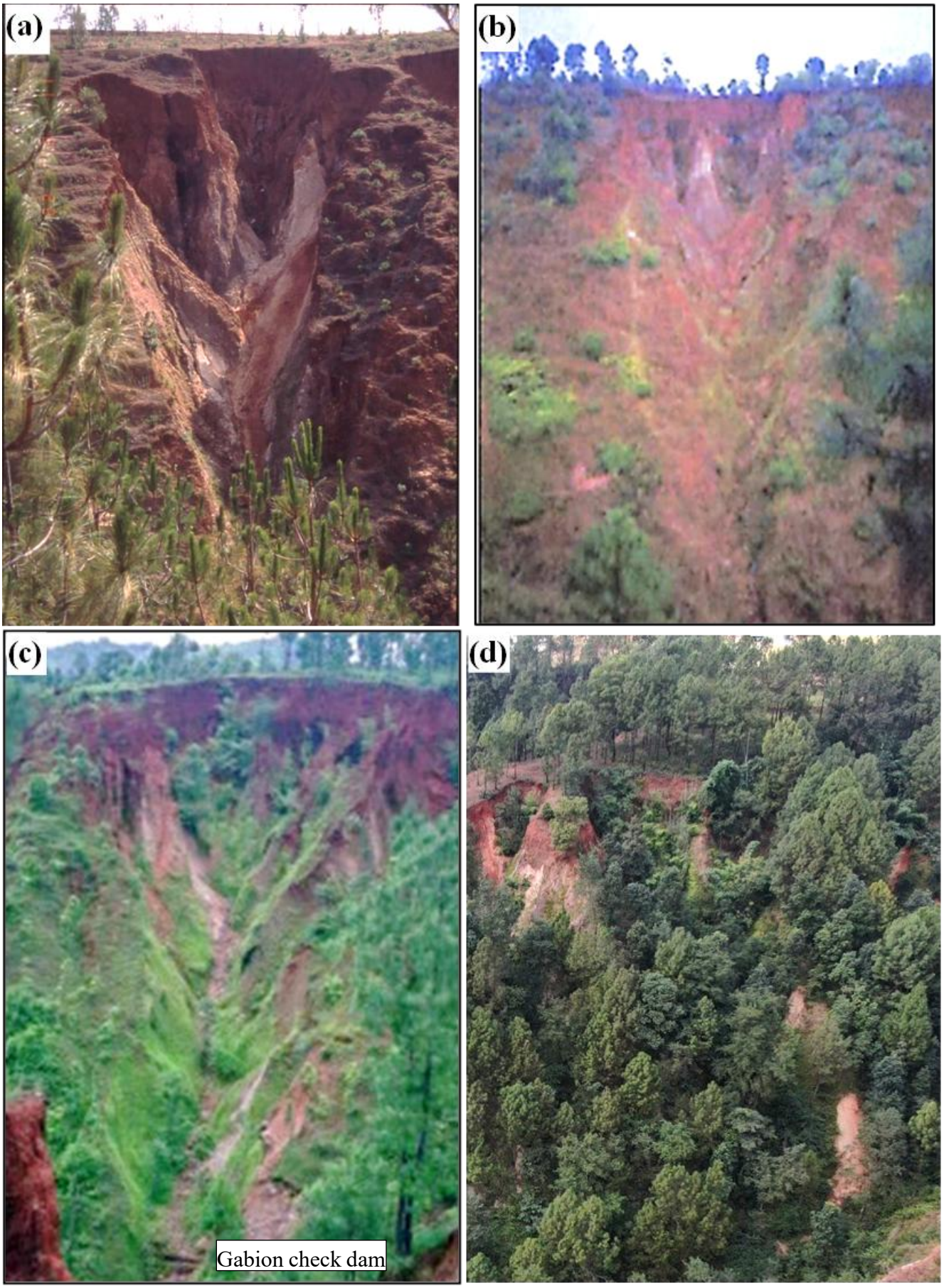
Length of mainstream	1200 m
Watershed area	0.26 km^2
Elevation	1400 m - 2600 m
Average slope	about 20 degrees
Geological feature	Phyllite, limestone, quartzite, sandstone, slate, siltstone (DPTC, 1999)
Past condition	Debris flow disaster occurred on 30th Sept. 1981 due to heavy rainfall. ⇒damaged arable land and several infrastructures
JICA project	Construction (Gabion check dam, Ground sill, Channel work)
Bagmati watershed project	Hillside work, sloping terraces (upstream)



Supplementary Fig.3.
Overview of Nallu Khola model site

Supplementary materials 2

1. Vegetation recovery status (Upper Pipaltar site)



Supplementary Fig.4. Vegetation recovery on the gully (a) Photo taken in May 1995 (courtesy of D. Higaki). (b) Photo taken in 1997 (courtesy of D. Higaki). (c) Photo taken in September 2003 (Suzuki, 2003). (d) Photo taken in November 2024

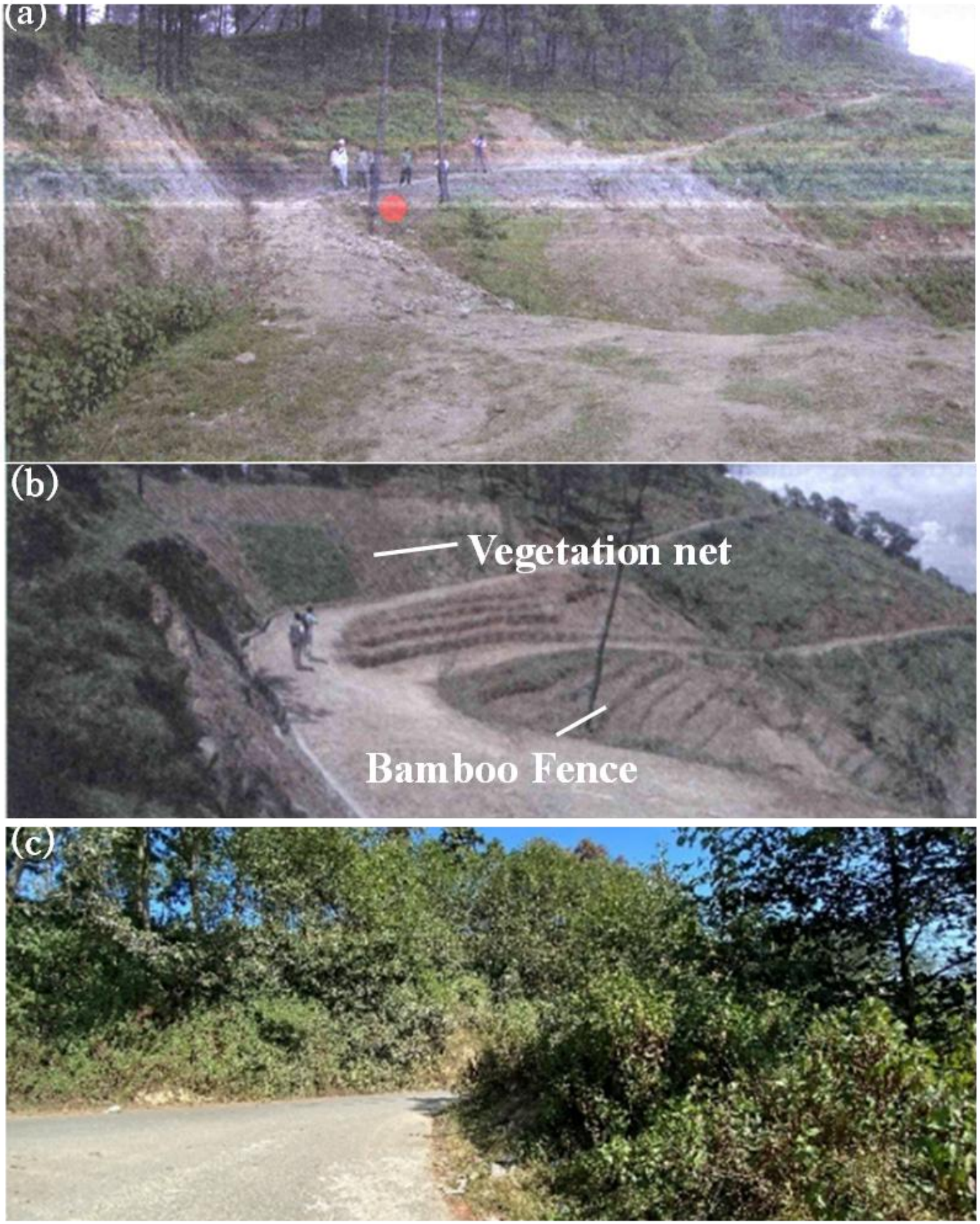
Supplementary Fig.5. Vegetation recovery around the gully head, focusing on bamboo and agave (*Agave spp.*) plantings. (a) Photo taken in December 2013 (courtesy of D. Higaki). (b) Photo taken in April 2018 (Higaki et al., 2021). (c) Photo taken in November 23, 2024.

Function of Agave

1. Prevents of soil failures by taking advantage of dense roots
2. Prevention of animal infestation by leaf spines
3. Rope use by residents through leaf collection

Schematic diagram of **Agave**

2. Vegetation recovery status (Dahachowk site)



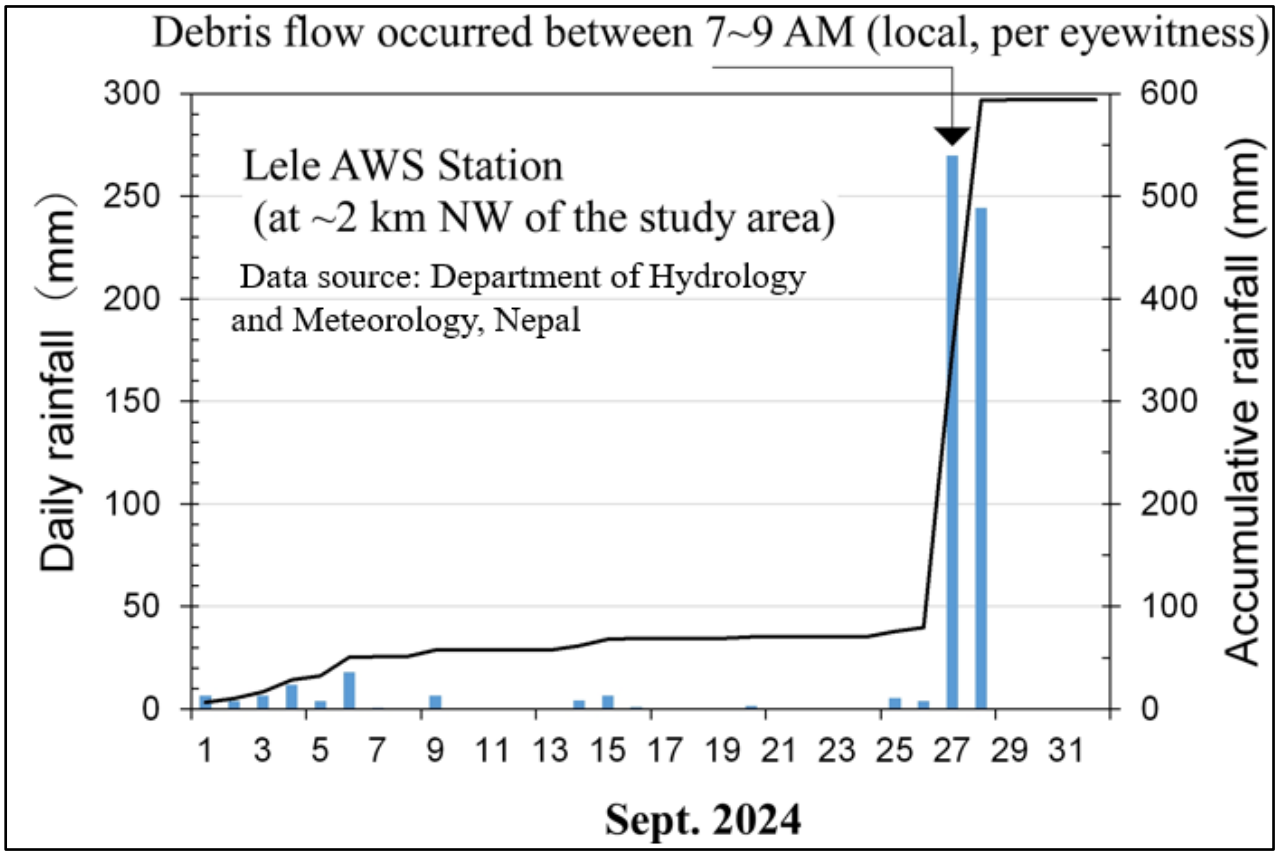
Supplementary Fig.6. Vegetation recovery at the landslide head where bioengineering techniques were implemented at the Dahachowk site. (a) Photo taken in August 2000. (b) Photo taken in August 2004. (c) Photo taken in November 26, 2024. Figures a–c are referred from DWIDP (2004).

Supplementary materials 3

・effectiveness of countermeasures against sediment disaster

(debris flow disaster by heavy rainfall on September 26-28, 2024)

1. Rainfall information during debris flow occurrence in Nallu Khola



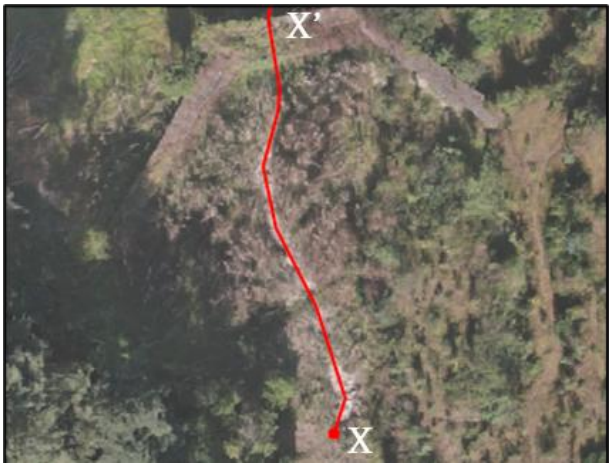
Supplementary Fig.7. Daily and cumulative rainfall in Nallu Khola (Courtesy of C. -Y. Tsou)
Sediment disaster occurred between 7-9 AM

At Lele AWS metrological station of Department of Hydrology and Meteorology, Nepal, located about 2 km NW of the study area, the cumulative rainfall during this event reached 518 mm–approximately 4.3 times the total monthly rainfall for September 2023.

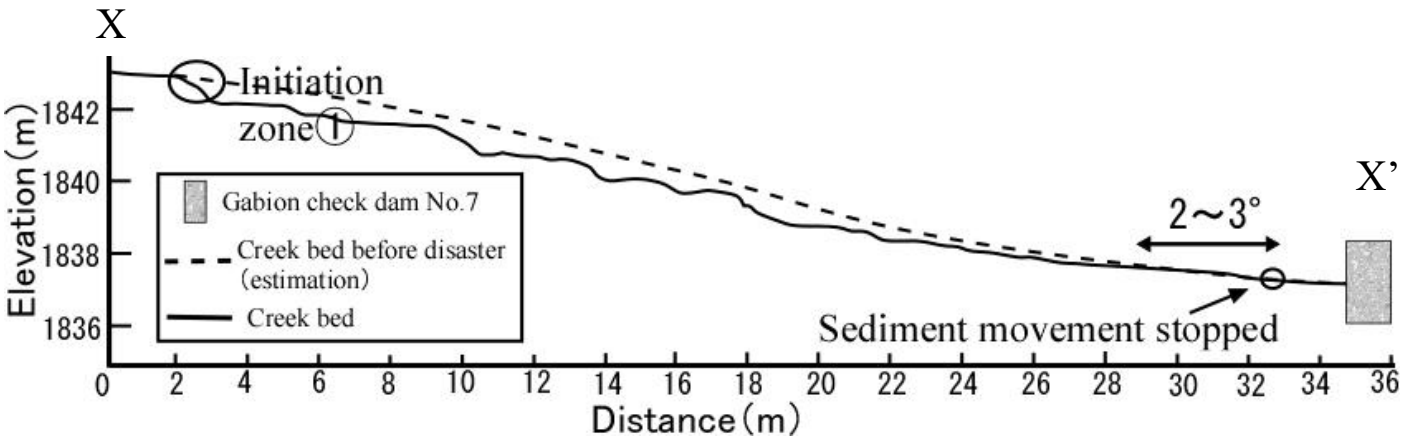
2. Initiation zone① in creek No.8 in Nallu Khola

Supplementary Fig.8. Function of gabion check dam No.7 sediment area

Supplementary Fig.9.
Scale of initiation zone①

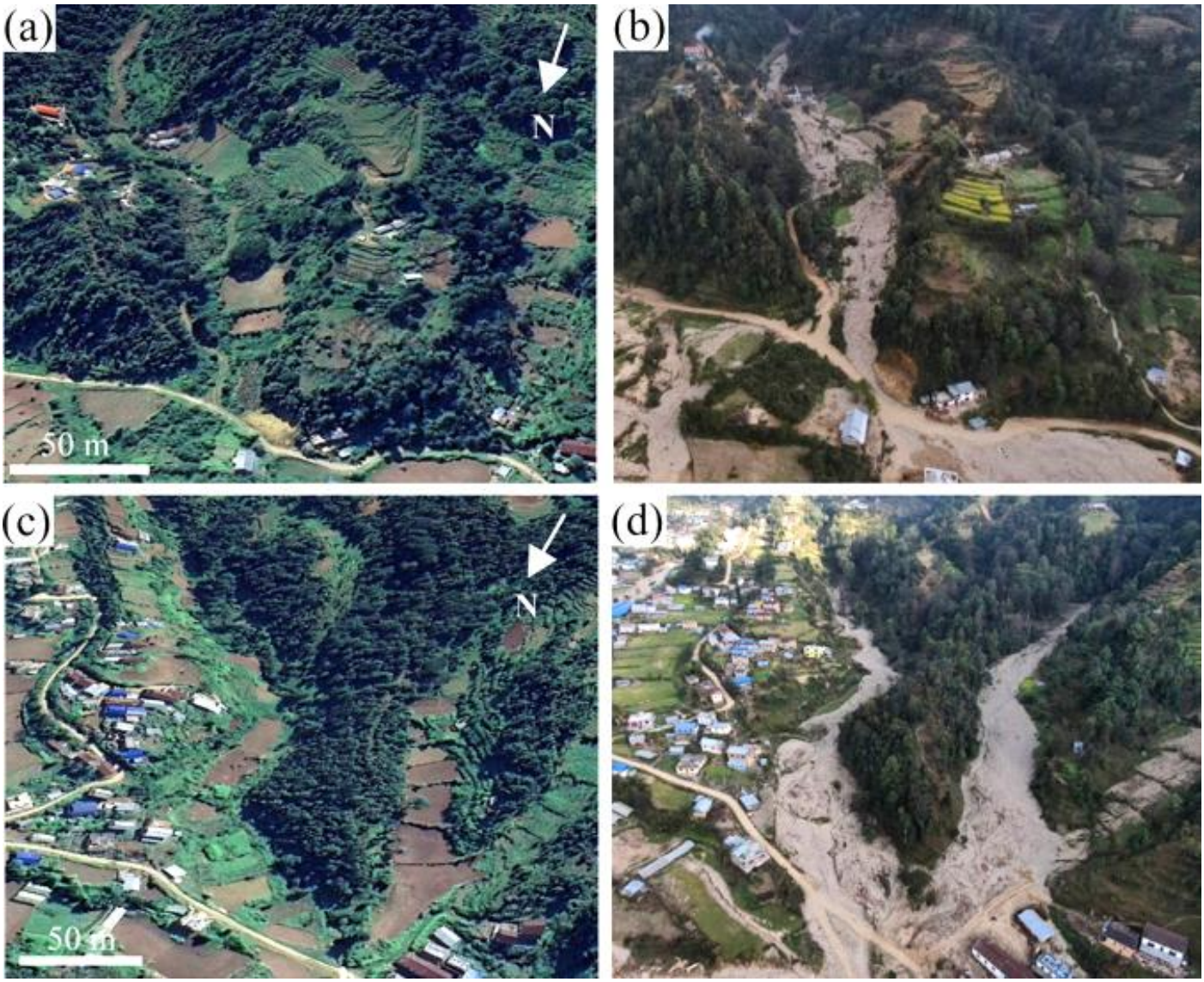


Supplementary Fig.10.
Vertical section measuring line



Supplementary Fig.11. Vertical section of initiation zone ① - Gabion check dam section

3. pre- and post-disaster comparison of unmitigated creek in Nallu Khola.



Supplementary Fig.6. Condition of unmitigated creek (a) Gully ca. 300 m upstream of Creek No. 8 before the rainfall event (Google Earth image, September 23, 2023). (b) Same gully of Fig. 15a after the rainfall event (photo taken on November 24, 2024). (c) Gully ca. 600 m upstream of Creek No. 8 before the event (Google Earth image, September 23, 2023). (d) Same gully of Fig. 15c after the event (photo taken on November 24, 2024).

In areas where no countermeasures had been taken, damage to people's homes, farmland, and roads was observed.

Supplementary materials 4

・livelihood benefits of JICA projects to local community - Questionnaire (Upper Pipaltar)

	Respondent					Remarks	Item intention
Question	A (20s female, service industry)	B (Male, 40s, farmer)	C (Male, 40s, farmer)	C (Male, 50s, farmer)	E (30s Male, service industry)		
Q1: Are users groups (groups that carry out forest conservation and other activities with the participation of local residents) still active?	○	○	○	○	○		Assess ongoing status of resident activities
Q2: How long do you think vegetation restoration (restoration of bamboos, forests, herbaceous plants, etc.) will be useful as a countermeasure against collapse and slope erosion after planting?	8-10 years later	8-10 years later	8-10 years later	8-10 years later	8-10 years later		Assess the effects of countermeasures by resident-led initiatives
Q3: Do you use vegetation used for countermeasures (disaster reduction, soil conservation, etc.) in your daily life?	×	○	○	○	×	From Q16, all 4 respondents have used this in the past.	Assess the impact of ecosystem utilization measures on the local socioeconomy
Q4: Do you use artificially planted? Or is the vegetation you use naturally grown?	naturally	artificially, naturally	artificially, naturally	artificially, naturally			
Q5: What did you use?	Bamboo	Bamboo, Grasses	Bamboo, Grasses	Bamboo, Grasses			
Q6:please indicate if you know the variety, species, etc.		Napier grass	Napier grass				
Q7: please indicate the height to which the harvest will be harvested.		Grass(1 m), Shrub(1 m)	Grass(0.5 m), Shrub(1 m)	Grass(0.6 m), Shrub(1 m)			
Q8: Please indicate the height you will leave when you pick.		Bamboo(6 m), Shrub(1 m)	Bamboo(5 m), Shrub(1 m)	Bamboo(5 m), Shrub(2 m)			
Q9: For those who chose "forest" and "fruit trees" in Q5, how many fruits do you leave when you pick?	2-4 pieces	1-2 pieces	2-4 pieces	1-2 pieces			
Q10: For the items you selected in Q5, how often do you harvest or collect them?	2 to 3 times a week	once a month	once a week				
Q11: For the items selected in Q5, how much do you harvest or collect at a time?		Bamboo (enough to carry with both hands), Shrub (enough to carry with both hands)	Bamboo (enough to carry with both hands), Shrub (enough to carry with both hands)	Bamboo (enough to carry with both hands), Shrub (enough to carry with both hands)			
Q12: How do you use the products harvested or collected?	Hedge	Roofing materials, Cleaning tools、Hedge	Roofing materials, Livestock feed, Cleaning tools, Hedge	Roofing materials, Livestock feed, Cleaning tools, Hedge			
Q13: Can you live solely on the harvest of vegetation used for the measures?	×	×	×	×			
Q14: For those who selected "No" in Q3 or who used the vegetation in the past but do not use it now, what are your reasons for not using the vegetation used in the measures?	Because the harvest from the land I own is sufficient	Because the harvest from the land I own is sufficient	Because the harvest from the land I own is sufficient	Because the harvest from the land I own is sufficient	Because the harvest from the land I own is sufficient	From Q3, we used the vegetation used for the measures in the past, but the land we own now is sufficient.	
Q15: How has your life been affected by the measures taken? (Positive or negative)	Farmland preservation, Pest problem, Wildlife Capture		Improvement of living convenience		Farmland preservation, Pest problem, Wildlife problem		
Q16: What are your reasons for not using the vegetation used in the measures?		Two head of cattle, A head of buffalo, 6 goats, 100 ? Chickens	A head of cattle, 3 goats, 10 chickens	Two head of buffalo, 4 goats	10 chickens		
Q17: For the livestock you own in Q18, please indicate the amount and type of food you feed at one time.		Cattle 1kg, Buffalo 1kg, Goat 1kg	Cattle 1kg, Goat 1kg, Chicken 1kg	Buffalo 1kg, Goat 1kg		The type of grass is not stated, but it is assumed from Q6 and Q12 that grass (Napier grass) is used.	
Q18: How often do you feed the livestock you own in Q18?		Three times a day		Three times a day	Two times a day		
Q19: Various measures were taken in this area as a JICA project from 1993 to 2003, but how many disasters have occurred since then?	Slope failure (three times)、Earthquake	Slope failure 、Earthquake		Slope failure 、Earthquake	Slope failure (three times)、Earthquake		Understanding the Effectiveness of Countermeasures for Slope Movement Phenomena
Q20: What countermeasures were damaged by the disaster?	PNC panel	PNC panel	PNC panel	bamboo, PNC panel	bamboo fence, PNC panel		
Q21: What countermeasures have been effective against the disaster?	Bamboo, Gabion check dam	Bamboo, PNC panel Gabion check dam,	Bamboo, PNC panel Gabion check dam,	Bamboo, Gabion check dam	Bamboo, Gabion check dam, Forest, Catch drain		
Q22: Do you think that the current disaster prevention measures alone are sufficient?	Somewhat agree	Somewhat agree	Somewhat agree	Somewhat agree	Somewhat agree		
Q23: Are you involved in the maintenance and management of disaster prevention measures?	○	○	○	○	○	Based on the information we have heard that residents are not currently allowed to enter the gully, we assume that they were involved in the past.	Assess the effects of countermeasures by resident-led initiatives
Q24: For those who selected "Yes" in Q26, what kind of disaster prevention materials are you involved in?	Forest	Forest, Bamboo fence	Forest, Bamboo fence	Forest, Bamboo fence	Forest		
Q25: For those who selected "Yes" in Q26, how often do you need to maintain and manage the measures in the countermeasures?					Forest(two times a month)		
Q26: For those who selected "Yes" in Q26, is it easy to maintain?	×(economic problem)	×	×	×	×(economic problem)		