CLIMATE-RESILIENT DAMS AND HYDROPOWER INFRASTRUCTURE INTEGRATING ENVIRONMENTAL SUSTAINABILITY IN PLANNING AND DEVELOPMENT

Integration of Environmentally Sustainable Planning and Development of Climate-Resilient Hydropower Infrastructures

Madhuban Lal Maskay | Astech Consultants (Pvt.) Ltd., Nepal

DEFINING THE PROBLEM

The Hydropower Sector faces multiple "Existential Climate Threats"

Infrastructure at Risk

Landslides:

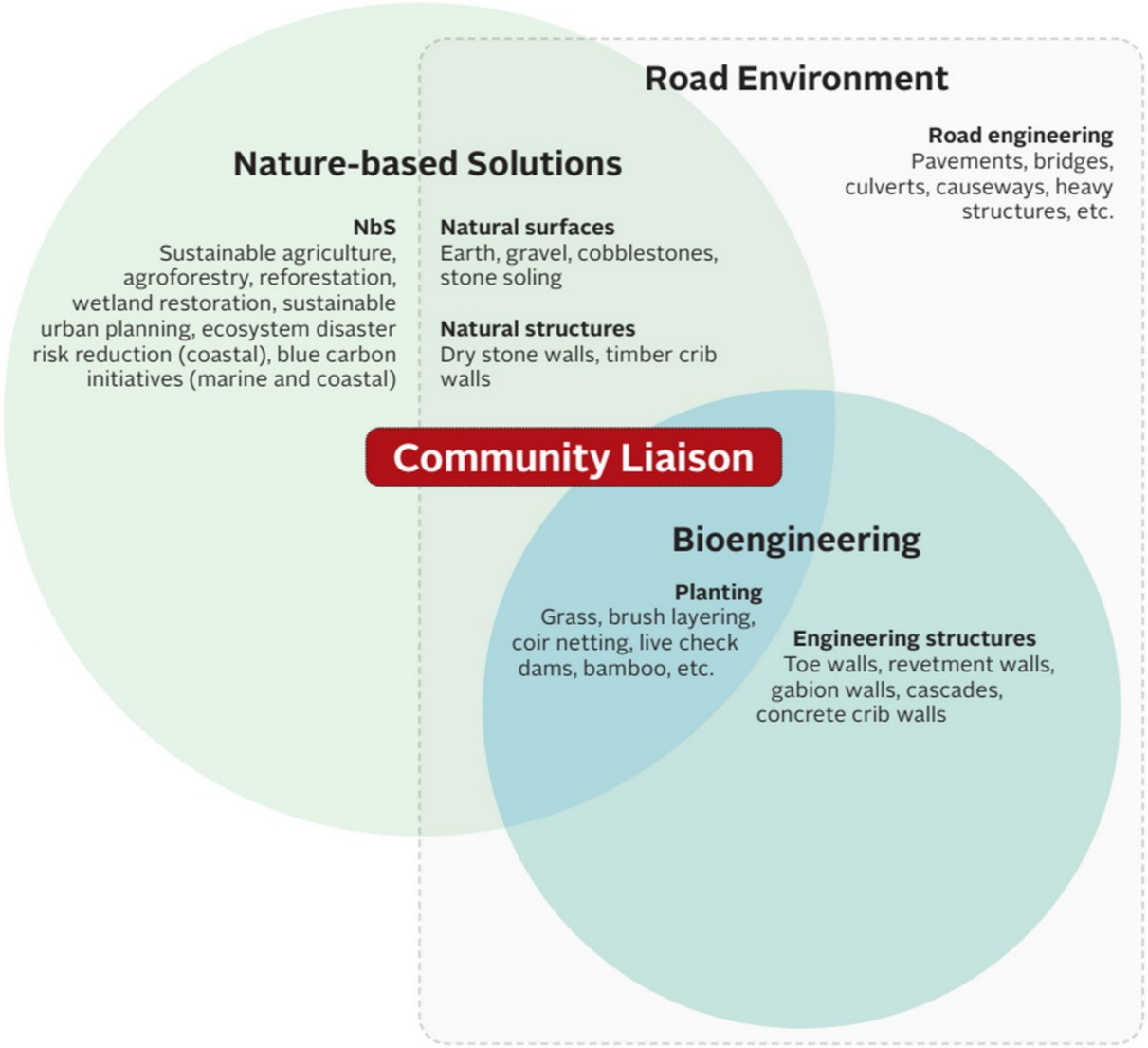
- Slope failures destroy penstocks, headworks, and transmission lines.
- In 2023, floods/landslides damaged 30 hydropower projects (463 MW total) in Nepal.

Sedimentation:

- High sediment loads from eroding catchments damage turbines (abrasion),
- reduce generation efficiency, and shorten reservoir life.

(SANDRP, 2025)

DEFINING THE SOLUTION



Extracted from John Howell's presentation with the SWN, and ADPC

DEFINING THE SOLUTION

Soil Bioengineering

A specialized subset of NbS. It is the use of living plants as engineering materials to perform technical functions:

- **Catch:** Stems catch eroding debris.
- **Armour:** Dense vegetation protects slopes from rain splash and runoff.
- **Reinforce:** Roots bind soil particles, increasing shear strength.
- **Anchor:** Deep roots anchor surface soil to firmer strata.

THE STRATEGIC NECESSITY

Why Transition from Grey to Green ?

It is no longer an option, but a

“Necessity”

THE STRATEGIC NECESSITY

Nepal ranks as the 20th most vulnerable country to hazards. (Source: UNDP and GoN)	Rigid structures alone are insufficient.
Asset Longevity	• Soil Bioengineering gets stronger over time • Concrete weakens with age
Resilience	Vegetation recovers from damage self-sufficiently; concrete requires expensive repairs.

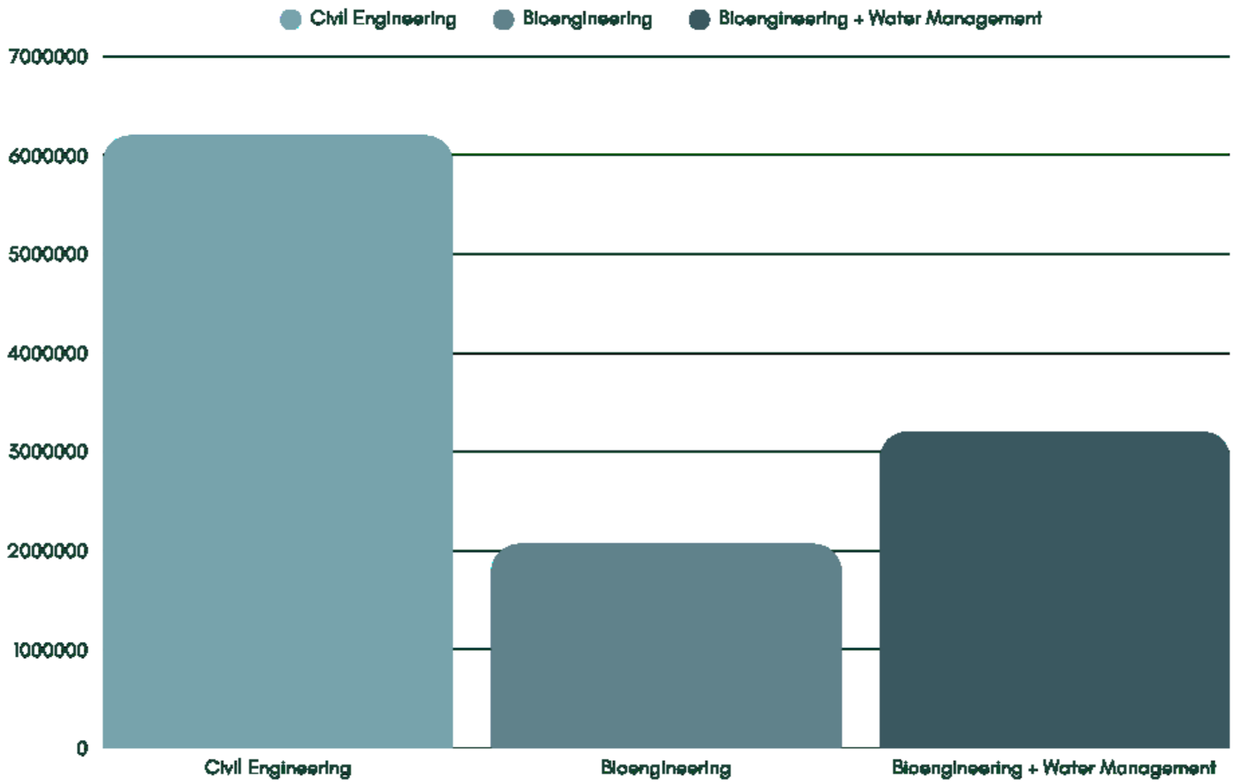
APPLICATION IN HYDROPOWER

Catchment Area:	Afforestation and check dams to regulate water flow (act as "sponges") and reduce peak flood risks.
Slope Stabilization	Penstocks & Access Roads
Brush Layering & Palisades	To stabilise steep slopes.
Vetiver Grass:	Deep roots for riverbank and slope protection.
Transmission Lines:	Soil bioengineering at tower bases prevents landslide-induced tower collapse—a major cause of grid failure.

THE FINANCIAL CASE

Lower CAPEX	Soil Bioengineering relies on local materials (seeds, cuttings, bamboo) and local labor, hence, avoiding expensive imported cement and steel.
Better Cost Efficiency Ratio	General Rule: Soil Bioengineering costs are typically 10% to 23% of conventional civil engineering costs.
Higher Maintenance Savings	Reduced need for heavy machinery and continuous concrete repairs.
Monetization	Healthy catchments provide "Ecosystem Services" (sediment control) that can be monetised to finance maintenance.

COST COMPARISON IN NEPAL



As per the cost comparison analysis carried out by Monsoor and Tripathi, 2025*

ANDSLIDE STABILIZATION

Civil Engineering Cost	NRs. 6,199,496.55
Bioengineering + Water management Costs	NRs. 3,202,854.52

Findings: Bioengineering + Water Management was roughly 50% cheaper (ratio of 1:1.94)

Conclusion: Even when including some civil structures (like riprap) within bioengineering, the cost advantage is massive

EMPOWERING COMMUNITIES-SECURING PROJECTS

Job Creation	Soil bioengineering is labour-intensive, employing local community members for nursery management, planting, and maintenance.
Gender Inclusion	Nursery and planting tasks often provide significant employment opportunities for women in rural areas.
Reduced Conflict	Involving locals in "Green Jobs" fosters a sense of ownership, reducing local opposition to hydropower projects.
Livelihoods	Communities can harvest sustainable products (fodder, broom grass, bamboo) from the stabilized slopes.

GLOF Disaster impacts numerous HEP in Nepal

- Glacial Lake Outburst Flood (GLOF) disaster in Lekende Khola river on July 8, 2025 (Water levels rose by 3.5m in Rasuwa)

- Kerung and Lehende rivers, merge to form the Bhotekoshi river (Trishuli Sub-Basin under Narayani river system)

- Some of the effected hydropowers included:
  - The 111 Mw Rasuwagadhi HEP (most affected)
  - The 60 MW Trishuli 3A HEP,
  - 22 Mw Chilime,
  - 60 Mw Trishuli 3A,
  - 25 Mw Trishuli,
  - 14 Mw Devighat HEP, and
  - Other under construction HEPs

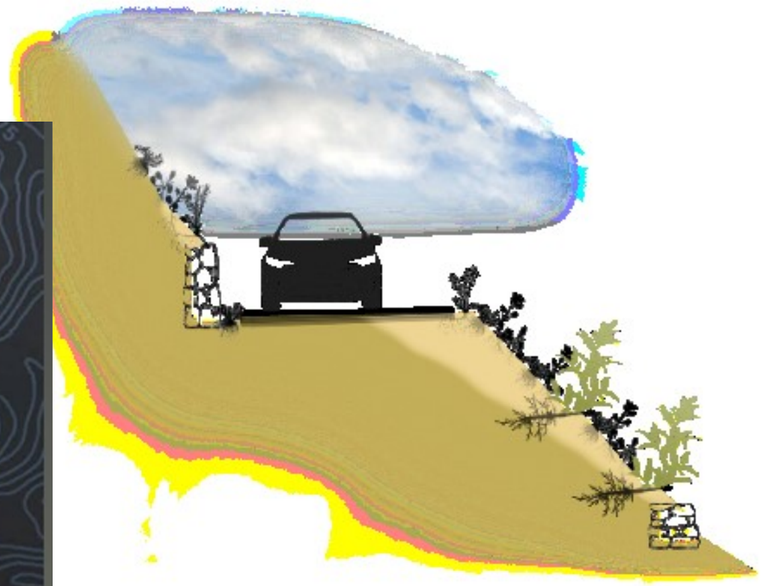
(Damages to the 111 Mw Rasuwagadhi HEP include: Floods washing away the head works, dam gate structures, access roads, temp. cofferdam, campsite, 9 vehicles, and 2 bridges were left vulnerable)

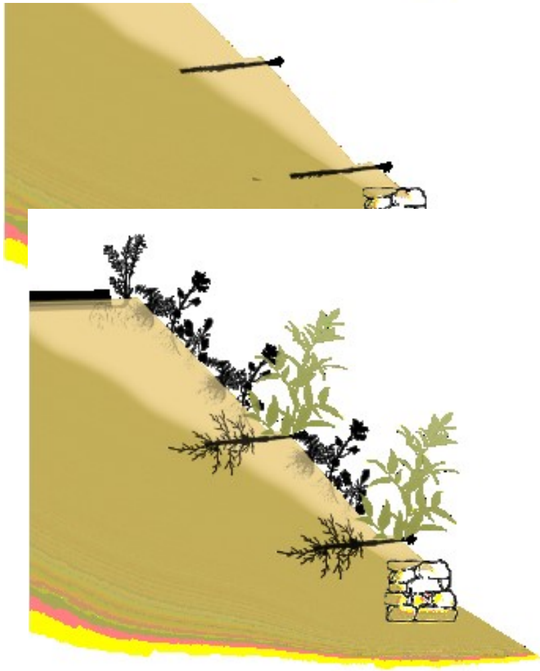
(SANDRP, 2025)

SOIL BIOENGINEERING WORKS

IN BRIEF

(Before and After)





Section

ISSUE- FLASH FLOOD

RCC retaining wall proposed for strengthening existing bank

DURING TWO DAYS OF INTENSIVE RAINFALL ON 27 & 28 SEPTEMBER 2024

FRAGILE AND VULNERABLE CONDITION WITH RILLS AND GULLy DEVELOPMENT

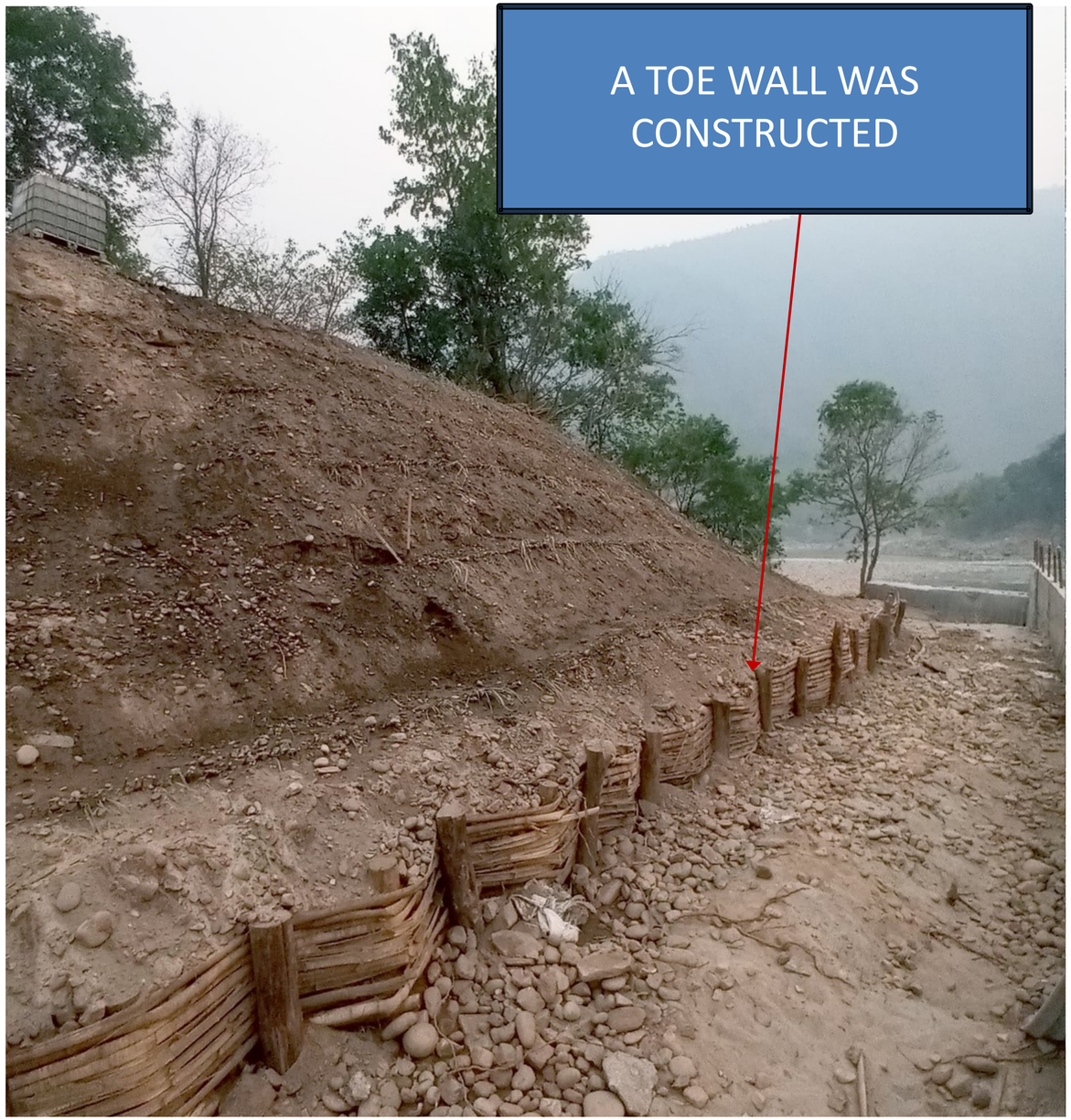
IMMEDIATE MEASURES WAS TO BE TAKEN THROUGH SOIL BIOENGINEERING MEASURES

PLANT NURSERY WAS ESTABLISHED




TRIMMING AND DRESSING OF THE SLOPE AT FIRST

STARTING FROM THE FOOT OF THE SLOPE SOIL BIOENGINEERING MEASURES WITH THE BEST SUITABLE TECHNIQUES PROPOSED USING AVAILABLE LOCAL RESOURCES



A TOE WALL WAS CONSTRUCTED

RESULT AFTER COUPLE OF WEEKS

INCOLD

CENTRAL BOARD OF IRRIGATION & POWER
ESTD. 1927
NEW DELHI

INCOLD

CENTRAL BOARD OF IRRIGATION & POWER
ESTD. 1927
NEW DELHI

GOOD GROWTH PERFORMANCE OF BAMBOO SHOOTS WITH OTHER PLANT SPECIES

DENSE GROWTH OF ELEPHANT GRASS WITH KIMBU AND KHIRHOO

PREPARATION OF PLANT CUTTINGS FOR SOIL BIOENGINEERING WORKS

SEVERAL ROWS OF BRUSH LAYERING

Use of local plant species … fast and effective results


Debris Disposal Site – Before Rehabilitation
Techniques Used
Hedge Brush Layering, Live Palisade Wall, Hedge Plantation at the top edge


Debris disposal site after Rehabilitation using Soil Bioengineering


Before
After
Brush Layers:

Examples of Rehabilitated Debris Disposal Sites:

REFERENCES

SANDRP, 2025. SANDRP. [Online]
Available at: https://sandrp.in/2025/11/15/2025-hydro-projects-accidents-disasters-in-himalaya/
[Accessed 28 January 2026].

Howell, J., n.d. Nature- Based Solutions in the Road Sector: Where are we?. s.l., s.n.

Monsoor, N. H. & Tripathi, R. K., 2025. Civil Engineering structure and Bioengineering Technique for landslide reduction and there cost comparison; with reference to study in Kageshwori Manohara Municipality of Kathmandu, Nepal. Universal Technical Journal of Lumbini International Academy of Science and Technology, 1(1), pp. 1-16.

UNDP, n.d. *UN Info.* [Online]
Available at:
https://un.info.np/Net/NeoDocs/View/History/Default.aspx?RefId=4243#:~:text=UN%20Digital%20Library%20Nepal:%20Document%20History&text=Abstract:,among%20poor%20and%20disadvantaged%20groups.
[Accessed 29 1 2026].

SANDRP, 2025. *SANDRP.* [Online]
Available at: https://sandrp.in/2025/07/24/july-2025-glof-disaster-impact-ten-heps-in-nepal/
[Accessed 29 Jan 2026].


Thank You