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Assessing the Performance of Landform Evolution Models in a Natural Catchment Analogous to a Post-Mining Landform

Indishe P. Senanayake, Gregory R. Hancock

School of Engineering, The University of Newcastle, Callaghan, NSW 2308, Australia.

Indishe.Senanayake@newcastle.edu.au, Greg.Hancock@newcastle.edu.au

INTRODUCTION & AIM

- For the mining industry, once the valuable mineral is extracted, the waste material is often piled at a designated location, capped with topsoil, and vegetation is established with the aim of blending these constructed post-mining landforms into the natural surroundings.
- Long-term erosional stability of post-mining landforms remains a key priority, as these constructed landscapes are prone to gullying and rilling, leading to high soil erosion rates (Fig 1).
- Assessing erosion rates is essential not only on post-mining landforms—during both design and operational phases—but also on adjacent natural hillslopes used as analogue sites.
- Numerical modelling using landform evolution models (LEMs) offers a practical means for such assessments, through the dynamic modification of digital elevation models (DEMs).
- However, Field validation of LEM predictions is challenging, as long-term erosion rates are difficult to measure.

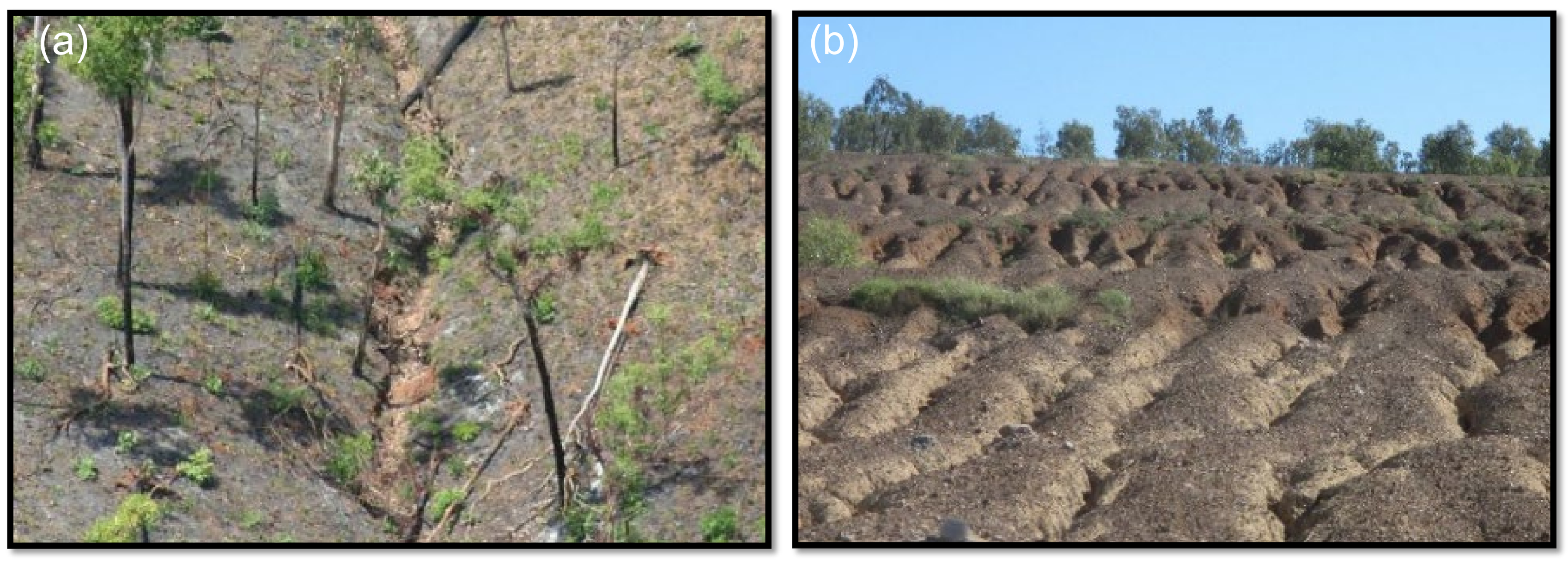

Fig 1. (a) Gullies and (b) rills formed on constructed post-mining landforms.

Aim: To evaluate two LEMs—(i) SIBERIA, widely applied in the Australian mining industry, and (ii) SSSPAM, a state-of-the-art coupled soilscape–landform model—against two field-based methods: (i) sediment yield from a farm dam and (ii) the ^{137}Cs technique, using a natural catchment in the Upper Hunter region of Australia as an analogue for constructed post-mining landforms.

METHOD

Fig 2. The study catchments and the sediment dam.

Erosion rate calculation

LEM Simulations

1. SIBERIA LEM – 100 years
2. SSSPAM LEM – 100 years

(a) Moderate grass cover | (b) Dense grass cover

Field methods

1. Sediment load at farm dam
2. ^{137}Cs isotope method

Study Area

- Two adjacent catchments (77,766 m² and 52,831 m²) in southeastern Australia, analogous to nearby post-mining landscapes (Fig 2).
- Covered with native pasture; previously grazed, undisturbed for the past 30 years.
- Cattle water dam acts as a sediment pond, collecting surface erosion from both catchments (~70 m downstream).

LEM Simulations

- SIBERIA and SSSPAM LEMs were parameterised with site-specific data for both moderate and dense grass cover scenarios using LiDAR-derived high resolution DEMs resampled to 1 m *(Willgoose, 2005; 2018, Welivitiya et al., 2019).*
- Simulations were performed for 100-year period at annual time steps.
- Average erosion rates calculated from model outputs.

Field Measurements

Cesium-137 (^{137}Cs)

- Distribution of ^{137}Cs used as a tracer to estimate soil erosion and deposition rates, compared to reference (non-eroded) sites (Loughran, 1994) (Fig 3).

Sediment load at farm dam

- Historical aerial imagery (NSW Spatial Collaboration Portal) used to determine sediment dam age (Fig 4).
- Sediment cores from dams analysed to calculate sediment volume captured (Fig 5).

Fig 3. Hyperpure germanium detector used ^{137}Cs analysis.

RESULTS & DISCUSSION

- Historic aerial photographs show that the sediment dam was absent in 1953 but present by 1974, providing a 50–71-year period from dam construction to field sampling in 2024 (Fig 4).

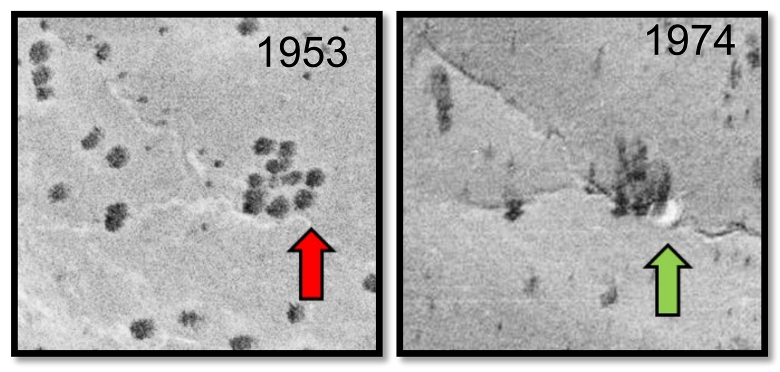

Fig 4. Historic aerial photographs of the site in 1952 and 1974.

Table 1. Soil erosion rates in the study area estimated using two LEMs and two field methods.

Method	Estimated erosion rate
SIBERIA LEM	1.07 t/ha/yr (dense grass cover) 3.74 t/ha/yr (moderate grass cover)
SSSPAM LEM	0.35 t/ha/yr (dense grass cover) 2.43 t/ha/yr (moderate grass cover)
Sediment dam	0.43 t/ha/yr - 0.61 t/ha/yr
^{137}Cs method	1.5 t/ha/yr (max. erosion rate) 1.1 t/ha/yr (max. deposition rate)

Fig 5. A soil core from the sediment pond. Soil cores indicated a sediment depth of 120 cm.

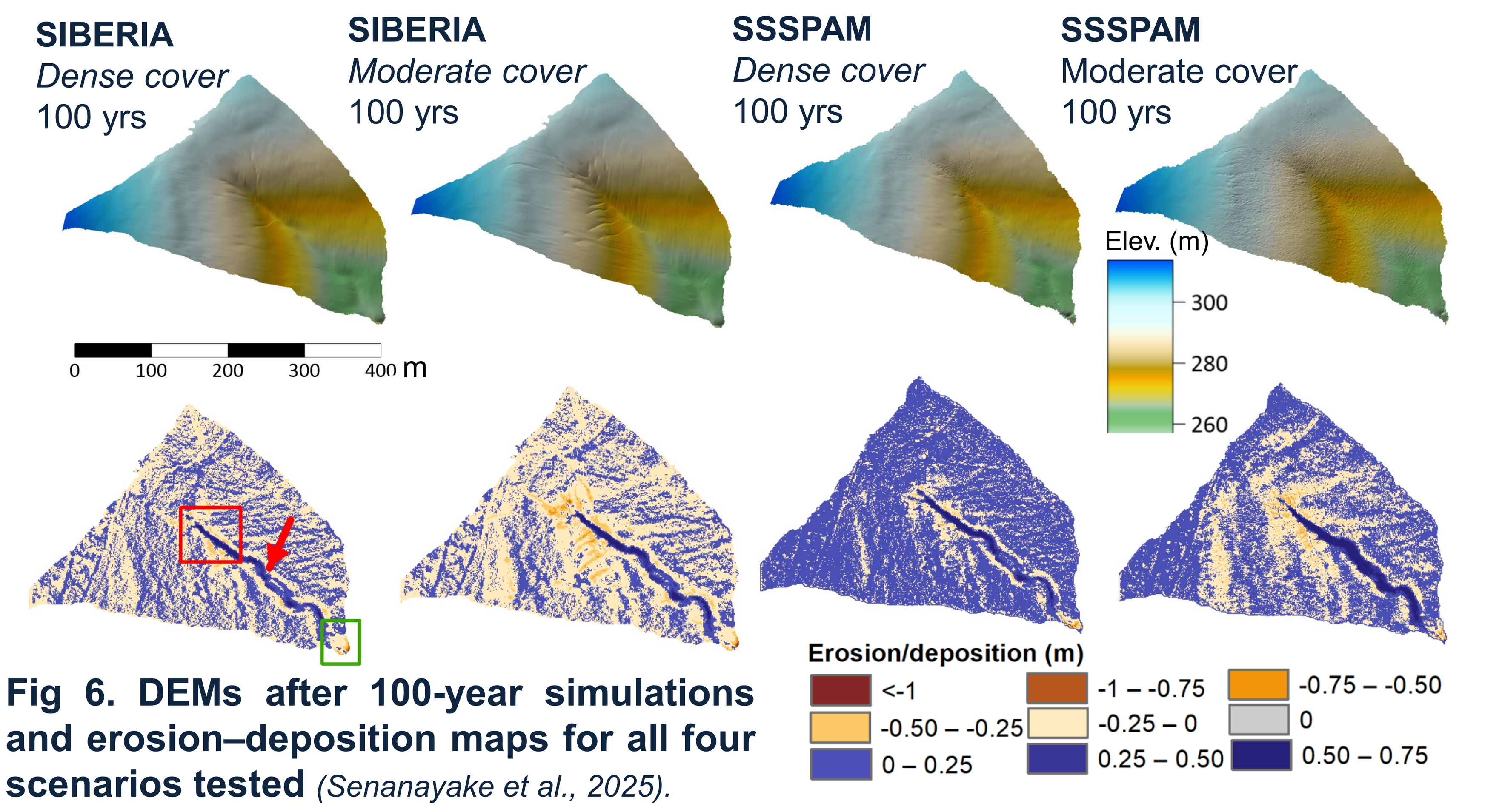

Fig 6. DEMs after 100-year simulations and erosion–deposition maps for all four scenarios tested *(Senanayake et al., 2025).*

CONCLUSION

- Results from both field methods (sediment dam and ^{137}Cs) and LEMs (SIBERIA and SSSPAM) fall within comparable ranges (mean = 1.40 t/ha/yr; SD = 1.08 t/ha/yr), providing confidence in model reliability (Table 1, Fig 6).
- This provides strong data-based evidence of LEM performance across the landscape, supporting their use for post-mining landform design and calibration.
- Future work will focus on the rapid assessment of erosion rates by integrating modelling with AI and machine learning.

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