Bamboo retaining structures for riparian erosion control: A pilot test on the Richmond River

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Key points

- We tested a nature-based solution for riparian erosion as an alternative to hard engineering methods.
- It involves the construction of a geotechnical retaining structure using biodegradable bamboo poles.
- This structure stabilises the slope against landslide and enables revegetation.
- Newly established vegetation is to ensure long term stability.
- This solution is applicable to both riparian and coastal environments.

Abstract

Riparian erosion causes substantial environmental damage and economic costs, both in Australia and internationally. To stabilise banks, traditional hard engineering solutions based on concrete and steel are often undesirable because they are costly and environmentally harmful; in many cases, they are not permitted.

Here, we present an alternative method of slope stabilisation for riparian and coastal environments. This nature-based approach uses bamboo poles to construct biodegradable retaining structures. The retaining structures provide temporary support to slope, to enable revegetation efforts, after which they biodegrade. The newly established vegetation, through its root systems, provides the long-term slope stabilisation.

We trialled this method on a slip zone adjacent to the Richmond River (Kyogle, NSW) at a site affected by a deep-seated rotational landslide that continues to move due to toe erosion. To stabilise the site, we designed and built a 15 m-long, two-tier retaining wall using 3 m-long bamboo poles. The retaining wall comprises driven piles and sleepers made of bamboo pole bundles; it also includes back-ties and underground drainage constructed with bamboo. Revegetation involved planting a diverse mix of deep-rooted grasses and local native trees both below and above the wall.

We present the lessons learned from this pilot test in terms of effectiveness and ease of installation and further discuss the potential of this nature-based innovation to mitigate erosion in a variety of riparian and coastal environments.

Keywords

Riparian erosion; Nature-based solution; Slope stabilisation; Bamboo retaining wall

Introduction

Erosion and deposition are natural processes that have been shaping the course of rivers over geological time scales. On agricultural lands and in the built environment, it can occur in an abnormal manner and pose significant challenges (Apan, 2002; Shellberg, 2026). Vegetation removal from the riverbanks as well are insufficient stock control tend to make the geomaterials of the bank more prone to mobilisation (Dunn, 2022). This leads to much faster rates of erosion, with banks significantly retreating on time scales of the order of a year or shorter. This leaves little time for our society and the environment to adapt. Mitigating erosion is a considerable task: Rous Council (Brooks, 2025) estimates that about $300 million dollars are necessary to address erosion on the 1442 km of the Richmond River (NSW) alone; this is only a small fraction of the millions of kilometres of Australian waterways (Australian Bureau of Statistics, 2022).

The cost of doing nothing is dire, both economically and environmentally. Erosion of riverbanks leads to a loss of valuable agricultural land and a loss of habitat for diverse riparian ecosystems. Feeding rivers with vast quantities of organic soil not only wastes this vital and hard to renew resource, it also affects the rivers' biochemistry by favouring the growth of bacteria and algae, which in turn consume oxygen at the detriment of other species.

In the foreseeable future, there is little reason to hope that the problem of riparian erosion will resolve by itself. On the contrary, the continuing expansion of agricultural land and of the built environment combined with an increase in frequency and intensity of floods -byproduct of climate change- are likely to make this problem increasingly severe (Phillips, 2025). This compels some intervention.

Acting to prevent and address riparian erosion faces several challenges, including financial and legal implications, which comes down to two questions: who pays for it? And who has the right or the obligation to act? Assuming that these questions are resolved – and this is no simple task for a society in general and for policymakers in particular– there remains a more fundamental and technical question: what to do?

Answering this question requires appreciating that different mechanisms of erosion exist, and that they require tailored mitigation measures. For instance, rocks such as limestone and sandstone experience chemical degradation when exposed to water, which leads to their mechanical weakening. Rock bolts and fracture grouting may assist with regaining stability. A second erosion mechanism is commonly occurring on grounds made of clays, silts, sands or organic soils: surface water run-offs can then detach and carry away fine soil particles. Mitigation measures such as ground vegetation cover, silts fences, which could be made of natural material like twigs, or jute mesh can help trap these particles and prevent them from being carried further away.

Figure 1 illustrates a third erosion mechanism, which is the focus of this paper. It is prevalent in riverbanks and also common in dunes in coastal environments. This mechanism is a cycle of events. It starts with the gradual erosion of soil particles at the base of the bank. The resulting undercutting reduces the mechanical support of the slope. It eventually collapses under the action of its own weight, typically by the means of a rotational or wedge-shaped landslide. This landslide mobilises a large volume of soil, which is deposited lower down. This displacement material is then eroded away by the flowing water and the cycle repeats itself (Fox, 2010).

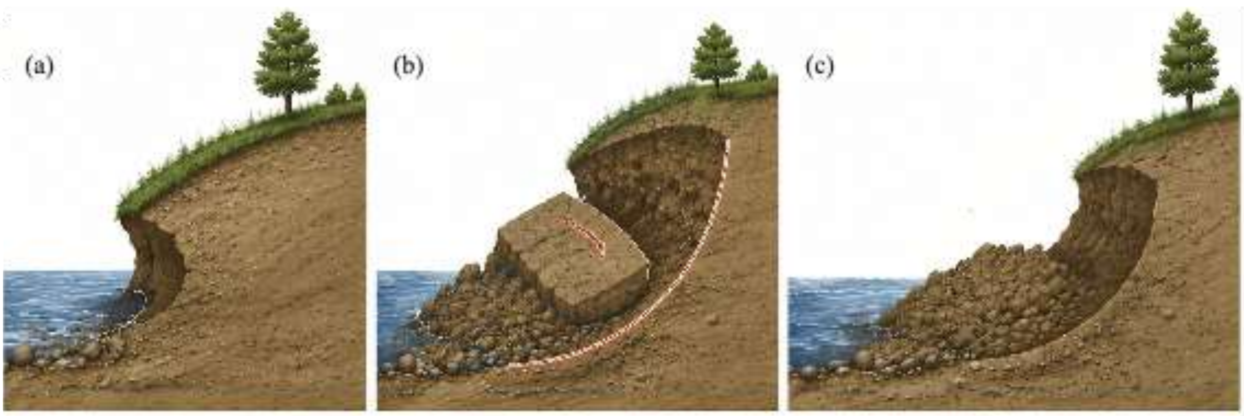

Figure 1 Illustration of the undercutting-sliding erosion process on a riverbank. (a) Flowing water gradually erodes soil particles from the toe of the bank, undercutting it; (b) the bank becomes unstable and fails - the red line denotes the slip failure line, which typically is a circular arc; (c) the landslide deposit is gradually eroded and the cycle continues

Solutions to break this cycle involves armoring the toe of the landslides and/or providing a barrier to mitigate "chewing" of the toe. This is turn provides inherent stability to the slope. This can be done by using hard-engineering methods well known to geotechnical engineers, such as concrete retaining walls or rock armoring – that is covering the bank with a layer of large boulders. However, these techniques are not always suitable. Their high cost, high CO_2 footprint, and their reliance on non-sustainable materials presents significant obstacles to scaling up to address the thousands of kilometers of riverbanks in need of stabilisation. More importantly, they do not preserve a livable habitat for the rich riparian ecosystem. For this reason, legislation tightly restricts such hard-engineering stabilisation techniques (NSW Water Mng Act 2020).

Establishing vegetation in the riparian zone is an alternative and promising solution (Hubble, 2010). Vegetation can reduce the moisture content of the soil by "pumping" ground water out by transpiration, thereby reducing the self-weight of the slope. Roots further stabilise the slope by providing an additional resistance to two modes of loading, shear and tension, which are the most common drivers of soil failure (Massi, 2021; Dyson, 2014). However, vegetation takes some time to grow, from a few months to a couple of years, and one needs to ensure that the bank remains stable during that time.

We present here a pilot test aiming at demonstrating a sustainable solution to achieve such a temporary slope-stabilisation. The solution consists of using bamboo poles to construct a retaining structure at the toe of the slope to both armor it and resist its slip. Revegetation is then undertaken through planting of a diverse range of species. Species are selected to provide both faster root growth and short-term stability enhancement as well as planting of deep-rooted species, often taking longer to grow but providing long-term stabilisation of the slope. The bamboo poles will eventually naturally biodegrade, leaving no enduring footprint.

The first section describes the site conditions, which present a scenario similar to that on Figure 1. The second section details the design of the retaining structures and the steps taken for its construction. A conclusion summarises the lessons learnt from this pilot.

Pilot test site on the Richmond River, Kyogle NSW

Configuration

The pilot test site is located near the Richmond River in the city of Kyogle, NSW. It is adjacent to the riverbank but not in contact with the river water during non-flooding conditions. Nonetheless, the river water has the potential to rise to this site during moderate floods and can completely submerge the site during severe floods.

Figure 2 shows the topography of the site. It presents a drop in elevation of about 10m over a horizontal distance of 20m. This site before remediation, shown in figure 2a, comprises two steep sections: a top scarp with a 4-5m elevation, and a second 2m scarp. Both scarp are inclined between 60° and are near-vertical in sections. The top scarp is about 25m in length and follows a circular arc shape, as highlighted by the white dashed line of figure 2b. The second scarp is approximately 15m in arc length.

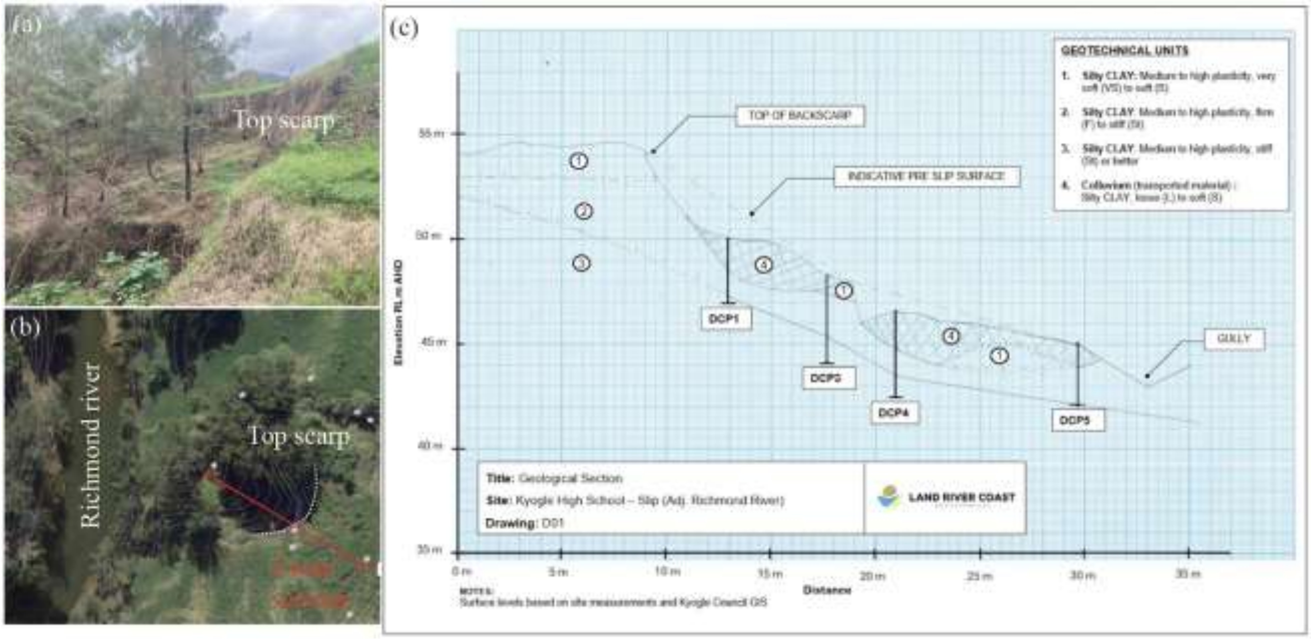

Figure 2 Configuration of the test site. (a) front and (b) top views of the site. (c) Geological cross section inferred from dynamic cone penetration tests (DCP) and visual and tactile assessment of scarp faces

Soil conditions

A series of dynamics cone penetration (DCP) test were conducted at different location to test the strength of the soil strata and establish a geological profile for this site. Figure 2c shows this profile. Between DCP locations, the soil strata are not directly tested; instead, their nature is interpolated from adjacent DCP sites. This survey identified the presence of a very soft silty clay and colluvium deposit up to 2m thick (hashed areas of figure 2c) laying on a comparatively stiffer silty clay.

Evidence of past landslide activity

The topography, including the presence of a lower and upper scarp, both circular in shape, as well as the presence of colluvium deposits suggests past occurrence of one or several rotational landslides on this site. Figure 2c shows an indicative pre-slip surface consistent with this activity.

Mitigating further landslides using a bamboo retaining structure

Risk of slope instability

Figure 3a shows the potential risk of erosion and landslide on this site, consistent with the geological profile. The major risk is a global rotational failure of the slope, illustrated with a dashed red line. The gradual erosion of the toe would reduce support of the material above it, eventually leading to instability. The colluvium material located between DCP 1 and 5 (see figure 2c) is likely to be the remaining deposit of previous occurrences of such rotational landslides. When left unsupported this material is likely to continue to erode during flood events.

A secondary risk of stability concerns the top scrap, which could also experience a rotational failure under adverse conditions. For instance, rapid water withdraw after major floods could leave a fully saturated soil, which is heavier but not stronger, more prone to failure.

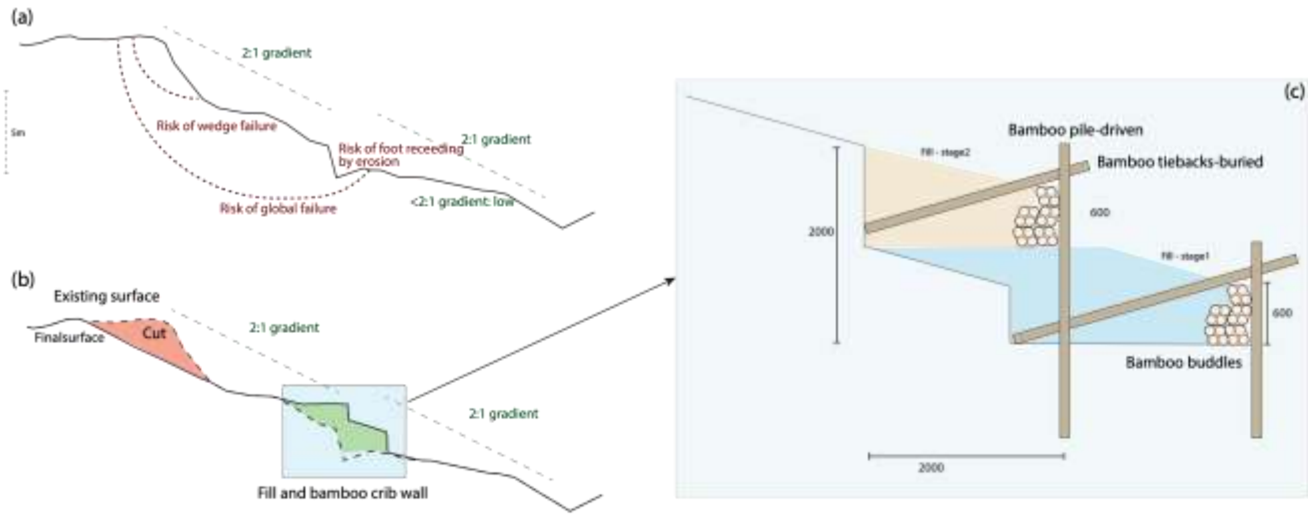

Figure 3 Slope stability risk and mitigation. (a) Profile of the slope highlighting likely modes of failures including (i) erosion of the toe, (ii) local rotational failure of the top scarp and (iii) global rotational failure. (b) Mitigation solution including battering of the top scarp and installation of a bamboo retaining wall. (c) details of the bamboo retaining wall comprised of driven bamboo bundles, to act as piles (piles are not up to scale, the real embedment is 2m), horizontal bamboo bundles to act as sleepers, and tie backs poles to stop floating or uplift of the sleepers

Overview of the mitigation measures

To mitigate this risk of slope failure, the proposed mitigation measure consists of battering the top scarp and installing a two-stepped bamboo retaining wall at the toe (see Figure 3b). The purpose of battering the top scarp is to remove weight from the top of the slope and mitigate the risk of regressive failure, such as a wedge or rotational collapse. Such failure would be detrimental to re-vegetation efforts underneath the top scarp. Moreover, the battered slope allows easy access to people on foot and is gentle enough to be re-vegetated.

The purpose of the bamboo retaining walls is two folds. Firstly, it acts as an armor for the toe of the slide: it prevents its gradual erosion and retreating. Second, it constitutes a mechanical retaining structure that provides lateral support for the slope, thus contributing to its stability. The choice of splitting the wall into two shorter walls rather than one single, higher wall is made to i) avoid large overturning moments and ii) avoid creating a large, unstable step after the wall disintegrates. The two-tiered wall also provide a flattened overall slope, advantageous for revegetation. The length of the top wall is 9m and the bottom wall is 15m long.

Bamboo retaining wall design

The retaining wall is entirely made of dead bamboo poles and follows the principle of a two-tier retaining wall: bamboo piles are embedded vertically into the ground, which support horizontal bamboo poles acting as sleepers (see figure 3c and figure 4).

For ease of construction, we opted to work with bundles of four bamboo poles tied together, rather than individual poles for the piles. Each bundle is 3m long. The diameter of the bamboo poles varies from approximately 7cm to 12cm. Bundles weigh about 15-20kg and are easily handled by a single person. They have the important advantage of minimising the adverse effect of the natural variability in strength of bamboo poles: if one weaker pole fails, the bundle would keep most of its mechanical integrity.

Each pile is composed of one bundle of four bamboo poles. Piles were embedded at a depth of 2m, with one meter being above ground. To install them, the ground was pre-drilled with a 20cm auger to a depth of 1m. The piles were then driven by pushing them down with the bucket of a 5-ton excavator.

This process took about 5 minutes per pile. Piles were installed every 1.5m so that the 3m sleepers are retained by two piles. A total of 21 piles were installed.

Sleeper bundles were placed at the back of the piles. They are shown on figure 4b. Four rows of bundles are staked vertically to achieve the desired height. The bottom two rows are doubled to provide additional base friction and increase the resistance against lateral earth pressure. About 54 bundle-sleepers have been used.

We added tiebacks made of a pair of bamboo pole attached to the top of the piles and buried in the backfill. They are visible on figures 4b, c. They serve two purposes. First, they provide an additional resistance for the piles against overturning. Second, they provide a resistance against uplift of the sleeper-bundles: bamboo being buoyant, these could otherwise lift-up when submerged (i.e. during floods).

Lastly, we placed a few bamboo poles in the backfill to serve as drains. We punctured the culm of these poles to have them acting as pipes. As in traditional retaining wall design, these drains prevent excessive build-up of pore water in the material behind the wall and its adverse effect on wall stability.

Working with bamboo as a construction material

In our experience, working with bamboo as a construction material has proven beneficial in several respects. First, with bamboo being an invasive species in this region, is widely available for free. The cost of this material is reduced to the labor cost for cutting the poles and their transport to site.

Secondly, as the poles are very light, construction involved a minimal use of expensive or heavy machinery.

Moreover, handling of poles and bundles during construction was undertaken with relative ease, generally as one or two-man lifts. The poles installation thus created a minimal amount of noise during works. Excess poles were buried into the ground following completion to allow for disintegration. In turn little to no waste remained on site. When compared to using heavy materials like rocks and concrete, or even timber, this is likely to be a key advantage for many riparian sites, as access to larger machinery is typically difficult or impossible on steep riverbank slopes. Minimising waste is also increasingly beneficial as removal and disposal is often expensive. As such left over material is often stockpiled, which can result in harmful erosion in these riparian environments.

Figure 4 Bamboo retaining wall. Construction stages showing (a) the vertical bundles placed into the pre-drilled holes just before being driven one meter deeper – stack of bundles are visible on the ground. (b) Completed top retaining wall including piles, sleepers, tiebacks and drains all made of bamboo, before backfilling. (c) Completed wall

Conclusions

This pilot test demonstrates the potential of a nature-based solution to offer erosion remediation in riparian environments, which may be a useful alternative to hard engineering approaches. Ultimately, this solution aims to enable the revegetation of riverbanks and to use this as a long term, natural method for erosion mitigation. To enable this revegetation, we propose to use biodegradable bamboo poles to build retaining structures to prevent instabilities or slippage of our riverbanks.

The ease of constructing with bamboo, its local availability, its low environmental footprint, its natural strength and its lightweight make it an ideal candidate for temporary soil stabilisation in a variety of contexts. For instance, it is likely that the technique we employed here in a riparian environment would be equally well suited for stabilising and help reforming dunes in coastal or marine environments.

We expect that constructing geotechnical structures with bamboo is best suited in sites involving soft soils or sands, where driving poles underground is possible. Sites involving rock strata or floating boulders may need a more involved process of pre-drilling to achieve similar retaining structures.

Lastly, a pressing question is that of the durability of the bamboo in underground conditions. While it is well known that adequately treated bamboo can last decades above ground, there is simply no data available to help predict how long bamboo poles can retain their mechanical property underground. The monitoring of this pilot test will provide an element of answer to this question.

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