Feed the Future Innovation Lab for Collaborative Research on Adapting Livestock Systems to Climate Change

Research Brief

Sieve Structures to Control Gully Erosion on the Borana Plateau, Ethiopia

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Abstract

Gully erosion is a widespread problem on the Borana plateau. Gullies are the main pathway for sediment accumulation in community ponds, especially during heavy rains, which reduces pond capacity. Sediment movement in gullies can be substantially reduced by installation of sieve structures that slow down water flows and allow sediment to settle out of suspension. Sieves can be easily constructed from trees by community labour at low cost. The community should develop a landscape-level plan and follow a suitable sieve design. Project Kalo collaborators have demonstrated that a series of sieve structures down a secondary gully in the Dikale pond enclosure can effectively trap sediment. The main gullies feeding ponds have large catchments generating rushing flood-waters that destroy sieve structures downstream. The appropriate, comprehensive treatment is to begin at the gully head with brush barriers to steer overland flows away from the gully, and branch layers to protect the head cut itself. When gully head treatments are accompanied by a series of sieves in the main channel, gully erosion can be arrested, gully floor and walls revegetated and sediment captured. This approach has been validated by OARI colleagues at the Kobo Watershed gully and on a degraded portion of the Beke pond catchment. It has also proven successful in small channels at Dikale and other enclosures.

Gully erosion is a major problem on the Boran Plateau

Degradation in the Borana Region has been accompanied by severe erosion leaving landscapes with extensive bare ground. Rainwater washes across these bare surfaces and carries away the sandy and clay-loam topsoil that then accumulates in ponds. The pathway for sediment transport is a network of gullies. Most gullies lie in topographic depressions; many develop from livestock paths down to water points or along vehicle tracks.

There are two essential components to managing the erosion problem: rehabilitating the landscape to control the source of soil loss, and reducing sediment flow through the gully system. Our project addressed both of these components. Another report describes the benefit of protection from livestock to foster revegetation of degraded landscapes that will hold soil in place and enhance rainfall infiltration. This report describes strategies and mechanisms to heal gullies and restrain sediment movement into ponds.

A pair of sieve structures at the confluence of 2 secondary gullies in the Dikale enclosure. The basic design consists of two rows of tree stubs sunk into the gully floor and packed with acacia branches. Some excavation has occurred in sand at the base of the sieve near the camera due to animal activity. (Photo credit: Brien E. Norton).

A pair of photos showing (left) an intact sieve structure and (right) the same structure destroyed by flooding in the heavy spring rains. All the branch packing, the large ballast logs, and most of the upright stubs have been washed away in the right photograph. (Photo credits: (left) Brien E. Norton and (right) Bedasa Eba).

Can we stop gully erosion?

It has been common practice to implant concrete or rock barriers into erosion gullies in the hope that a solid barrier will counteract erosive activity and capture sediment. The rock barriers take the form of check dams made from a wall of rocks, or of "gabions" created by filling a strong wire cage with rocks. Several gabions may be placed across a broad gully.

These efforts to control gully erosion with a solid barrier usually fail. Rocks in the check dam are washed downstream, while soil surrounding the gabions is excavated by water burrowing underneath or around the edges, and the gabions collapse into the gully channel. If the barrier holds, water will flow over the top like a small waterfall and erode the gully floor on the downstream side even faster than if the barrier had not been there. A concrete or rock apron beneath the barrier can protect the gully in the short term until its downslope edge is undercut, but that is an expensive structural addition.

A solid barrier persists only where it is anchored to both an underlying rock foundation across the gully and also to rocky sides, but the 'waterfall' phenomenon remains. The rule of thumb is "hard on hard" and "soft on soft" when planning gully interventions. Occasionally one finds a rock base across the gully floor, but generally the gully sides at these places are soft. The floor and walls of gullies in Borana are usually composed of easily eroded soil. In this situation the appropriate strategy is "soft on soft," avoiding solid barriers that are not only vulnerable to failure but are also expensive in establish, an investment whose effectiveness is likely to be short-lived.

Gully erosion cannot be stopped completely, especially when gullies receive rushing floods of water from heavy rainfalls. However, gullies can be treated to achieve long-term suppression of sediment transport, and when combined with better landscape management the erosion can be substantially reduced. A "soft" intervention in the gully itself must be accompanied by appropriate treatment at the gully head. This combination was applied by a Project Kalo colleague to a deep gully in the Kobo Watershed near Yabello, and positive results were evident within a year.

A "soft" gully intervention: sieve structures

The concept of a "sieve structure" is to slow down gully water flows, not stop them. When the speed of water is reduced, the heaviest suspended particles in the stream settle to the bottom. With further slowing of water flow, the next largest particles precipitate out of suspension and sink into sediment. A series of effective sieve structures will remove most of the sediment before it reaches a pond.

Sieve structures are 'porous dams' that can be made from trees growing near the gully. Posts or 'stubs' cut from the main tree-stem are placed upright across the gully, buried into the gully floor and rising 50-150cm above it. Gaps of 10-15cm are left between the upright posts. Branches are then packed horizontally upstream against the row of posts. If sprigs of aloe plants can be harvested from the neighbourhood, they should be planted among the posts where they will grow. Similarly, if stubs from Commiphora trees are available to be incorporated into the row of posts, they too will sprout and together with aloe sprigs form a living sieve. OARI staff have observed stolons of the perennial grass Cynodon dactylon and other plants growing into the sieve framework, contributing to the integrity of the structure.

The soil and water conservation team at OARI experimented with different designs of sieve structures. The initial efforts in March-April 2014 comprised a single row of posts, often incorporating aloe sprigs, across shallow depressions. They were effective in reducing water flow and trapping sediment as long as the margins extended across the entire gully depression. The second generation of sieve structures installed in October 2014 comprised two rows of posts 25-50 cm apart. The space between the rows was packed horizontally with Acacia branches, mixed with large stones when available. These stronger structures were placed in major gullies leading to the ponds targeted for rehabilitation in the four focal Pastoral Associations.

Sieve structures were built across the gully at regular intervals, the spacing depending on the slope of the gully. For a steep and deep gully carrying a lot of water, the interval may be 20-30m. For a shallow gully down a gentle slope, an interval of 30-50m or more may be sufficient.

These sieve structures can be installed quite quickly by a team of community workers. Eight substantial sieve structures were installed within one day across the main gully flowing into the target pond at Harweyu PA.

Altogether, about 75 sieve structures were established in October 2014 in gullies leading into the four ponds targeted for rehabilitation. The majority are within the enclosures surrounding Dikale and Harweyu ponds.

Monitoring sieve structure effectiveness

In September 2014, in association with an Australian landscape ecologist (Dr. Hugh Pringle), Dr. Norton developed a sieve-structure monitoring scheme. The monitoring of sieve structures is based on assessing their ability to slow down gully stream flows and their effectiveness in causing sediment to be deposited in the gully. Twenty sieve structures at Dikale enclosure were monitored in February 2015 and given a score between 1 and 5. Concise descriptors for the scores are as follows:

1. The sieve structure is partially effective in slowing down water flows, but openings in the sieve allow sediment to pass and the structure is not secured to the bank or gully floor, so that water can erode around the edges or burrow underneath.

2. The sieve structure is able to trap small twigs and leaves and some sediment is trapped on the upstream side, but a lot of sediment still passes through. The structure is vulnerable to fail with a large flow due to sieve permeability, weak sides or the margins being inadequate to prevent water sweeping around the edges. The sieve is at risk of collapse and blow out from a rainstorm flood.

3. The sieve structure is secure, with strong attachment to gully sides, and could be dislodged by only a strong thunderstorm. It needs to be tested under stress conditions. Perennial vegetation has not yet established in trapped sediment.

3.5. Intermediate stage of a maturing sieve with build-up of leaves and twigs against the filter. Vegetation is colonizing the sediments, but the gully floor may remain raw at points several m upstream. Under 'normal' rainfall events, this sieve will progress to scores 4 and 5.

4. Sieve structure is robust and effective. It has survived the test of heavy rains and is unlikely to blow out. Vegetation is growing in the sediment extending upstream, and also on the downstream side. Plants are growing intertwined with the structure. Upstream gully walls are healing. In time, this sieve will progress to score 5.

5. Fully mature and stabilized sieve structure with a mix of inert and living filters. Both the sieve and the perennial vegetation extending upstream serve as an effective sediment trap. Gully floor and walls are healing both above and below the sieve. Able to withstand a heavy rainstorm event, even one where the water overtops the sieve structure.

This scoring system implies a time sequence and a topographic sequence. The score 5 stage could be the end-point of a series of sieve structures that have been installed at intervals down a gully. A fully mature and fully effective sieve (Score 5) may have several less mature sieve structures further upstream (Scores 3.5 and 4). As water movement is progressively slowed down from one sieve to the next, the effectiveness and maturity of the sieves increase.

Initial monitoring in February 2015

In February 2015, sieve structures were inspected inside the enclosure at the Dikale pond. The focus was on structures that had been installed in October 2014, near the end of the previous rainy season. The purpose was to use the score descriptors to assess sieve structure effectiveness and to see if the criteria in the monitoring system could be easily applied.

Secondary gully

Ten new sieves were examined in a secondary drainage gully running north into the main gully to the east of the Dikale pond. Scores ranged between 2 and 3, with an average of 2.4. Low scores were assigned because of weak edges where water could flow around the sieve, or because of animal excavation activity at the base of the sieve where water could tunnel underneath.

High scores indicated a well-constructed sieve structure embedded into the sides of the gully, with stolons of the perennial grass Cynodon dactylon already growing into the sieve framework, or where litter had already accumulated against the sieve from October rains. Even though several sieves scored a 3, their strength and integrity needed to be tested against the flooding rains of the upcoming long rainy season.

Main gully

Five new sieve structures were placed in the main gully lying south-east of the pond. Due to the size of the gully, these sieve structures were larger than any others installed at Dikale. The three sieves closest to the pond were in a gully 1.5 to 2m deep. Two sieves placed further upstream are on a broad depression of sandy soil formed from previous sediment deposits.

Only that portion of the gully within the enclosure was addressed, leaving 500-600m of upstream gully untreated. The length of this main gully outside the enclosure fence was served by several secondary gullies and drained a catchment of around 0.5 km^2. It is the principal source of both water and sediment feeding the Dikale pond.

The three sieve structures in the deep gully were well constructed with their sides strongly embedded into the walls of the gully. They rise at least 1m above the gully floor. Commiphora stems were used to form part of the sieve frames, and in February they were already beginning to sprout. These sieves showed evidence of sediment trapped from stream flows during the October rains. The three sieve structures were each awarded a score of 3, but their effectiveness over the long rainy season was yet to be tested.

Data were collected on the gully length between consecutive sieve structures, the mean width of the gully and depth of sediment. The intent was to compare the volume of sediment in a gully section before and after a rainy season. However, the failure of these three sieves in the long rains of April-May 2015 annulled the exercise.

Further from the pond the deep gully rises into a broad depression across which two sieve structures had been erected. The first of these received a 2.5 score due to some digging by animals at the base of the sieve, low sieve height and need for renovation. The second sieve structure, closer to the enclosure fence, terminates abruptly and fails to extend across the entire depression. Water flows can easily sweep around the northern end of the structure and excavate a channel in the sandy substrate. The more concentrated stream flow will create a deep gully where there had been a gently sloped depression. This sieve scored only 1.5, with anticipation of failure.

Northern slope of the pond catchment

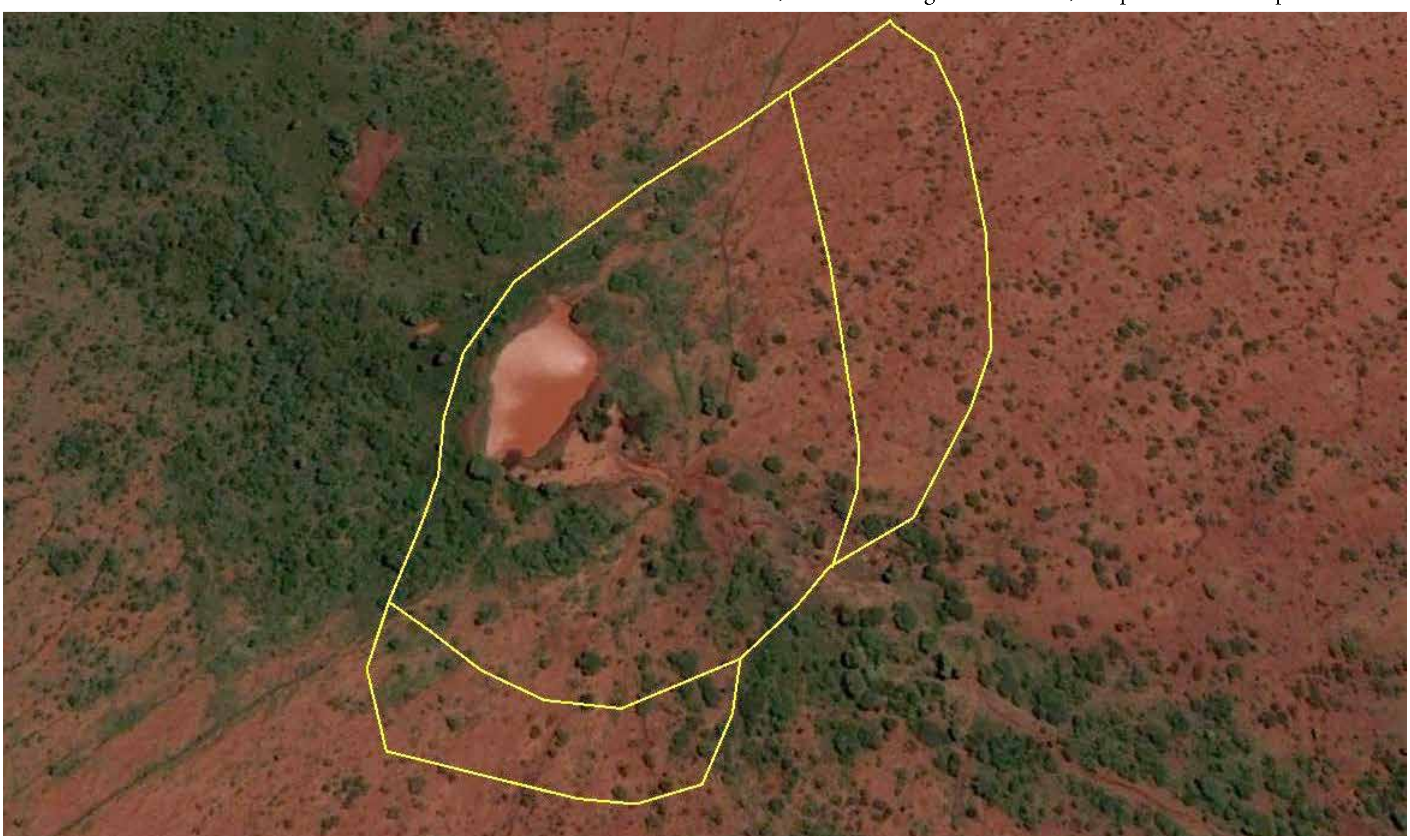
A number of sieve structures were installed in October 2014 on the northern slope of the Dikale catchment, within the enclosure and its extension. Several of these were observed to exhibit the problem of inadequate width to prevent water streaming around one or both edges of the structure. A score of 1.5 was assigned in these cases due to likely development of new channels from concentrated flow of gully water.

The sieve-structure scoring system served well as a first draft. However, it must be modified through field experience and adapted to specific environments. For example, the likelihood of animal activity excavating burrows at the base of the sieves had not been anticipated.

Success and failures

In June 2015 following the long rainy season, the OARI team surveyed the sieve structures previously monitored. In general, the sieves in the relatively short secondary gully had maintained their structure, serving to slow gully flows and capture sediment. Sieves that had received a low score of 1.5 were ineffective in stopping erosion around the exposed edges. The three sieves in the deep part of the main gully all failed. The packing branches had washed away and only some of the upright stubs remained. The same failure of sieve structures had occurred in the main gully leading into the Harweyu pond.

This is not a surprising result. No attempt was made to manage the head of the Dikale main gully system nor to control water flowing down its long straight length. Landscape ecologists from southern Africa, now working in Australia, emphasize the importance of



A Google Earth image showing the original fence outline at Dikale and the two extensions to the enclosure. Note the main gully running into the pond from the south-east, and a pair of secondary gullies that flow north, converge and join the main gully close to the pond. The main gully runs straight into the pond from a catchment of 0.5 km^2 and is the principal source of both water and sediment. (Image compiled by Brien E. Norton) beginning any gully remediation at the head, before installing sieve structures or other porous barriers in lower reaches of the channel.

A landscape approach: begin with the gully head

In order to rehabilitate a gully-infested landscape, a comprehensive approach should be taken. The failure of sieve structures across the main gully in the Dikale enclosure inadvertently demonstrated the importance of beginning gully remediation at the gully head. Control of head cutting must come first, otherwise erosion will continue to cut back upslope. None of the sieve structures installed in lower reaches of a large gully can stop the onslaught of floodwater rushing into the porous barriers and destroying them. Full-scale gully remediation should be applied to the secondary gullies as well as the main gully in the Dikale pond catchment.

A comprehensive approach of treating the gully head followed by placement of sieve structures and gabions in the principal gully was employed at Kobo Watershed near Yabelo with great success. The Kobo strategy included planting of perennial grasses such as Rhodes grass and Vetiver grass in the upstream sediment trapped by the sieves.

Appropriate treatment of the gully head is explained and illustrated in the items for further reading by Tinley and Pringle, and on the EMU website. Branches and brush are placed over the head-cut so that they overlap the non-eroded upslope area by at least 1m, and fill in the downslope part of the gully head by at least 1m. The brush may need to be pinned in place by stakes holding wire that is wrapped around the branches. The brush needs to be held close to the ground, otherwise water will channel underneath.

Most gully heads comprise an inverted delta of converging small gullies. For a multi-branched set of head-cutting gullies a semi-circular fence of brush branches or a bund of soil could be constructed that goes right around the group of head-cuts, diverting water to the sides. When it rains, water will pond on the upslope side of this brush barrier, and litter and sediment will collect there too. When the rainy season starts, bunch grasses like Vetiver grass and Pennisetum, and segments of the creeping grass Cynodon dactylon, should be planted in the damp soil near the uphill edge of the brush barrier. These grasses will establish quickly and spread out to cover the upslope area and enhance gully-head protection.

In the case of the successful treatment of Kobo gully, a semi-circular wall of Acacia branches placed around the top of the gully heads was a sufficient buffer to restrict water input to the gully system. Vegetation grew rapidly within the protection of the thorny branches.

Secondary gullies in the catchment should also receive head-cut treatment, or they will progress to a worse situation. A series of sieve structures at regular intervals down the gully channel is necessary to complement remediation of the head-cuts. A network of interventions across the landscape can solve gully erosion problems but the treatment must be comprehensive to succeed.

A case study of a successful erosion control program may be found in the watershed of Beke pond. An area of 35 ha was treated comprehensively in 2013 under the supervision of the soil and water conservation specialist at the OARI station in Yabello. Sieve structures were installed with an aloe sprig component; contour trenches and "eyebrow" pits were dug on the catchment slopes; seeds and plants were introduced to the depressions and bunds of these structures; and grass seed was spread on degraded sites. Livestock grazing was prohibited. Within one year the landscape had been rehabilitated with vegetation growing profusely in gully bottoms and on formerly degraded slopes.

Conclusion: A vision for the future

Effective technology for controlling erosion at the landscape level and rehabilitating active gully systems has been demonstrated at field sites on the Borana plateau. The critical components are sieve structures placed at intervals down the gully. The materials required for gully installations are freely available close by: Acacia and Commiphora trees and Aloe plants. The only cost is labour. A large sieve structure can be installed in an hour or two with community labour.

It is necessary, however, to adopt a landscape approach that tackles the entire gully network, beginning where the gully erosion starts in both primary and secondary gullies. Without remediation of the actively eroding gully head, the face of the head-cut will continue to be undermined and erosion will inevitably creep upslope, no matter what interventions are made in lower reaches of the channel.

A community action plan can reverse degradation in catchments of the Borana plateau. Gully remediation is one part of a program to eliminate erosion; the other part is rotational management of livestock grazing that allows recovery of vegetation to protect the soil surface.

What can we expect from a comprehensive landscape rehabilitation plan?

- o Higher infiltration of rainwater where it falls, and less surface erosion.
- o Greater cover of vegetation and higher forage production.
- o Greater livestock production when grazing pressure is carefully managed.
- o Gullies healing with vegetation growth on the walls and gully bottoms.
- o Less sediment transported into ponds, and higher pond storage capacity.
- o Cleaner water flowing into ponds, and healthier consumers of pond water.

The above predictions are the consequence of both grazing management and gully remediation working together. Once that has been achieved, vegetation composition can be fine-tuned by seeding landscapes with desirable plant species, cutting patches of woodland to release herbaceous growth, and employing prescribed burning to control woody plant regeneration.

This vision is within the grasp of Pastoral Associations on the plateau. It only requires community planning, community action, coordination and monitoring.

Further Reading

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URL for Ecosystem Management Understanding (EMU) program: www.emulandrecovery.org.au

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Prjoect: Sustainable Pastoralism on the Borana Plateau: An Innovation Systems Approach

Principal Investigator: D. Layne Coppock, Utah State University

This project is focused on the study and testing of best-bet land and livestock interventions that can move the Borana pastoral system back towards sustainability. These efforts will consider livestock herd diversification, improvements for forage production, changes in common-property management, as well as pastoral livelihood diversification. A partnership including Utah State University, the Oromia Agricultural Research Institute (OARI), Managing Risk for Improved Livelihoods (MARIL PLC), and other stakeholders will be forged to help meet project objectives.

Feed the Future Innovation Lab for Collaborative Research on Adapting Livestock Systems to Climate Change is dedicated to catalyzing and coordinating research that improves the livelihoods of livestock producers affected by climate change by reducing vulnerability and increasing adaptive capacity.

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