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# Low-cost soil conservation technique for controlling gully erosion in the semi-arid area of the Free State province

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***ABSTRACT***

*In South Africa, soil erosion is a major problem confronting natural resources. Gully erosion has a huge negative impact on soil productivity and potable water supplies, while measures to control it are expensive. Sannaspos farm which has been threatened by gully erosion was selected as a demonstration site for controlling gully erosion using low-cost control measures. The main aim of this study was to control gully erosion resulting in improved rangeland production. The technique entailed the use of old tyres and bags filled with soil. Three reference points were selected along a 240 m gully in August 2016 and monitored over 42 months. After 17 months (January 2018), gully depth decreased from 70 to 34 cm, 45 to 20 cm and 35 to 19 cm at the three reference points. After 24 months (August 2018) gully depth further decreased from 34 to 27 cm, 20 to 14 cm, and 19 to 10 cm for the three points. Thirty months after installing control measures (February 2019), the gully was sealed at all reference points. By February 2020 (42 months after initiation of the trial), the entire gully was sealed and covered with various vegetation types. Use of this low-cost method to control gully erosion is recommended under similar conditions.*

**Keywords:** Gully erosion, low-cost soil conservation, erosion control

## 1. INTRODUCTION

Soil erosion which is a critical component of land degradation is a worldwide phenomenon. According to Thomsell (2017), 40% of the land in Africa is degraded. In South Africa, soil erosion is a major environmental problem threatening land and water resources, and thereby also future food security. Research indicates that soil erosion has affected more than 70% of South Africa's landscape (Garland, Hoffman & Todd, 2000; Le Roux *et al.*, 2008a). In terms of area, Le Roux *et al.* (2010) indicated that gully erosion had affected 577 224 ha of land in South Africa by 2010. According to these authors, the Free State province accounted for 11% (64 674 ha) of the gully erosion affected areas in the country at that time.

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Gully erosion is both a natural and a human-induced process. Gully erosion can be defined as stream channels whose width and depth do not allow normal tillage (Soil Science Society Of America, 2015). In addition to its negative impacts on soil productivity and potable water supplies, gully erosion can threaten infrastructure such as roads, fences and buildings, while eroded soil ends up in waterways, road culverts, dams, reservoirs and marine environments. Depositions in streams can result in decreased hydraulic capacity, leading to more frequent overbank flooding, while deposition of eroded soil in dams considerably decreases their storage capacity. For example, surveys by the Department of Water Affairs (DWA, 2011) indicate that due to siltation, the storage capacity of the Welbedacht Dam near Dewetsdorp in the Free State reduced rapidly from 115 million $m^3$ to approximately 16 million $m^3$ within 20 years after its completion in 1973.

As stated by Seutloali and Beckedahl (2015), the most efficient and economic soil erosion control strategy is re-vegetation. It is further indicated that vegetation cover provides a cheap long-term erosion control and requires less maintenance than complex engineering structures. According to Mararakanye and Sumner (2017) most research on gullies in South Africa was conducted in the Eastern Cape and KwaZulu Natal provinces and little information exists in other provinces. In the current study, Sannaspos farm which has been threatened by gully erosion was selected as a demonstration site for controlling gully erosion. The main aim of the study was to demonstrate how gully erosion can be controlled using low-cost control technologies.

## 2. MATERIALS AND METHODS

### 2.1 Study site

The study site (Sannaspos Farm) lies 28 km east of Bloemfontein along the N8 road on the way to Botshabelo (Free State province, South Africa). The total size of the farm is 227 ha comprising of 203 ha of rangeland and 24 ha of old arable land. The climate of the area is semi-arid with an average annual rainfall of 545 mm.

### 2.2 Treatment

The gully where the conservation technique was implemented measured 240 m in length. Figure 1 illustrates the layout of control measures implemented at the study site. The technique entailed filling old tyres and fertilizer bags (50 kg polypropylene bags) with soil and placing them inside the gully. Filled tyres were spaced 10 m apart, with two bags spaced approximately 3 m apart in-between the tyres. The main function of the soil-filled tyres and bags was to decrease velocity of runoff water in the gully, while at the same time ensuring siltation. Three reference points (1, 2 and 3) were selected along the gully on 26 August 2016. The three points represented deep, medium and shallow gully depths, respectively, and had initial depths of 70 cm (point 1), 45 cm (point 2) and 35 cm (point 3). Gully depth was again measured at the reference points on 10 January 2018, 1 August 2018, 28 February 2019 and 6 February 2020.

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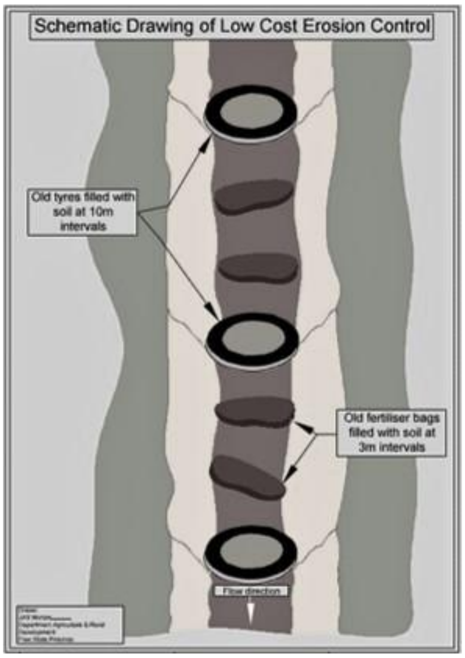


**FIGURE 1: A schematic representation of the implemented gully control technique.**

### 2.3 Soil, climate and vegetation data

A soil survey was performed at the study site. Soils were classified according to the South African classification system (Soil Classification Working Group, 1991).

Rainfall data was taken from an automatic weather station (Woonhuis Weather Station) managed by the Institute of Soil, Climate & Water (Agricultural Research Council). The weather station is located approximately 1 km from the study area.

At the end of the study, plant species that established during the course of the demonstration trial were also recorded.

## 3. RESULTS AND DISCUSSION

### 3.1 Dominant soils

The dominant soil form at the study site was found to be Valsrivier. This is in accordance with the duplex soil forms that is dominant for Land Type Dc17 (Land Type Survey Staff, 2002). Duplex soils have relatively permeable topsoils overlying a very slowly permeable diagnostic B horizon. These soils are prone to runoff, which leads to water erosion.

### 3.2 Gully erosion control

Figure 2 illustrates depth reduction at the three reference points over the study period. The measurements taken on 10 January 2018 indicate that the gully depth decreased from 70 to

34 cm, 45 to 20 cm and 35 to 19 cm for point 1, point 2 and point 3, respectively. This translates to a 51, 56 and 46% reduction in gully depth for point 1, point 2 and point 3, respectively over the first 17 months after installation of control measures. Precipitation at the study site amounted to 140 mm over this time (26 August 2016 to 10 January 2018).

Approximately 24 months after installing control measures (1 August 2018) gully depth further decreased from 34 to 27 cm, 20 to 14 cm and 19 to 10 cm for point 1, point 2 and point 3, respectively. This represents a further 21, 30 and 47% reduction in gully depth at point 1, point 2 and point 3, respectively. This improvement was achieved after precipitation of 684 mm at the study site over the 7 month period (11 January 2018 to 1 August 2018).

Measurements on 28 February 2019, 30 months after initiation of the study, showed that gully depth was reduced from 27 to 0 cm (point 1), 14 to 0 cm (point 2) and 10 to 0 cm (point 3), representing 100% recovery. Since implementation of this technique at the study site, the gully wall has been stable and showing no signs of gully erosion continuation.

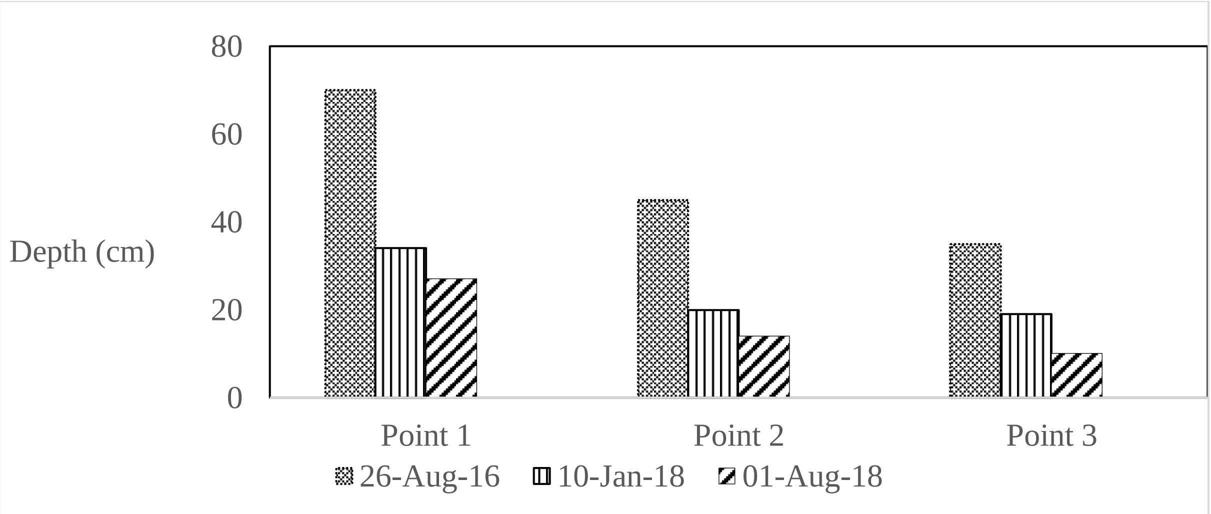


**FIGURE 2: Reduction of gully depth at the study site**

By 6 February 2020, 42 months after onset of the trial, the whole gully was completely sealed, and this following precipitation of 1400 mm at the study site over the entire period (26 August 2016 to 6 February 2020).

Similar studies using old tyres to stabilise soil also yielded positive results in other parts of the world. Belabdelouhab and Kebaïli (2015) reported similar results where tyres were used to stabilise a steep slope. It was found that the constructed structure was very stable and did not exhibit any sliding or any local instability with regards to the tyres. In studies by Martin *et al.* (2007) in Colombia, a slope was covered with parallel rows of scrap tyres. Each row was sustained by a rope tied to an anchor at the upper part of the slope. The tyres were also filled with soil and the erosion effects were monitored by measuring accumulation sediments. Results indicated that after six rainfall events (95 mm) there was 83% reduction in erosive effects at the study area.

### 3.3 Vegetation

Not only did implementation of the low-cost erosion control technique eliminate gully erosion at the study site, but there was also an impact on vegetation. A change in species composition at the bottom and banks of the gully was observed. Before the soil conservation technique was implemented, the gully was mainly bare, with little vegetation. After implementing the soil conservation technique, seedlings of the annual *Chloris virgata* (feather-top chloris), pioneer grasses such as *Aristida adscensionis* (annual bristle grass) and *Cynodon hirsutus* (hairy couch) occurred. The sub-climax grasses such as *Eragrostis chloromellas* (curly leaf) and *E. lehmanniana* (Lehmann's love grass) also emerged. Highly palatable shrubs, including *Felicia muricata* and *Rosenia humulis* increased. *Panicum stapfianum* (small buffalo grass) and *Themeda triandra* (red grass), both highly palatable grass species, were also established. The importance of *T. trianda* as a key species for this vegetation type is continually emphasised, since it is an exceptionally good indicator of rangeland condition (Van der Westhuizen, Van Rensburg & Snyman, 1999).

### 3.4 Economic implications

The cost of implementing this technique at the study area was exceptionally low. The farmers obtained the old tyres free of charge. Two trips were made to collect the tyres and the total distance covered was 140 km. Using South Africa's Department of Transport tariffs, the transport cost totalled R412.86. In terms of labour, the farmers implemented the soil conservation technique themselves, working for 16 hours. If, for example, three farm workers were to be employed to perform the task at the current minimum wage for farm workers (March 2020), it would have amounted to R896.64 for labour. Therefore, the total cost for implementation of the soil conservation technique was approximately R1309.50.

### 3.5 Extension implications

LandCare is a community-based and government-supported approach to the sustainable management and use of agricultural natural resources. The LandCare Implementation Framework (Implementation Framework For LandCare Programme, 1999) states that the overall goal of the programme is "to optimise productivity and sustainability of natural resources in order to achieve greater productivity, food security, job creation and better quality of life for all". One of the focus areas of LandCare projects is to recommend environmentally friendly and low-cost soil conservation techniques (Republic Of South Africa, 2020). Extension services play a major role in terms of disseminating research results to farming communities. In order for the Research and Development output from this study to reach the end-user, the research results will be communicated with the provincial LandCare representative. The information will then be disseminated to Agricultural Advisory Services in various districts. In this way, these results could then be extrapolated to other affected farms by extension services through seminars, workshops, farmers's days or demonstration trials.

## 4. CONCLUSIONS AND RECOMMENDATIONS

After implementing soil conservation by using soil-filled tyres and bags in the gully, the gully completely sealed within a period of 30 months. There has also been an increase in grass and other desirable plant species in the gully, translating into improved rangeland conditions and sustainable livestock production. Since controlling gully erosion may be very expensive, it is recommended that this low-cost method be used under similar environmental conditions.

As stated by Horner (1996), old tyres contain several heavy metals which can leach into the soil and end up in groundwater during tyre decomposition. It is therefore recommended that monitoring of these heavy metals be considered.

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## REFERENCES

BELABDELOUHAB, F. & KEBAÏLI, N., 2015. Large scale experimentation slope stability of soil tyre in Mostaganem (Algeria). *Energy Procedia* 74:699-706.

DWA, 2011. Dams in South Africa: Welbedacht Dam: Free State. Department of Water Affairs, South Africa. http://www.ewisa.co.za/misc/damfswelbedacht. Accessed on 16 March 2020.

GARLAND, G.G., HOFFMAN, M.T. & TODD, S., 2000. Soil degradation. In: Hoffman, M.T., Todd, S., Ntshona, Z. & Turner, S. (eds). A national review of land degradation in South Africa. South African National Biodiversity Institute: Pretoria, South Africa. pp. 69-107. http://www.nbi.ac.za/landdeg. Accessed on 16 March 2020.

HORNER, J.M., Environmental health implications of heavy metal pollution from car tires. *Rev Environ Health*. 1996 Oct-Dec;11(4):175-8. doi: 10.1515/reveh.1996.11.4.175. PMID: 9085433.

IMPLEMENTATION FRAMEWORK FOR LANDCARE PROGRAMME, 1999. https://www.gov.za/sites/default/files/gcis_document/201409/landcare.pdf. Accessed 26 May 2021.

LAND TYPE SURVEY STAFF, 2002. Land Type Survey Database. ARC-ISCW, Pretoria.

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http://dx.doi.org/10.17159/2413-3221/2021/v49n3a12987 

LE ROUX, J.J., NKAMBULE, V.T., MARARAKANYE, N. & PRETORIUS, D.J., 2010. Provincial mapping of gully erosion at the field scale using high resolution satellite imagery (SPOT 5). ISCW Report No. GW A/2009/04. ARC-Institute for Soil, Climate and Water: Pretoria, South Africa.

LE ROUX, J.J., MORGENTHAL, T.L., MALHERBE, J., SUMNER, P.D. & PRETORIUS, D.J., 2008a. Water erosion prediction at a national scale for South Africa. *Water SA* 34(3):305-314.

MARARAKANYE, N & SUMNER, P.D., 2017. Gully erosion: A comparison of contributing factors in two catchments in South Africa. *Geomorphology*. 288: 99–110.

MARTIN, H.B.B, MARISSA, M.R., NOEL, L. & ISRAEL, L.C., 2007. Improvements on a system for soil erosion control of slopes using scrap tyres. *Int. J. Environ. Pollut.* 31(3-4):316-324.

REPUBLIC OF SOUTH AFRICA., 2020. Frameworks for Conditional Grants to Provinces. GOVERNMENT GAZETTE, 3 JULY 2020. 710 No. 43495.

SEUTLOALI, K.E. & BECKEDAHL, H.R., 2015. A review of road-related soil erosion: An assessment of causes, evaluation techniques and available control measures. *Earth Sci. Res. J.* 19(1):73-80.

SOIL CLASSIFICATION WORKING GROUP, 1991. Soil classification. A taxonomic system for South Africa.

SOIL SCIENCE SOCIETY OF AMERICA, 2015. Glossary of Soil Science Terms. https://www.soils.org/publications/soils-glossary. Accessed 26 May 2021.

THOMPSELL, A., 2017. Soil Erosion in Africa: Causes and efforts to control. Available at https://www.thoughtco.com/soil-erosion-in-africa-43352. Accessed 26 May 2021.

VAN DER WESTHUIZEN, H.C., VAN RENSBURG, W.L.J. & SNYMAN, H.A., 1999. The quantification of rangeland condition in a semi-arid grassland of southern Africa. *Afr. J. Range Forage Sci.* 16:49-61.