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Research paper

Building capacity of communities to monitor the effects of rehabilitation techniques in degraded catchments

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The uThukela catchment area in South Africa plays a vital role in water provision, generating 25% of the country's water. The communities that live in these mountainous areas rely on the natural resources for their livelihoods. However, the absence of effective management plans and the lack of community involvement in conservation have had a negative impact on these natural resources. Degradation and the loss of grass cover on these steep mountain slopes have resulted in poor water infiltration, increased overland flow and severe soil erosion. Various initiatives in the area, starting with a pilot LandCare project, have built the capacity of the community to implement different erosion control techniques. However, there has been a lack of quantitative data on how successful the techniques have been. The aim of this project was to develop and implement a community-based system to monitor the effect of rehabilitation efforts. The monitoring techniques successfully adapted for use by the communities were those utilizing splash boards, plant basal cover quadrats and runoff plots. All techniques were applied to eroded and rehabilitated sites. The most effective technique was the runoff plots where, for example, at the Oqolweni subward, runoff from the eroded site (2 680 mm) was 28% higher than from the rehabilitated site (1 950 mm) over an 8-month period. The monitoring results indicate that rehabilitation by the community has achieved a significant decrease in soil loss and runoff. However, no single technique can be recommended for rehabilitation as each technique has specific advantages and disadvantages. This monitoring project has played a key role in the government's Working for Water programme by establishing indicators for a form of 'payment for ecosystem services', whereby the government pays communal land users to manage and monitor environmental services, particularly the delivery of watershed services.

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INTRODUCTION

The uThukela catchment area plays a vital role in water provision for KwaZulu-Natal and Gauteng. Twenty five percent of South Africa's water is generated in this region (Diederichs and Mander, 2004). One of the largest water transfer schemes in South Africa, the Thukela-Vaal, utilizes water from this catchment area. The communities that live in this mountainous area rely on natural resources as their main productive asset. However, the lack of effective management plans within these communal areas has negatively impacted on the conservation of the natural resources (Thobela et al., 1998). Loss of grass cover on steep mountain slopes due to overgrazing has resulted in poor water infiltration, increased overland flow and severe soil erosion, leaving large parts of this area seriously degraded. This in turn leads to reduced levels of soil moisture and dry season flows that are key to sustainable grazing regimes and the consumptive use of water during the winter months. Increasing human population pressure, encroachment of rangelands by other land uses, and the breakdown of traditional resource management structures are thought to contribute to the degradation problem (Kuse, 2018; Thobela et al., 1998). Therefore, the communities are losing land for crop as well as livestock production. In addition, large quantities of silt are being washed into the rivers of the catchment and are subsequently deposited into the dams which make up the Thukela-Vaal water transfer scheme (e.g. Woodstock Dam and Sterkfontein Dam). This silt not only reduces the capacity of the storage reservoirs but is also expensive to remove.

One of the remedies proposed by Irwin and Lotz-Sisitka (2005) for addressing the problem of environmental degradation is the introduction of conservation measures and making people aware of their benefits through education. These authors stated that local communities and stakeholders must play an important part in the process if sustainable development is to be achieved. Community-based natural resource management (CBNRM) is increasingly seen as an approach to encourage better resource management with the full participation of communities and resource users in decision-making activities and the incorporation of local institutions, customary practices and knowledge systems in management processes (Armitage, 2005). CBNRM places emphasis on local communities' participation, and is hence termed as a participatory paradigm (Zuma, 2003). This project engaged natural resource based community development. By monitoring their natural resources, community members develop an understanding of their natural resource base, enabling them to make more sustainable management decisions.

Through the South African National LandCare programme (National Department of Agriculture, 1999), the Government took the initiative to involve communities in conservation. A pilot LandCare project was initiated at Okhombe, a ward in the Upper Thukela region of KwaZulu-Natal. It embarked upon an intensive job creation programme which focused on community involvement in the rehabilitation of degraded areas in the Drakensberg catchment area. LandCare is based on the belief that land users should be encouraged to assume responsibility for local problems. The main focus of the LandCare project which took place over a period of 3 years (2000–2004) was capacity building and training of community members in the implementation of a number of erosion control techniques. Local community involvement in project monitoring had, however, been ignored in this programme and monitoring was left to experts only (Zuma, 2003). The success of the erosion control techniques was documented in the final project evaluation where Sisitka (2004 p. 26) stated that "Most of the rehabilitation areas are showing clear signs of stabilization." Similar subjective impressions of successful natural resource management projects by communities in Southern Africa have been documented by Critchley and Turner (1996). However, one of the biggest criticisms of this type of rehabilitation work is the lack of quantitative information on how successful the different techniques have been. In a gully reclamation project in Lesotho, Turner (1996, p. 63) stated that "The project's apparent lack of detailed monitoring data" made it difficult to determine the size of the gullies worked on and how extensive the rehabilitation was.

To accurately assess the success of the rehabilitation activities of the LandCare project it was necessary to monitor the effect of the techniques used. The development of suitable tools to monitor the impact of land rehabilitation was identified as a major need in the fight against soil erosion. A monitoring project was therefore initiated with funding from the South African Water Research Commission (2003–2007). The aim of this project was to develop a community-based monitoring system to quantitatively determine the effectiveness of rehabilitation efforts in reducing soil erosion and runoff and increasing vegetation cover in the previously degraded areas.

One of the challenges in implementing community-based monitoring systems was the development of scientifically rigorous techniques that were at the same time accessible to community members lacking formal education. The implementation of community participatory monitoring, whereby the rural participants recorded and analysed differences and changes, provided an opportunity for learning. It also empowered the people involved in the monitoring process to make subsequent decisions about the selection of technologies that are sustainable and suited to the local social and environmental conditions. In this way, local capacity and community involvement were enhanced.

MATERIALS AND METHODS

Study area

Okhombe is located in the Upper Thukela catchment area in the province of KwaZulu-Natal, South Africa (28° 42' S; 29° 05' E) at an altitude ranging from 1 000 to 1 800 m amsl. Most of the Okhombe area is steep, with the flat land characterizing the upper plateau. A number of streams and the Okhombe River cut through the area and flow into the Thukela River. The area receives approximately 800 to 1 265 mm of rain per annum. Most of the precipitation falls in the months of October to March (Schulze, 1997), accounting for up to 82% of the total annual rainfall (Dollar and Goudie, 2000). Despite its high annual rainfall, Okhombe does occasionally suffer from drought periods. The area also experiences hail and thunderstorms. The high amount of precipitation during the summer period has led to significant soil nutrient leaching and severe erosion along the slopes (Fig. 1).

The vegetation in the Okhombe area is influenced by burning regime and altitude, and is classified as fire climax grassveld (Tainton, 1999). The vegetation falls within the Northern Drakensberg Highland Grasslands (Gd5) and Ukhahlamba Basalt Grasslands (Gd7) (Mucina and Rutherford, 2006).

The Okhombe Ward falls under the Amazizi Traditional Authority of the Upper Thukela and comprises 6 sub-wards. The Okhombe community consists of about 4 000 inhabitants, who rely heavily on the surrounding natural resources for their daily living. Approximately 4 000 head of cattle and 2 000 small stock, mainly goats, live in the area. Grazing on the hill slopes takes place in summer from September to May. In winter, cattle are allowed to graze the remains of crops, mostly maize stalks, at the bottom of the valley since grass has by then become unpalatable.

Figure 1. Gully in the Okhombe area, located in the Upper Thukela catchment area

Participatory rural appraisal techniques

The participatory methods used in this study built on a foundation of participatory work that had been carried out with the Okhombe community in previous projects. The key techniques which laid the groundwork for the community's involvement in catchment management were a vision workshop, a catchment modelling exercise, the formation of a monitoring group and a participatory impact monitoring workshop.

Visioning and planning workshops

At the beginning of the project a visioning workshop was held which was designed to create a shared vision among the community members and to learn together about the catchment (Everson et al., 2007). The visioning exercise provided the basis for a planning workshop in which the community and project team planned how they could work together to help the community achieve its vision.

Catchment modelling exercise

An understanding of local resource management systems and the factors that underlie their functioning is essential for finding appropriate solutions that meet the community's needs. A catchment modelling exercise was held in which the community built a physical 3-dimensional model of the landscape using soil and plants. Community members then added the houses, fences, furrows, springs and streams, dongas and other important features using stones, sticks and coloured powder. As a next step, the community and project team analysed the catchment together to learn about the system. Discussions were held on the causes of the erosion and the denuded slopes, after which the community added the cattle access routes to the model. Finally, the model was used to plan where the rehabilitation measures should be applied.

Formation of the Okhombe Monitoring Group (OMG)

Since the success of CBNRM depends on the functioning of innovative community-based organizations, the first step in this process was to develop institutional capacity of the community to participate in the project. The Okhombe Monitoring Group (OMG) was formed, drawing on 24 volunteers from the 6 sub-wards within Okhombe. The OMG took on the responsibility of developing and implementing a rehabilitation, monitoring and land-use management plan for Okhombe.

Participatory impact monitoring workshop

The next step was to hold a participatory impact monitoring workshop at Okhombe to introduce the concept of monitoring. One of the challenging aspects of this workshop was the development of an understanding of qualitative and quantitative indicators and relating these to land care. A number of participatory workshops were then held with the OMG where the group members developed objectives and indicators of land rehabilitation for the Okhombe catchment. The group then assessed the extent and severity of soil erosion in the different sub-wards and drew up a work plan that identified the activities to be carried out.

Training module for the community-based programme to rehabilitate and monitor soil erosion

The detachment and transport of soil particles resulting from the impact of raindrops (rain splash) is usually considered an important first step in the chain of processes leading to loss of soil and subsequent sediment transport (Mouzai and Bouhadef, 2003). Once detached, sediment is easily movable by overland flow. This may lead to the formation of rills which may further develop into gullies or dongas. During the LandCare project the community had been trained in a number of erosion control techniques. These included physical structures (e.g. stone packs, stone lines, swales, cattle steps) and vegetative structures such as vetiver grass planted on contour lines, trees planted in micro-catchments and indigenous and exotic grasses planted on eroded slopes. An assessment of erosion and rain splash detachment is important to identify areas potentially vulnerable to accelerated soil loss so that corrective action can be initiated.

Sophisticated techniques to quantify the effects of rain splash erosion have been developed in recent years, many of which involve the use of rainfall simulators and complex, physically based models. There remains, however, a need for simple techniques for community-based monitoring of the extent of soil detachment. Techniques suitable for use by the Okhombe Monitoring Group had to meet several criteria:

- The technique had to be easily communicated to members of the community, many of whom had little formal education
- The equipment used had to be robust and of low cost
- Interpretation of the results had to be straightforward requiring little manipulation of the collected data for final presentation

The following monitoring techniques, which fulfilled the above requirements, were tested and implemented by the OMG. The techniques were initially implemented at 6 sites. Later, at the request of the tribal council, the sampling was extended to include a further 6 sites to represent different villages.

Splash board

A splash board is a simple device to measure the extent of soil detachment as a result of rain splash (Ellison, 1944). It was constructed by attaching a central shaft to a rectangular board on which parallel horizontal lines were drawn equidistant apart, forming 14 x 1 cm wide bands. Each band within the board was numbered from 1 (closest to the ground) to 14. The splash board was placed within the area to be monitored in such a way that the bottom edge of the board was 5 cm above the soil surface (Fig. 2). Soil particles which become dislodged from the soil surface during a rainfall event are ejected upwards, some of which adhere to the surface of the board. By noting the height of staining on the board it was possible for the community to infer the extent of soil loss by rain splash.

Morgan splash cup

The Morgan splash cup (Fig. 3) was used to measure the quantity of soil particles detached from the soil surface by raindrop impact. It consisted of an inner hollow cylinder, 11 cm long and 10 cm in diameter, which was inserted into the ground until level with the soil surface. The inner cylinder was surrounded by a circular tray, 30 cm in diameter, with a 10 cm high outer wall. The tray was divided into an upslope and a downslope compartment. When positioned on a horizontal surface the apparatus caught all particles splashed from the soil in the inner cylinder while the outer wall prevented the splashing in of most of the soil particles detached by raindrop impact outside the collection tray (Morgan, 1981). Once all water had evaporated from the collection tray and the sediment was completely dry, the dislodged soil was collected separately from the upslope and downslope compartments, carefully transferred into a 15 mL measuring cylinder using a scoop and a small brush and the volume of the soil was measured. The combined upslope and downslope volumes represented a measure of splash detachment while the downslope volume minus the upslope volume was considered a measure of the net downslope splash transport (Morgan, 1981).

Figure 2. Splash board showing the extent of soil detachment as a result of rain splash

Figure 3. A Morgan splash cup used to quantitatively measure up- and downslope erosion

Gully profile

Gullies, locally termed dongas, are larger scale erosion features, which occur extensively within the region. Cost-effective simple techniques for monitoring gully development were needed. A common approach to assess gully development is to measure its cross profile. This approach was chosen and a fixed frame of reference was constructed perpendicularly to the long axis of the gully. At either side of the gully metal fence stakes were driven into the soil and a stiff strand of wire with markings spaced equidistantly apart was attached to the stakes to demarcate the edge of the gully (Fig. 4). Beginning from the left-hand side and always facing upslope, the perpendicular distance from the wire to the gully floor was measured at each marking. The results were then plotted either electronically or manually on graph paper to derive the gully cross-profile. Measurements taken prior to rehabilitation provided the reference profile. The procedure was repeated at approximately 6-monthly intervals to determine changes in gully morphology and assess the effectiveness of gully stabilisation efforts carried out by the community.

Plant basal cover quadrats

Plant basal cover was determined using a 1 m^2 quadrat which was subdivided into 100 squares (Fig. 5). The quadrat was placed in exactly the same position on each occasion when basal cover was recorded so that changes could be monitored over time. Presence and absence of plant cover were recorded in each square and how much soil was covered by vegetation was then expressed as a percentage of the total quadrat. Initially, squares with rooted cover were marked with the initials of the species encountered (e.g. k for kikuyu) while bare soil squares were marked with a 0. However, since the grassland was heavily grazed and had no inflorescences, identification of species proved to be too difficult for the community members. Consequently, the technique was simplified so that any square in which rooted vegetation was present was marked with an X. This minor modification enabled illiterate people to participate in the recording of basal cover.

Rain gauges

Rainfall was measured with manual rain gauges which were positioned according to the standard guidelines for high-altitude grasslands (1.2 m above the ground) in the vicinity of the monitoring sites in each sub-ward (Toucher et al., 2020). The amount of rain received was determined by community members after each rain event and the rain gauges were manually emptied.

Runoff plots

Runoff plots (Fig. 6) were installed to determine runoff water quantity and quality on slopes. They consisted of metal frames measuring 1 m x 1 m. Each frame, 10 cm in height, was inserted into the soil to a depth of 5 cm and connected via a plastic pipe to a 2-L Coke bottle. All runoff water from the plot was collected in the bottle. Once the soil particles contained in the collected runoff water had settled, the depth of the sediment in the Coke bottle was measured with a ruler and served as an indicator of water quality. The volume of the collected water was determined using a measuring cylinder.

In order to accurately assess the effectiveness of erosion control, the OMG carried out each monitoring technique on an eroded and a rehabilitated site. In addition to data collection, the OMG received training in computer literacy and in data interpretation and presentation. A number of computer workshops were held in which the OMG learnt how to enter the data they had collected into Microsoft Excel spreadsheets and present them in the form of graphs. Since the main objective of the project was to build capacity of the rural community to collect quantitative data, it should be noted that the data collected were not high-quality scientific data to which rigorous statistical tests could be applied.

Figure 4. Gully profile measurement

Figure 5. Plant basal cover is assessed using a one square metre quadrat subdivided into 100 squares

Figure 6. Runoff water quantity and quality on slopes are assessed using runoff plots

RESULTS AND DISCUSSION

The development and implementation of a community-based monitoring programme was an ongoing process throughout the 5 year duration of the project. Modifications to the techniques and data sheets were continually made by the OMG during this period. The community collected quantitative data that enabled simple/basic analyses that were sufficient to demonstrate the effectiveness of the employed erosion control measures.

The catchment model enabled the community and the project team to jointly develop a holistic picture of the catchment and formulate a plan of action after analysing all aspects of this complex situation. It also highlighted the association between the degraded areas of the catchment and the main causes of soil erosion which were cattle access paths and overgrazing.

By applying the simple monitoring techniques, the community noticed great differences between the eroded and rehabilitated sites. In Enhlanokhombe, basal cover of the vegetation increased from 55% to 71% at the rehabilitated site; but decreased at the eroded site from 33% to 24% over the period from 10 September 2003 to 25 January 2004 (Fig. 7). Although the quadrat-based estimation of basal cover is a scientific, quantitative technique, the modifications made to it enabled it to be easily operated by members of the OMG, even those who were illiterate. The notable increase in basal cover following rehabilitation and grazing exclusion was one of the main factors responsible for the implementation of a rotational resting–grazing plan by the community. This illustrates how natural resource based community development gives communities an understanding of their natural resource base, enabling them to make more sustainable management decisions.

The community also noted greater rain splash heights in bare areas compared with areas that had good vegetative cover. Figure 8 shows the rain splash heights recorded with the splash board at the Mpameni sites between 17 December 2003 and 3 January 2004. Bearing in mind that the splash boards were installed 5 cm above the soil surface, the mean rain splash height at the eroded site (11.25 cm) was 33% higher than at the rehabilitated site (7.5 cm).

Splash cups installed in highly erodible areas trapped substantially more sediment than those installed in less erodible areas. The community recorded decreasing amounts of sediment in the collection trays of the splash cups in areas that were experiencing increases in vegetative cover.

Figure 9 illustrates that the sediment collected from March 2004 to January 2005 at the eroded Mpameni site (223 mL) was 42% higher than that collected at the rehabilitated Mpameni site (130 mL). A positive correlation between amount of rainfall and amount of sediment trapped in the cup at the eroded site was also observed.

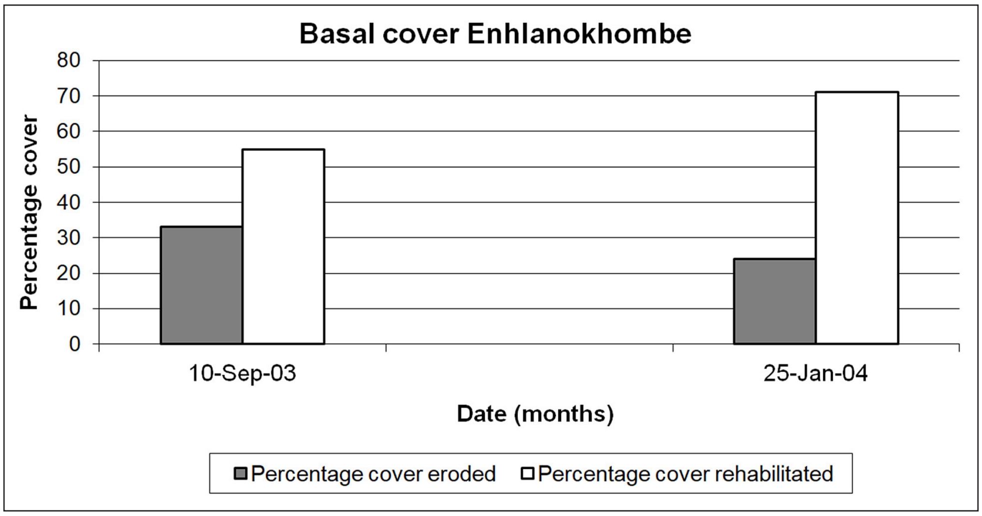

Figure 7. Changes in plant basal cover at Enhlanokhombe during the period from September 2003 to January 2004

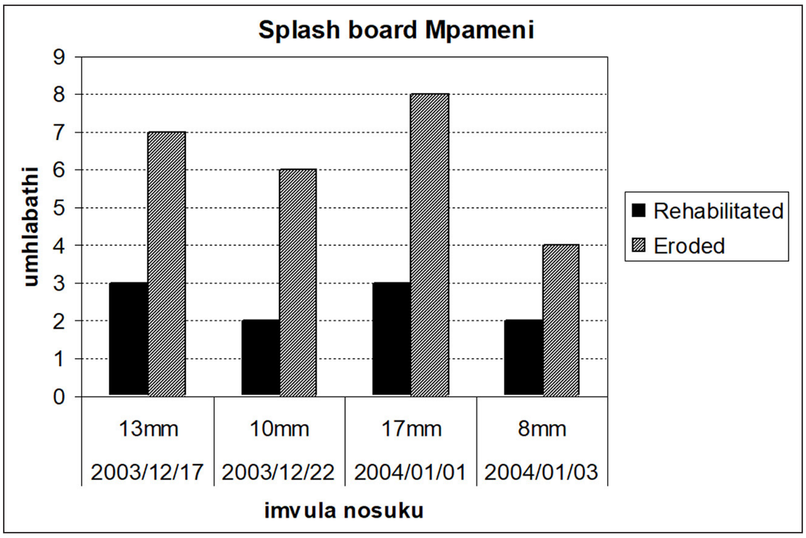

Figure 8. Height of rain splash determined with the splash board at the Mpameni site (the *y*-axis represents the band number on the splashboard; *umhlabathi*: soil, *imvula nosuku*: day with rain)

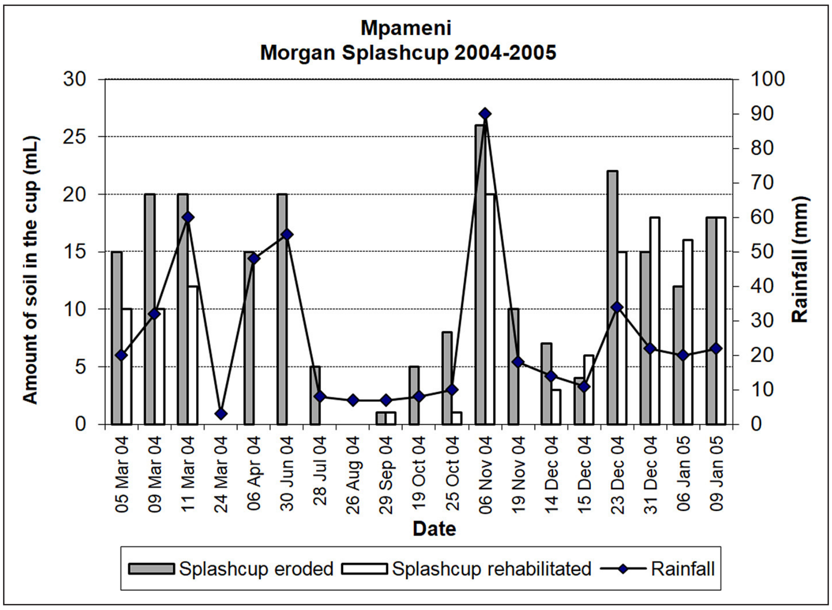

Figure 9. Soil volume (mL) detached by raindrop impact from eroded and rehabilitated areas at the Mpameni site determined using Morgan splash cups

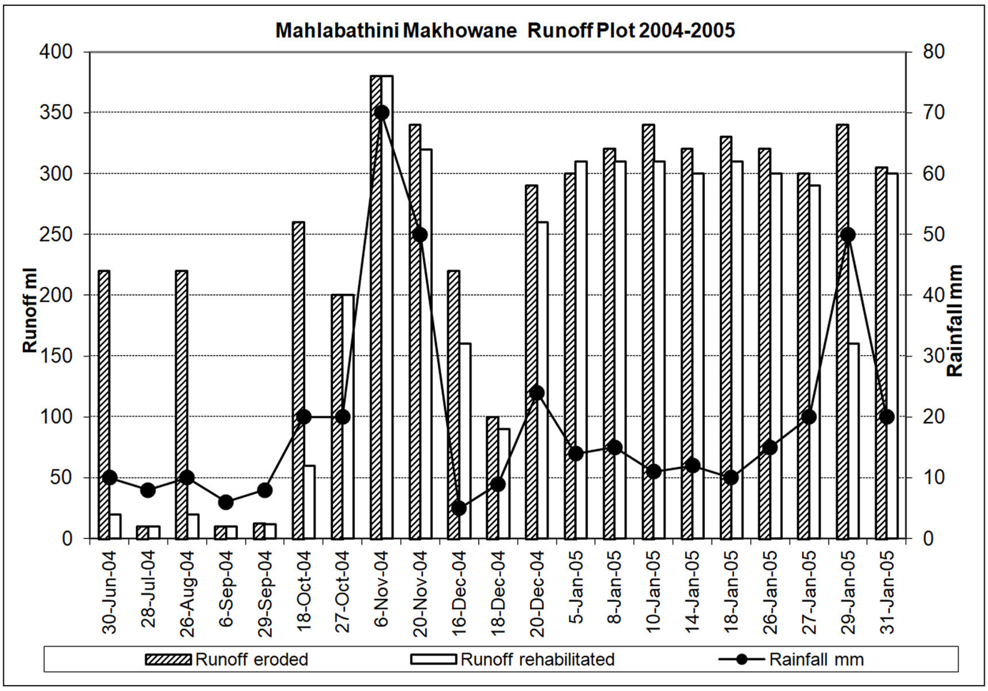

Figure 10. Runoff water (mL) and rainfall (mm) recorded at the Mahlabathini Makhowane site for each rainfall event

The use of runoff plots proved to be a very effective technique for monitoring the effect of rehabilitation on runoff water quantity and quality. The water collected from the rehabilitated sites was visibly clearer and lower in quantity than that from the eroded sites. Data from the runoff plots at Mahlabathini Makhowane (Fig. 10) demonstrate that total runoff collected over the period from 30 June 2004 to 31 January 2005 from the eroded site (5 137 mm) was 20% higher than that collected from the rehabilitated site (4 132 mm). Although attempts had been made to quantify the amount of silt collected in the bottle using a dip stick, these were often unsuccessful due to the long time it took for the sediment to settle.

The donga profile measuring technique required significant modification as initially there was too much flexibility in the donga cross-wire which served as a reference from which the depth to the gully floor was measured. In spite of those problems, the results of the measurements indicated considerable change in gully profile and sediment deposit following the construction of stone packs in the gully (Fig. 11).

In general, all techniques employed in the project, although simple, were able to effectively monitor changes in vegetation and soil conditions. The OMG favoured the use of the splash board and the runoff plots because they were easily understood, had a high visual impact and were relatively easy to record.

In addition to building capacity of the members of the OMG to monitor changes in vegetation and soil conditions within the catchment, capacity was also built in computer literacy. The OMG used the graphs they had generated in presentations to the traditional administrative council, school groups, local and international visitors and in community meetings to illustrate how effective the rehabilitation of the severely eroded areas of

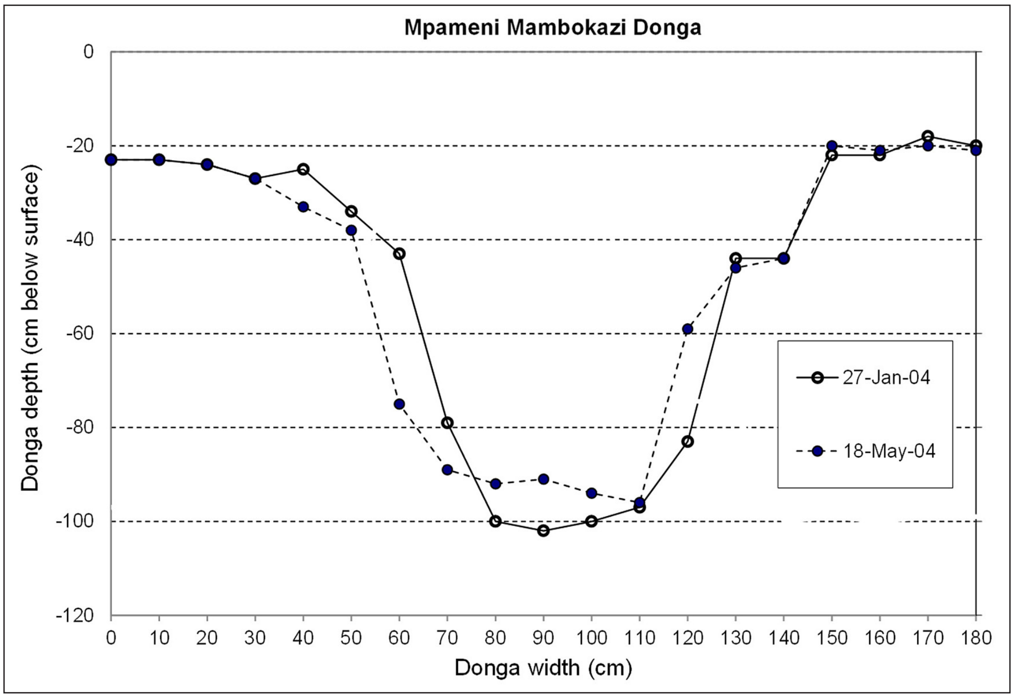

Figure 11. Change in gully profile at the Mpameni site

Okhombe had been. Figures 7 to 11 are examples of the graphs produced by members of the OMG. They document the success of the community-based erosion control techniques as well as the community members' computer skills, again illustrating the importance of natural resource based community development in community decision making.

Leach et al. (1999), who analysed the reasons why CBNRM frequently falls short of expectations, cautioned that the formation of a new, formal organization often cannot fulfil the roles of the multiple institutions which are generally involved in natural resource management, and which support individual claims to environmental goods and services. These institutions are usually informal and flexible, and adapt to changing ecological, social and political circumstances. The success of the Okhombe Monitoring Group might be attributed to its informal nature and the fact that many of its members had been actively involved in other institutions (e.g. livestock, school, development and tourism committees). These institutional relationships enabled the OMG to work together with the livestock committee to address the main cause of erosion which is overgrazing. The result of this natural resource based community development initiative was that the Okhombe community consequently implemented a rotational grazing system to increase vegetation basal cover and grass production. The community continued to be actively involved in erosion control and monitoring even after the project was concluded. This supports the view of Graham et al. (2024) that community-based monitoring (citizen science) holds significant value for achieving just and sustainable water futures by enabling broader participation in data collection, fostering co-learning and co-development of solutions, and enhancing environmental awareness.

If sustainable development of natural resources is to be achieved there should be appropriate sharing of responsibilities between national and local governments, civic organizations and local communities (Berkes, 1995). The United Nations' International Labour Organisation (2024) suggests that public employment programmes focusing on nature-based solutions have the potential to make significant contributions to mitigate the impacts of climate change, halting and reversing biodiversity loss and decreasing land degradation. The programme focuses on nature-based infrastructure to improve water security, with an emphasis on climate-smart agriculture practices, grasslands and livestock production to reduce land erosion, increase the productive potential of the land and improve water retention. Communities like Okhombe are therefore ideally placed to implement such public employment programmes.

Diederichs and Mander (2004) stated that in South Africa, various government agencies were seeking effective income distribution mechanisms for natural resource-based public works programmes. One such intervention has been the South African Government's Land User Incentives initiative (payment for ecosystem services), a subset of the well-known Working for Water, Working for Wetlands, Working for Ecosystems and Working on Fire programmes that have worked in partnership with local communities and individual land users. The initiation of a community-based monitoring programme that records the effect of different rehabilitation techniques on the reduction of soil erosion and improvement of water quality will therefore have long-term benefits, both for the community and for water users further downstream in the catchment. Although still in the pioneer stage, the payment of communities for looking after their natural resources has the potential to support the National Water Act to ensure the sustainable management of this important catchment area. The national Department of Water and Sanitation has the mandate to implement such projects through its catchment management agencies, water user associations and other water utilities. The National Water and Sanitation Master Plan (DWS, 2018) allows for funding to improve raw water quality by investing in communities that practise restoration and ongoing maintenance of ecological infrastructure. The funding can be secured via the water pricing strategy (DWS, 2023) in a way that will honour existing partnerships with programmes such as LandCare and the national Department of Forestry, Fisheries and the Environment's programmes. The Department of Water and Sanitation also has a mandate to protect and restore ecological infrastructure by declaring strategic water source areas, critical groundwater recharge areas and threatened or sensitive aquatic ecosystems as protected areas as allowed for within the Water Resources Management Charge of the national Pricing Strategy for Raw Water Use Charges (DWS, 2024). Okhombe, situated in the most important strategic water source area of the country, has the potential to benefit from this programme. Building the capacity of local communities is therefore critical to unlock these investments and ensure access to the market.

CONCLUSION

While the project indicated that further research is needed on the most appropriate funding mechanism and institutional structures to support the programme, it was apparent that this programme has resulted in improved natural resources and management of the area. The monitoring results confirmed that the rehabilitation efforts made by the community have resulted in a significant decrease in soil loss and runoff and in an improved vegetation cover. This has the potential to promote water retention and improve base flow. There still remains a need to calibrate the data collected by the monitoring group against data obtained with conventional, scientific methods. Through the monitoring training programme the community has also become aware of the links between grazing management and hydrological benefits. In addition to the technical skills, the community members obtained a range of transferable competencies such as improved communication and negotiation skills, improved literacy and numeracy, and the ability to work as a team, all of which can help strengthen other aspects of people's lives. The payment for ecosystem services initiative, which is still in the pioneer stage, has the potential to ensure the sustainable management of the important uThukela catchment area by paying communities for looking after their natural resources. This will help to protect water resources and secure fodder production in the area.

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AUTHOR CONTRIBUTIONS

Terry Everson: conceptualisation of the project, research project management, methodology of the study, data collection and fieldwork, writing of the paper. Colin Everson: intellectual input during the research, data collection and fieldwork, writing of the paper. Khumbuzile Zuma: methodology, data collection and field work, writing of the draft paper. Christo Marais: intellectual input during the research, investigation of payment for environmental services models, review and editing.

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