Advancing Water Resources Sustainability in Lesotho

Abstracts of Thesis Work
from the First Cohort of the Integrated Catchment and Water Resources Management Master's Programme, National University of Lesotho's Water Institute

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ReNOKA is a national programme and citizen movement for the restoration of land and water in Lesotho and the Orange-Senqu basin. Support for ReNOKA is provided through a partnership between the Government of Lesotho, the European Union (EU) Delegation to the Kingdom of Lesotho and the German Federal Ministry for Economic Cooperation and Development (BMZ). The EU and BMZ contributions are implemented through a technical assistance project 'Support to Integrated Catchment Management in Lesotho' by the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH.

Maseru, 28 November 2025

Foreword

The first cohort of students from the Integrated Catchment and Water Resources Management Master's programme graduated from the National University of Lesotho's Water Institute in October 2025.

This marks an important milestone in the country's progress towards implementing Integrated Catchment Management (ICM) to rehabilitate and conserve our precious ecosystems.

The Master's programme was designed to address a critical gap in the capacity-development landscape. The Government of Lesotho has introduced ReNOKA, a dedicated ICM coordination unit and national movement. ReNOKA observed that experts in ICM planning and implementation—often recruited from neighbouring countries—were not always familiar with Lesotho's unique context. For the long-term and effective implementation of ICM measures, Lesotho must build its own pool of experts working across government, academia and civil society organisations. This is why ReNOKA identified the need for a dedicated ICM Master's programme. Now, bachelor's students from various related fields can progress to a Master's degree specialising in ICM and Integrated Water Resources Management. The programme aspires to develop future leaders in natural-resource management—leaders who will help secure and advance Lesotho's livelihoods and prosperity through its water resources.

The holistic approach of ICM is reflected in the multidisciplinary nature of the Master's programme. Lecturers from diverse disciplines share their insights to help overcome siloed thinking. The final theses of the first cohort demonstrate this clearly: from soil analysis to erosion modelling, and from social to infrastructural aspects, students have focused on real-world challenges and identified practical ways to address them. The expertise gained is already being applied within the governance processes surrounding ICM planning and implementation.

With this brochure, we are delighted to present the abstracts of their final theses.

We extend our gratitude to the European Union, the German Government and WaterNet for their support in designing and implementing the programme. A special thank you goes to Dr 'Mamohau Seutloali-Thamae, Senior Lecturer and Acting Director of the National University of Lesotho Water Institute, for her vision, expertise and dedication—both to advancing research in the field of ICM and to her outstanding work in establishing this Master's programme. We are proud that the programme has now been set up to run independently, without donor support.

Finally, we would like to congratulate the graduates. We look forward to seeing you further advance ICM efforts.

Makomoreng Fanana
National Coordinator, Integrated Catchment Management Unit

Water demand forecasting for peri-urban settings in Lesotho using a machine-learning approach

By Qenehelo Mahamo

Abstract

The increasing challenges related to water security, exacerbated by rapid urbanisation, population growth and climate variability, necessitate accurate and reliable forecasting methodologies to support sustainable water resources planning. This study explores water demand forecasting in Ha Foso, Lesotho, by evaluating three machine learning models: multiple linear regression (MLR), support vector regression (SVR) and artificial neural networks (ANN). Utilising time series datasets covering meteorological inputs (2012–2022), population data and water consumption records (2017–2024), the study assesses the influence of climatic and demographic variables – specifically precipitation, maximum and minimum temperatures, and population – on domestic water consumption.

The research first used MLR to assess the influence of population, maximum temperature, minimum temperature, precipitation and other factors on water demand. Subsequently, the study evaluated the predictive performance of the MLR, SVR and ANN models. Performance was evaluated using metrics including the coefficient of determination (R^2), root mean squared error (RMSE), mean absolute error (MAE) and mean absolute percentage error (MAPE).

The regression analysis consistently identified population as the only statistically significant predictor of water demand ($p<0.001$), while climatic variables showed no significant influence during the study period. In the comparative evaluation, the SVR model demonstrated the highest accuracy and generalisation capacity, outperforming ANN and MLR, with the least error metrics in both the training phase and the testing phase. The two-year forecast highlighted the distinct behaviours of each model, with the SVR and ANN models providing more moderate growth projections compared to the steep, linear increase predicted by the MLR model.

This study presents the potential of machine learning, particularly SVR and ANN, in addressing the intricate, non-linear relationships inherent in water demand forecasts, delivering precise and actionable water-demand forecasts for peri-urban settings in Lesotho. The findings suggest the adoption of advanced architectures and the incorporation of socio-demographic variables to strengthen predictive capacity. The outputs are expected to support utility companies such as the Water and Sewerage Company (WASCO) in strategic planning, conservation and infrastructure investment decisions.

Keywords: determinants of water demand, water demand prediction, artificial neural networks (ANN), machine learning, support vector regression (SVR), multiple linear regression (MLR)

Community perceptions on the water, energy, food, and ecosystem (WEFE) nexus: A case study at Ha Seeiso Metolong, Maseru, Lesotho

By Kamohelo Jeanett Mahloane

Abstract

Water, energy, food and ecosystems (WEFE), as the essential resources underpinning human existence, are critical to the sustainable development of humanity. The local community exerts a significant influence in fostering the sustainable development of these resources. Limited information exists on the effectiveness of nexus resource management in facilitating livelihoods and ensuring resource security. These challenges are associated with local communities' insufficient knowledge concerning the utilisation and exploitation of water, energy and food resources. This lack of awareness leads to trade-offs, particularly in local and marginalised regions.

Through the analysis of data collected from a local community via a questionnaire, this research endeavours to investigate the perceptions of the local community regarding the WEFE nexus. The findings suggest that community perceptions of WEFE nexus resources are comprehensible through the lenses of social, natural, economic, human, physical and environmental indicators. The results indicate that people's perceptions of WEFE nexus resources are based more on the advantages of individual resources rather than on how they are related to one another. This might be the outcome of how the community views a certain nexus resource (e.g. food and water) from the four nexus sectors. The community's primary nexus resources in the study region are food and water. This indicates that there is a missing link between the utilisation and management of cross-sectorial resources and the full-scale adoption of the WEFE nexus to enhance living conditions.

Our results indicate that the livelihood advantage of individual WEFE nexus resources is the main focus in the community under study, and that there is a lack of knowledge regarding the usage and management of these resources. Based on these findings, we recommend that the government and other interested stakeholders take further steps to enhance the local community's awareness of WEFE nexus resources so that they may better comprehend the connections between WEFE sectors.

Keywords: WEFE nexus, community perceptions, community participation, resources security, ecosystem integrity

Effects of sedimentation on water quality in the Metolong Reservoir, Maseru, Lesotho

By Mats'eliso Celestina Makhakhe

Abstract

Reservoir sedimentation is a significant environmental challenge affecting the sustainability of water resources, particularly in Lesotho, where soil erosion and land degradation are prevalent due to intensive land use and fragile ecosystems. The Metolong Reservoir, a critical water source for approximately two-thirds of Lesotho's population, is challenged by rapid sedimentation, which lowers the water quality and threatens the long-term viability of the reservoir. Despite its importance, no known studies have correlated sedimentation and water quality in the area.

This study investigated how sedimentation affects water quality in the Metolong Reservoir by quantifying sediment accumulation from 2020 to 2022 and analysing its impact on key water-quality parameters. The study employed historical bathymetric and water-quality datasets (2020–2022), complemented by GIS-based spatial analysis and R statistical modelling to assess the spatial and temporal relationships between sediment deposition and changes in water-quality parameters. The research followed a causal–comparative design.

Water quality parameters analysed included aluminium, electrical conductivity (EC), iron, manganese, nitrates, nitrites, phosphates, sulphates, total dissolved solids (TDS) and turbidity. Bathymetric analysis revealed a total sediment accumulation of approximately 1,705,583 m^3 (2.68% of reservoir capacity) between 2020 and 2022, concentrated primarily near the reservoir's middle and towards the dam wall, resulting in an annual storage loss of 1.34%.

Linear regression analysis revealed turbidity as the most significantly affected parameter ($p<0.05$). The study also identified turbidity and nitrates as key water-quality parameters significantly influenced by sedimentation. Turbidity showed the strongest correlation with sediment volume ($r=0.60$) and nitrates demonstrated a moderate correlation ($r=0.2$), suggesting possible links with upstream land use and nutrient runoff. There was an increase in nutrients and heavy metals concentration from 2020 to 2022, indicating a need for intervention. However, most water-quality parameters were still within World Health Organization (WHO) and South African water quality standards.

The findings confirm that sedimentation negatively affects water quality, underscoring the need for integrated catchment management that includes sediment control, land-use planning and systematic water-quality monitoring to safeguard reservoir operations and public health.

Keywords: erosion, pollution, reservoir, sedimentation, water quality

Socio-economic and environmental impacts of the abandoned Maqalika Dam on the surrounding communities in Maseru, Lesotho

By Rosemary Masentle Maloisane

Abstract

Maqalika Dam was constructed in 1983 to supply potable water for households and other users in Maseru, Lesotho. However, since its abandonment, the site has suffered progressive degradation due to pollution, sedimentation and unregulated urban encroachment. Against this backdrop, the study examined the socio-economic and environmental impacts of the dam's abandonment.

A mixed-methods approach was employed, comprising household surveys (n=310), key informant interviews with institutional stakeholders and field observations. Tabulations and content analysis were used to assess the multifaceted consequences of the dam's discontinued use.

The findings indicated that over 55% of nearby residents experienced livelihood disruptions, especially in irrigation, livestock watering and small-scale fishing. Environmentally, over 94% of respondents reported pollution, waste dumping and eutrophication as prominent challenges that posed risks to public health and aquatic life. Institutional neglect, rapid urbanisation and intentional pollution were identified as key drivers of the abandonment.

Although Metolong Dam now supplies Maseru, the Maqalika site remains a source of socio-environmental concern. Stakeholders have proposed interventions such as pollution-source mapping, ecological rehabilitation and participatory planning for sustainable reuse. The study concludes that integrated water-resource governance is urgently required, with an emphasis on rehabilitation or sustainable repurposing to transform abandoned urban dams from liabilities into community assets.

Keywords: Maqalika Dam, dam abandonment, socio-economic impacts, environmental degradation, sustainable reuse, water-resource governance

Impacts of climate change on streamflow and hydrological extremes in the South Phuthiatsana catchment, Maseru, Lesotho

By Makoanye Maphutseng

Abstract

Global climate change is predicted to significantly modify hydrological processes, which will have a big impact on ecosystem sustainability, flood risk and water availability. Knowing how future climate conditions may impact river systems is especially important in southern Africa, where population increase and fluctuating rainfall are already placing a strain on water resources. One such critical system is the South Phuthiatsana catchment, which serves as a vital supply of water for Maseru and surrounding metropolitan areas.

This study explores how projected climatic shifts may influence streamflow behaviour and the occurrence of hydrological extremes within the South Phuthiatsana watershed. Bias-adjusted data from the MPI-ESM12-LR global climate model, along with two emissions scenarios for the mid-21st century (2041–2080), were used to project climate inputs. The process-based model (SWAT+) was used to simulate streamflow, but suboptimal performance indicators showed that SWAT+ did not reliably capture historical daily flow patterns. As a result, SWAT+ was deemed insufficient for predicting future hydrological reactions in this context.

To address this limitation, a machine-learning approach using the XGBoost algorithm was adopted. This model was trained on bias-corrected climate variables to observe streamflow data, providing a more reliable tool for future streamflow prediction. XGBoost results revealed substantial and complex hydrological shifts, characterised by a consistent warming trend and highly variable seasonal precipitation patterns across both emissions scenarios.

Extreme high flows, represented by the 98th percentile (Q98), are projected to decline by more than 52% relative to historical values, suggesting a reduced risk of flooding. In contrast, low flows are expected to increase dramatically, with the first percentile flow (Q1) rising from near-zero historically to approximately 9.0 m^3/s, indicating a significant shift towards more perennial flow conditions.

Mid-range flows (Q25, Q50 and Q75) are also expected to increase substantially, depending on the flow percentile and scenario. While the absolute magnitude of low flows improves, the number of days with historically low-flow conditions may still rise during certain months, highlighting a shift in intra-annual flow variability.

Overall, these findings point to a future with diminished flood peaks, elevated baseflows and more frequent low-flow conditions during critical periods. Despite initial limitations with the process-based model, the machine-learning approach provided robust insights that support the development of adaptive, forward-looking water-resource management strategies. The results underscore the need for resilient planning to ensure long-term water security under evolving climate conditions.

Keywords: process-based model (SWAT+), machine-learning XGBoost algorithm, climate change, streamflow, hydrological extremes

Impacts of soil condition, topography and land use on the erosion characteristics of Phuleng-e-Nyane Ha Mantšebo, Lesotho: A USLE analysis

By Ntšolo Matšaba

Abstract

Soil erosion is a natural but complex process involving the detachment and movement of soil by agents including water and wind; it is often accelerated by human activities such as agriculture and changes in land use. Erosion threatens soil fertility, agricultural productivity and ecosystem health, making its assessment crucial for sustainable land management.

This study evaluated the impacts of soil condition, topography and land use on the erosion characteristics of Phuleng-e-Nyane Ha Mantšebo, Lesotho, using the universal soil loss equation (USLE) model. A randomised complete block design in a split-plot arrangement was employed to assess soil erosion across the area. The main plot factor consisted of two farming systems: cropland and long-term fallow land. Within each farming system, the subplot factor was the toposequence position, comprising four levels: summit, shoulder, back-slope and toe-slope. The USLE factors included rainfall erosivity, soil erodibility, topography, crop management and conservation.

Disturbed and undisturbed soil samples were collected, with disturbed samples taken using soil auger at a depth of 30 cm and undisturbed samples taken using core samplers. Secondary rainfall data were obtained from the Lesotho Meteorological Services at Moshoeshoe I International Airport, while slope length was measured using a 100 m open-reel fiberglass tape. Google Earth imagery was used to look at land use and land cover over time. Correlation analysis examined relationships between soil loss and contributing factors, and a localised soil-loss prediction model was developed.

The total soil loss from the study area was calculated at 12.25 Mg ha^{-1} yr^{-1}. Cropland contributed about 95.2% of the total soil loss (53.7% from the north transect and 41.5% from the southwest transect), while long-term fallow land contributed 4.8%, distributed almost equally between the two transects. Stepwise regression analysis revealed that land use is the most influential factor driving soil loss in the area, followed by topography. The study highlights the importance of integrating effective management practices to sustain soil health and reduce erosion hazards.

Keywords: land use type, Lesotho, soil erosion, soil properties, universal soil loss equation (USLE), toposequence, transect

Impact of altitudinal variation on selected soil properties and carbon dynamics in the alpine wetlands of Lesotho

By Mosiuoa Mochala

Abstract

Initiated in November 2024, this study was conducted as part of an ongoing project, 'Carbon modelling and omics approaches for screening of soil microbes for climate change adaptation in the alpine wetlands of Lesotho'. The study was designed in blocks (sub-catchments) with six altitudinal variations (2,500–3,155 m a.s.l), representing alpine wetlands from three sub-catchments – Senqunyane, Khubelu and Sani – as follows: Khorong (2,500–2,550 m a.s.l.) and Tenesolo (2,552–2,600 m a.s.l.) in Senqunyane; Khamoqana (2,839–2,880 m a.s.l.) and Khalong-la-Lichelete (2,891–2,950 m a.s.l.) in Sani; and Lets'eng-la-Likhama (3,040–3,080 m a.s.l.) and Koting-sa-ha-Ramosetsana (3,087–3,155 m a.s.l.) in Khubelu. Each treatment was replicated four times. Across the alpine wetlands, the soils were loam to sandy loam, slightly acidic and non-saline.

Bulk density (BD) declined significantly with increasing altitude at 0–15 cm soil depth and was significantly lower (1.08 Mg m^{-3}) in Koting-sa-ha-Ramosetsana (KSHM) compared with other wetlands. The KSHM wetland also showed a significantly higher infiltration rate (IR) of 2.17 cm h^{-1}, maximum water-holding capacity (MWHC) of 57.51% and saturated hydraulic conductivity (Ksat) of 2.70 cm h^{-1} at 0–15 cm soil depth. In contrast, Tenesolo recorded a higher BD and the lowest IR, MWHC and Ksat. Soil organic carbon (SOC) and calcium (Ca) were significantly higher in KSHM and increased with altitude, except in Khorong (KRN), which did not follow this trend. KRN (2,500–2,550 m a.s.l.) had comparatively higher SOC and Ca. Electrical conductivity, cation-exchange capacity and available macronutrients (nitrogen, phosphorus and potassium) were not significantly affected by altitude.

Soil enzyme activities declined significantly with increasing altitude due to lower temperatures at higher elevations, which limit microbial activity. Dehydrogenase, fluorescein di-acetate and □-galactosidase activities were 3.92 and 45.33%, 1.82 and 32.20%, and 9.29 and 15.11% lower in KSHM (3,087–3,155 m a.s.l.) compared with Tenesolo (2,552–2,600 m a.s.l.) and Khorong (2,500–2,550 m a.s.l.), respectively. Higher carbon pools – very labile (CVL), labile (CL), less labile (CLL) and non-labile (CNL) – and total organic carbon (TOC) were recorded in the KSHM area compared with all other wetlands. The passive pool of carbon (CPSV) dominated the active carbon pool (CACT), with 75–79% of TOC. Both CPSV and CACT were higher at the higher-elevation KSHM site.

The soil quality index (SQI) was enhanced (42.54% and 42.51%) at both the upper (Koting-sa-ha-Ramosetsana) and lower (Khorong) elevation wetlands, indicating that altitude alone does not fully determine soil quality. Instead, wetland conditions, vegetation cover and site-specific environmental factors are critical in shaping soil functionality and regulating carbon processes in alpine wetland ecosystems. Further research should consider synergistic factors such as slope, topography and soil degradation in addition to the altitude.

Keywords: altitude, alpine wetlands, soil properties, carbon dynamics, Lesotho

Landslide susceptibility mapping: A case study of the Malibamatšo sub-catchment, Lesotho

By Mats'eliso Mocheka

Abstract

Landslides have a serious impact on development and national economies. This study presents a geospatial analysis of landslide susceptibility within the Malibamatšo sub-catchment, Lesotho, using remote sensing imagery and a GIS-based frequency ratio (FR) model.

The FR method was used to assess susceptibility to landslides based on ten conditioning factors, including topography, climate and proximity to streams and roads. The conditioning-factor datasets were derived from various sources such as digital elevation models (DEM), NASA and cadastral maps. The FR-weighted thematic layers were overlaid through numerical addition using the raster calculator to generate the landslide susceptibility index (LSI) map, which was then classified into five categories. The main contributing factors to landslides in the Malibamatšo sub-catchment, based on total FR values, were distance to roads (FR=15.09), slope aspect (8.79), land-use/land-cover (5.99) and rainfall (5.09). Areas within 200 m of roads exhibited high landslide susceptibility, with FR values up to 4.82. North-east-facing slopes, areas with bare or agricultural land cover and regions with high rainfall were generally more susceptible to landslides. Topographic factors such as slope gradient, curvature and elevation were relatively less important. However, moderate slopes (11–22□) were more prone to landslides than steeper slopes. Soil texture was the least contributing factor (FR=1.15).

The resulting landslide susceptibility map (LSM) classifies the landscape into five zones ranging from very low to very high susceptibility. Almost 20% of the catchment was found to be susceptible to landslides. The most susceptible areas were villages near national roads, often associated with agricultural activity, such as Ha Lejone, Ha Taunyane, Ha Sephapo, Taung, Ha Nkisi and Liphofung. Model accuracy was validated using the success rate curve (SRC), which yielded an area under the curve (AUC) value of 0.89, indicating high predictive performance.

The study's findings provide valuable input for land-use planning, infrastructure development and the implementation of mitigation strategies in landslide-prone areas.

Keywords: landslide susceptibility, GIS, remote sensing, frequency ratio (FR) model, contributing factors

Estimating soil erosion risk for sustainable land management: Insights from the Senqu sub-catchment, Mokhotlong District, Lesotho

By Polao Ishmael Moepi

Abstract

Soil erosion remains a major environmental challenge in mountainous catchments. This study estimated soil-erosion risk in the Senqu sub-catchment (SC-19), Mokhotlong District, Lesotho, using an integrated modelling framework that combines the revised universal soil loss equation (RUSLE), random forest and multi-criteria decision analysis. The framework quantified total soil loss and its spatial distribution, assessed the influence of RUSLE variables, evaluated model accuracy and prioritised conservation measures.

Field data, remote sensing and GIS were used to support the spatial analysis. The model estimated an annual soil loss of 17,417.2 tonnes across the catchment, with localised hotspots reaching up to 61.99 t ha^{-1} yr^{-1} and an average of 0.55 t ha^{-1} yr^{-1}. Over 54% of SC-19 was classified as high to very high erosion risk, highlighting severe land degradation.

Random forest analysis identified slope length and steepness, together with vegetation cover, as the most influential drivers of soil erosion, underscoring the influence of topography and land cover management in heterogeneous landscapes. Statistical analysis confirmed the model's robustness and reliability, with an NSE of 0.947, low RMSE (0.217) and MAE (0.049), and negligible bias (–0.002).[1]

The study proposed and prioritised targeted conservation interventions – vegetative measures, brush packs, grazing management, infiltration pits, diversions and stone-lines – to support sustainable land management and contribute to national efforts towards land-degradation neutrality. The findings provide valuable insights for policymakers and land-resource managers seeking to mitigate soil erosion impacts.

Keywords: soil erosion, revised universal soil loss equation (RUSLE), random forest, multi-criteria decision analysis, land-degradation neutrality

1 NSE (Nash–Sutcliffe efficiency), RMSE (root mean square error), MAE (mean absolute error) and bias are statistical measures of model performance.

Effect of waste disposal on nitrate and phosphate levels in Raleting Dam, Mafeteng, Lesotho

By Lepekola Moeti

Abstract

Surface water quality in urban areas is consistently declining due to the indiscriminate disposal of both liquid and solid wastes. Identifying the sources of waste and the factors increasing nitrate and phosphate levels in potable water bodies is crucial for water-resource managers seeking to mitigate nutrient pollution. This study evaluated the effect of waste disposal on nitrate and phosphate concentrations in Raleting Dam, located in Mafeteng, Lesotho. Fifty-four water samples were collected from nine sampling locations between March and May 2025. All samples were analysed using a HACH DR6000 spectrophotometer.

The results indicated that domestic waste and industrial effluents were the primary contributors of nitrate and phosphate in the reservoir, respectively. All water samples recorded nitrate concentrations within the World Health Organization's (WHO) acceptable contamination threshold of 50 mg/L, with an average value of 4.200 ± 1.083 mg/L. In contrast, phosphate concentrations in all samples exceeded the WHO acceptable contamination threshold of 0.03 mg/L, with an average value of 1.620 ± 0.740 mg/L. Higher nitrate levels were observed during the wet season compared with the dry season, with mean values of 1.987 mg/L and 1.694 mg/L, respectively. Conversely, phosphate concentrations were higher during the dry season than during the wet season, with mean values of 1.026 ± 0.114 mg/L and 1.003 ± 0.081 mg/L, respectively. No positive correlation was found between nitrate and phosphate levels, indicating a weak relationship between these parameters. Historical data suggest a gradual increase in both nitrate and phosphate levels over time. Further investigations are required around identified pollution hotspots to ascertain the particular sources and guide the implementation of corrective actions.

These findings will raise awareness among water resource managers and policymakers about the significant harm caused by the indiscriminate disposal of waste in Raleting Dam. The study can therefore serve as a basis for the formulation and implementation of waste management strategies by local authorities and policymakers. Future research should explore public perceptions of illegal dumping and include larger sample sizes over longer periods for improved accuracy. Prioritising physicochemical parameters in future studies is essential for assessing water quality for domestic use.

Keywords: Raleting Dam, surface water contamination, waste disposal, nitrate and phosphate concentrations

Non-revenue water in Teyateyaneng, Lesotho: Challenges, socio-economic impacts and strategic solutions for improved water management

By Noloane Letsoela Mofolo

Abstract

In Lesotho, non-revenue water (NRW) poses a significant threat to the country's water supply systems, undermining efforts to manage limited clean water effectively. This study examines the socio-economic implications of NRW in Teyateyaneng, Lesotho, to inform evidence-based water-utility management and consumer-welfare activities.

Water and Sewerage Company (WASCO) middle management and community members were surveyed quantitatively and interviewed qualitatively using the capital approach framework, which incorporates political, social, financial and human capital. Research shows that institutional and governance restrictions drive high NRW levels. Policy priority, regulatory enforcement and community trust and engagement are insufficient, resulting in limited political and social capital. Human capital has significant technical and operational skills, but inefficient knowledge-sharing platforms limit WASCO's ability to exploit these advantages. The absence of contingency funds and tariff agreements to cover NRW management expenditures undermines financial capital, even with investments in modern monitoring technologies and frequent audits. Water users face significant socio-economic consequences.

The majority of the analysed homes report inconsistent water delivery, and they perceive high water costs that do not align with the quality of service. Health difficulties, particularly gastrointestinal disorders, have been linked to discoloration and unusual odours in the water, thereby eroding trust in the utility. The statistical data reveal a strong correlation between water cost, perceptions of rate fairness and household income, highlighting the significant impact of NRW on vulnerable populations.

The paper recommends a multi-capital approach to NRW in Lesotho. Recommendations include comprehensive NRW-management strategies, legislative-framework strengthening, community involvement, infrastructure and metering-system investment, and organisational learning and capacity building. WASCO and similar utilities can overcome institutional barriers, decrease water losses and deliver reliable, equitable and sustainable water services using the multi-capital framework. This would improve customer welfare and support national development goals.

Keywords: non-revenue water (NRW), water utility management, capital approach framework, socio-economic impacts, institutional barriers

Evaluation of the water distribution system and its impact in Ha Foso, Berea, Lesotho

By Mofolo Tsepang Clementine

Abstract

The interplay between urbanisation, water demand and water-resource management is a critical issue, particularly as population concentration intensifies in peri-urban areas. Rapid urbanisation in Lesotho has exerted considerable pressure on water-supply infrastructure, particularly in emerging peri-urban communities like Ha Foso, where water-supply challenges have become an issue.

This study evaluates the performance, adequacy and reliability of Ha Foso's water distribution system. Hydraulic analysis was conducted using water-distribution modelling software (EPANET) to assess parameters such as pressure levels, flow rates and overall network efficiency. Complementing the technical analysis, quantitative and qualitative data were collected from 270 households, while participant interviews were held with water consumers and utility personnel. Logistic regression analysis was used to explore the relationship between infrastructure performance and user satisfaction, providing a robust assessment of the system's impact on the community.

Findings indicate systemic inefficiencies in the distribution network, including low water pressure, intermittent and unreliable supply, and widespread consumer dissatisfaction. By integrating technical data with community perspectives, the study proposes innovative interventions, such as installing booster pumps in households experiencing low pressure and pressure-reducing valves in high-pressure zones to protect infrastructure. These measures aim to improve water access, strengthen network resilience and support equitable and sustainable water-resource management.

Keywords: water reliability, water supply infrastructure, EPANET (water-distribution modelling software), peri-urban communities

Assessment of land-use and land-cover change and its impact on soil erosion and streamflow dynamics in the Senqunyane sub-catchment, Lesotho, using remote sensing and RUSLE modelling

By Ts'epang Kananelo Ngatane

Abstract

Soil erosion continues to degrade land and water resources across catchments. Despite ongoing control efforts, it remains a major threat to water resources in Lesotho, driven by factors such as land-use and land-cover (LULC) change and climate variability.

This study assessed the tempo-spatial changes in LULC and the associated impacts on soil erosion on streamflow dynamics within the Senqunyane sub-catchment. LULC classification was undertaken using Google Earth Engine, while soil loss was estimated using the revised universal soil loss equation (RUSLE). Results show that soil loss has increased significantly over the past four decades (1984, 1994, 2004, 2014 and 2024). Sedimentation in a downstream dam also increased in a similar pattern. Soil loss varied across different LULC types – bare land, agricultural areas and vegetated areas – with the highest erosion recorded on bare land.

By understanding the dual pressures of land degradation and hydrological stress, decision-makers are better positioned to implement coordinated responses that safeguard livelihoods, protect infrastructure investments and enhance sub-catchment resilience in a changing climate. The study concludes that soil erosion can be mitigated through LULC modification, particularly by increasing vegetation cover on bare land, which exhibited the highest erosion levels.

Keywords: land-use and land-cover (LULC) change, rainfall variability, remote sensing, soil loss, water-resource management

Governance institutions in range resource management: A case study of local community council and chieftainship institutions in the Qacha's Nek District, Lesotho

By Matlotla Agnes Pheku (Lineo Rabethane)

Abstract

This study explores the roles and interactions of dual governance institutions – chieftainship and local community councils – in managing range resources in the Qacha's Nek District, Lesotho. It focuses on the Range Management Area Programme and the traditional Maboeella system, examining their effectiveness before and after the 1997 decentralisation reforms. A mixed-methods approach was employed, combining quantitative data from structured surveys (n=90) with qualitative insights from key informant interviews and focus group discussions involving chiefs, councillors and community members. Quantitative data were analysed using descriptive statistics and Pearson correlation, whereas qualitative data were examined thematically using Taguette software.

The findings reveal that although both governance institutions contribute to range resource management, traditional chieftainship continues to enjoy greater community trust due to its cultural legitimacy and grassroots presence. In contrast, while councillors are more closely aligned with formal policy structures, they often lack local influence and enforcement capacity. Consequently, the coexistence of these systems has led to overlapping roles, institutional friction and limited coordination. Nevertheless, examples of effective collaboration demonstrate that clearly defined responsibilities and inclusive decision-making can enhance governance outcomes.

The study recommends the development of a hybrid governance model that integrates the strengths of both systems, supported by improved communication, formalised collaboration frameworks and legislative reforms to clarify roles and strengthen accountability. These insights offer practical guidance for harmonising governance structures to promote sustainable natural resource management in Lesotho and similar contexts.

Keywords: dual governance, chieftainship, local community councils, Range Management Area Programme, Maboeella system, range resource management, community participation

Livestock owners' perceptions and participation in rangeland conservation and management: The case of Motete, Butha-Buthe District, Lesotho

By Khauta Ramatutu

Abstract

Rangelands are vital to livestock owners' livelihoods in Lesotho, yet many of these ecosystems are experiencing degradation due to unsustainable use and limited local participation in conservation. In Motete, Butha-Buthe District, the participation of livestock owners in rangeland conservation and management remains inadequately understood.

This study examined livestock owners' perceptions of rangeland conditions, the extent and nature of their participation in conservation and management, and the key factors influencing their involvement. It also sought to identify strategies to enhance local engagement in sustainable rangeland management. A cross-sectional design was used, employing structured questionnaires with 109 livestock owners, complemented with seven key informant interviews. Quantitative data were analysed using descriptive statistics, combined with probit regression in SPSS, while qualitative data (key informants) were examined thematically.

The results revealed that although livestock owners generally regarded rangelands in Motete as being in fair condition, signs of degradation – overgrazing, brush encroachment, decline in palatable species, loss of vegetation cover, increased bare ground, invasion by alien species and rising soil erosion – were prevalent. Livestock owners actively participated in traditional practices such as rotational grazing, but their involvement in formal management initiatives was limited. The probit analysis showed that various factors significantly influenced participation, including education, age, poverty and welfare, land-tenure system, family labour, access to resources, access to information, incentives for change and tangible benefits ($p<0.05$). Key challenges included inadequate access to training, weak institutional support and unclear legal frameworks.

The study concludes that improving participation requires strategies such as capacity building, improved transparency, stronger enforcement of rangeland laws and community-based approaches. Future research should consider the broader range of stakeholders involved in rangeland conservation and management, including herders, women, local authorities, government agencies and non-governmental organisations. It is also recommended that livestock owners' capacity be enhanced and sustained through regular training and workshops that equip them with the skills needed for sustainable practices. Additionally, prioritising the control of shrubs and invasive species through targeted programmes is essential.

Keywords: community-based natural resource management, livestock owners' participation, perceptions, rangeland conservation, rangeland management, participation strategies

Participation of women in wetland conservation and management: The case of the Malibamatšo sub-catchment, Butha-Buthe District, Lesotho

By Tsepo Ramokuena

Abstract

Wetlands are vital ecosystems globally, essential for biodiversity, water regulation and sustaining livelihoods. In Lesotho, these functions are particularly critical for women, yet many wetlands are experiencing degradation due to unsustainable use.

This study investigated women's perceptions of wetland conditions, their participation in conservation and management, and the factors influencing their involvement in the Malibamatšo sub-catchment (SC11) of Lesotho's Butha-Buthe District. A mixed-methods approach was employed: structured questionnaires were completed by 60 women, with quantitative data analysed using descriptive statistics and probit regression in SPSS. Additionally, 11 key informant interviews provided qualitative data, which were thematically analysed.

Results revealed significant ecological decline in the SC11 wetlands, which most women perceived as being in 'poor' or 'very poor' condition. Reported indicators included reduced water availability, increased soil erosion, vegetation loss and shifts in plant species composition, with severe repercussions for local biodiversity, ecosystem services and community livelihoods. Women actively contributed to conservation efforts through manual and supportive tasks such as building gabions and leading awareness campaigns. However, their access to strategic decision-making, leadership or policy advocacy was limited, reflecting persistent gender disparities. Probit analysis showed that education, age, economic constraints, access to resources and information, and support from community leaders significantly influenced participation ($p<0.05$). Key barriers included inadequate training, weak institutional support and economic burdens.

Enhancing women's participation in sustainable wetland management requires strategies such as capacity building, improved transparency, stronger enforcement of wetland laws and community-based approaches that address these barriers directly. Future research should include a wider range of stakeholders involved in wetland conservation and management, including herders, women, local authorities, government agencies and non-governmental organisations. These findings offer practical insights for designing inclusive and sustainable wetland management strategies in Lesotho and similar contexts, providing an empirical basis for policy reform and contributing to Sustainable Development Goals related to gender equality (SDG 5) and ecosystem protection (SDG 15).

Keywords: women's participation, wetland degradation, wetland condition, participation factors, sustainable wetland management, conservation strategies

Qualitative assessment of gully erosion dynamics and drivers in the Puete micro-catchment, Maseru District, Lesotho

By Mpho Sekese

Abstract

Soil erosion is a significant environmental and socio-economic challenge in Lesotho, with gully erosion posing a severe threat to land productivity, water resources and rural livelihoods.

This research quantitatively assessed the temporal dynamics, underlying drivers and mechanisms of gully expansion of the Puete micro-catchment in the Maseru District, Lesotho. A mixed-methods approach was employed, integrating the geospatial analysis of historical satellite images; field and laboratory analysis of soil samples to determine physicochemical properties; topographic analysis using a digital elevation model (DEM); and rainfall analysis using Climate Hazards Group Infrared Precipitation Station (CHIRPS) data. Statistical analyses, including analysis of variance (ANOVA), correlation analysis and random forest (RF) modelling, were used to determine variable importance, while future gully expansion was forecast using an autoregressive integrated moving average (ARIMA) time-series model.

The findings show that the Puete gully expanded from 3,714 m^2 in 2004 to 6,362 m^2 in 2023, representing a 71% cumulative gully increase and an average expansion rate of 139.4 m^2 per year. The expansion was episodic, with a statistically significant acceleration around 2013, often following intense rainfall events. ARIMA forecasts estimate an additional 1,050 m^2 of land loss by 2028 if current trends persist. Topographic factors – particularly drainage area – emerged as the most influential variable in gully expansion, followed by cation-exchange capacity (CEC) and annual total rainfall. High sand content and low organic carbon at the gully head increased erodibility and susceptibility to subsurface erosion, while CEC was a significant predictor. Sodicity indices such as sodium adsorption ratio (SAR) and exchangeable sodium percentage (ESP) were below standard thresholds, making their role inconclusive. Total annual rainfall showed a weak positive correlation with gully expansion; rainfall intensity also reflected a weak correlation, although episodic high-intensity storms triggered rapid expansion.

It is therefore concluded that the Puete gully is rapidly expanding due to both surface and subsurface erosion, posing serious risks to local agriculture, water resources and livelihoods. Effective management will require an integrated, community-based approach that addresses environmental and human drivers. The analysis of contributing factors also establishes an essential baseline for evaluating the success of future conservation and rehabilitation interventions, supporting adaptive management.

Keywords: gully erosion, soil erosion models, geospatial analysis, soil physicochemical properties, topographic factors, ARIMA forecasting

Assessment of heavy metals and their impacts on aquatic ecosystems and river health in the Mohokare River, Lesotho, using SASS-5

By Sephooko Sepono

Abstract

To improve freshwater monitoring in southern Africa, this study recommends integrating chemical analysis with biological biomonitoring frameworks, such as the South African Scoring System version 5 (SASS-5), to detect ecological degradation early. This investigation assessed heavy-metal contamination and its ecological impacts on the Mohokare River, a transboundary river flowing between Lesotho and South Africa. Sampling was conducted at six strategically selected sites: Matsoaing (control site in Butha-Buthe), Matlakeng, Mohloka-qala, Ha Fusi, Ha Setho and Bolikela (in Mafeteng). These sites represent gradients of pollution, from upstream pristine conditions to downstream urban and agricultural zones.

Water and sediment samples were analysed for iron (Fe), zinc (Zn), copper (Cu), manganese (Mn) and lead (Pb) using atomic absorption spectroscopy (AAS). Sediment extraction involved Van Veen grab sampling and aqua regia digestion (HNO_3 and HCl) under controlled heating. Biological assessments were conducted using SASS-5 and average score per taxon (ASPT) metrics, with macroinvertebrates sampled via standardised kick sampling.

Results showed that Pb concentrations in water exceeded the South African aquatic-ecosystem standard (0.01 mg/L) at all sites, reaching up to 0.065 mg/L at Bolikela. Fe concentrations also surpassed acceptable levels (0.3 mg/L) at four sites, peaking at 2.45 mg/L. In contrast, sediment-bound metal concentrations remained within Canadian Sediment Quality Guidelines. The cleanest site, Matsoaing, recorded the highest SASS-5 (104) and ASPT (7.43) scores, indicating excellent ecological condition, while Ha Setho and Bolikela, downstream of Maseru, had the lowest scores (SASS-5: 38 and 46; ASPT: 4.22 and 4.60 respectively).

Multivariate analyses, including Spearman's correlation and principal component analysis (PCA), revealed strong negative correlations between Pb, Fe and the biological indices. These statistical insights helped pinpoint pollution sources and demonstrated a spatial pattern aligned with land-use impacts, especially urban effluents near Maseru and agricultural runoff downstream.

This study demonstrates that elevated heavy metal concentrations, particularly Pb, are linked to macroinvertebrate diversity loss and deteriorating river health. It emphasises the value of combined chemical-biological assessments in identifying pollution hotspots and guiding catchment management in data-scarce transboundary rivers.

Keywords: Mohokare River, heavy metals, South African Scoring System version 5 (SASS-5), macroinvertebrates, river health

Assessing the effects of Ts'osane dumpsite leachate on the water quality of Ts'osane runoff stream in Maseru, Lesotho

By Patrick Daniel Tsukulu

Abstract

Improper solid-waste disposal through open dumping presents environmental challenges such as water contamination and ecological degradation.

This study investigated the effects of leachate from the Ts'osane dumpsite on the Ts'osane runoff stream in Maseru, with a focus on water quality and potential environmental risks. The assessed physicochemical parameters included temperature, pH, dissolved oxygen (DO), electrical conductivity (EC), total dissolved solids (TDS), chloride (Cl^-), nitrate (NO_3^-), chemical oxygen demand (COD) and the metals copper (Cu), iron (Fe), manganese (Mn), lead (Pb) and zinc (Zn). Field sampling, on-site measurements and standard laboratory analyses were conducted across six sampling sites. Statistical techniques included descriptive analysis, Pearson correlation and principal component analysis (PCA), along with water-quality indices.

At the dumpsite pond (SD), COD (2,685.67 mg/L) exceeded the limits set by both the South African Department of Water Affairs and Forestry (DWAF) aquatic-ecosystem guidelines and the World Health Organization (WHO) drinking-water guidelines (10 mg/L). The TDS (6,694.33 mg/L) exceeded DWAF (450 mg/L) and WHO (500 mg/L) limits, while Fe (7.47 mg/L) exceeded the 0.3 mg/L guideline for both standards. Mn (2.59 mg/L) exceeded DWAF (0.1 mg/L) and WHO (0.01 mg/L) limits, and Pb (0.22 mg/L) exceeded DWAF (0.005 mg/L) and WHO (0.08 mg/L) limits. Nitrate (NO_3^-) concentrations (253.77 mg/L) were above DWAF (10 mg/L) and WHO (50 mg/L) thresholds. DO (1.70 mg/L) fell below the minimum 5 mg/L safe limit.

At the SP2 mixing site, increases were observed relative to the SP1 site in TDS (149.33 to 454.33 mg/L), EC (293.67 to 885.67 µS/cm), NO_3^- (6.79 to 16.23 mg/L) and Mn (0.11 to 0.13 mg/L), indicating potential leachate influence. At the SP3 site, several parameters remained above guideline limits, although declining levels downstream at SP4 and SP5 suggest the possibility of natural attenuation.

PCA identified three primary drivers explaining 85.8% of variance. Strong correlations were observed between COD–Fe (r=0.835), COD–Mn (r=0.854) and TDS–Cl^- (r=0.973). Additionally, the weighted arithmetic water quality index (WAWQI) ranged from 191.43 to 2058.05, with the lowest value at SP5 and the highest at the dumpsite pond (SD).

Overall, the findings may provide a critical baseline for mitigating contamination and protecting aquatic ecosystems. The study concludes that leachate from Ts'osane dumpsite degrades the water quality of the Ts'osane runoff stream and poses risks to aquatic ecosystems and potentially to human health. The water quality index (WQI) classified all sites as unsuitable for drinking without treatment. The study recommends engineered containment, leachate treatment and policy reforms aligned with sound municipal solid-waste (MSW) management practices to protect water resources and aquatic ecosystem health.

Keywords: leachate contamination, surface-water pollution, improper waste dumping, environmental risks, urban MSW management, water quality

Circular economy of solid waste management of open dumpsites in the Upper Mohokare catchment, Lesotho

By Lebohang Tlhatlosi

Abstract

Open dumpsites, common in developing countries, create serious health, environmental and socio-economic challenges by attracting pests, degrading water and air quality, and affecting nearby communities. In Lesotho, rising urbanisation and rural-to-urban migration have exacerbated this crisis due to limited waste management infrastructure and a continued reliance on open dumping and burning. Despite regulatory efforts, existing dumpsite management practices remain largely unsustainable, with consequences for both ecosystems and livelihoods.

This study aimed to determine the socio-economic and environmental impacts of solid-waste disposal in open dumpsites in the Upper Mohokare catchment from a circular economy perspective. A mixed-methods approach was used, incorporating qualitative ethnographic observations, desktop studies and structured questionnaires, intentionally selected to capture the complexity and contextual specificity of waste management dynamics in the area.

The findings indicate that incoherent policies, inadequate infrastructure and rapid urbanisation significantly undermine Lesotho's waste management system. The continued prevalence of open dumping and waste burning highlights the urgent need for improved infrastructure and a coherent waste management policy framework. The study further suggests that applying circular economy principles can help mitigate environmental impacts while addressing the social and economic challenges associated with open disposal sites. This study recommends legislative reforms that explicitly incorporate circular economy principles and harmonise and standardise waste management policies and regulations.

Keywords: solid waste, dumpsite, linear economy, circular economy, transition

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