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# Mires in the Maluti Mountains of Lesotho

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## SUMMARY

Lesotho is a landlocked country located in the south-eastern interior of South Africa. It is mountainous, with altitudes ranging from 1388 to 3482 m a.s.l. This article focuses mostly on mires occurring above 2750 m a.s.l. in the alpine region of Lesotho, that are characteristically devoid of trees due to the high altitude. Mountain mires in Lesotho are usually fed by groundwater and intermittent runoff from adjacent slopes. Few of them are in near-pristine condition and most have been severely degraded. Erosion has enhanced the drainage and desiccation of peat resulting in combustion of peat layers at several sites. The main threats to the mires include overgrazing and trampling by domestic animals on communal land, increased development as a result of the Lesotho Highlands Water Project, and diamond prospecting and mining. Attempts at rehabilitation have met with varying degree of success.

**KEY WORDS:** alpine vegetation; bog; fen; frost heaving; ice rats; thúfur

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## INTRODUCTION

Southern Africa is, in general, a semi-arid region with low and variable rainfall where mires are less common than in wetter temperate climates (Grundling *et al.* 2013). However, rainfall increases eastwards towards the Maluti Mountains and the enclaved country of Lesotho. Because the catchment areas of Lesotho receive some of the highest annual precipitation totals in southern Africa, this country is an extremely important source of water for the numerous semi-arid and arid areas downstream (Matete & Hassan 2005, Nel 2009). At the heart of the Maluti-Drakensberg Transfrontier Park between Lesotho and South Africa, immediately adjacent to South Africa's Quathlamba-Drakensberg World Heritage and Ramsar sites, numerous mires occur at higher altitudes and these contribute not only to local biodiversity but also to the importance of this region as the principal water reserve in southern Africa (Grab 2010, Nel 2009). The mires and wetlands occurring in this alti-montane zone or alpine region form the headwaters of the Senqu River (known as the Orange River in South Africa). The headwater tributaries also feed the Katse Dam, part of the Lesotho Highlands Water Project (Nüsser 2003) which will both generate hydro-electricity for Lesotho and transfer water to South Africa's most densely populated industrial heartland in Gauteng Province (Quinlan 1995).

It has been acknowledged by various authors that

the mountain wetlands of Lesotho are unique (Van Zinderen Bakker 1955, Backéus 1988). Various mires were assessed in 2001 and 2002 as part of the South African land cover project and the IMPESA initiative (Identification and Mapping of Peatlands in Southern Africa; Sliva & Grundling 2002) as well as during the International Mire Conservation Group (IMCG) Lesotho field symposium in September 2004, mostly in the upper catchments of the Senqu River in north-eastern Lesotho as well as the area towards Qachas Nek in southern Lesotho.

This article reviews literature sources and information collected during the various field excursions. We first describe the setting and main features of the Maluti Mountains mires. We then give an overview of threats and the mechanisms by which these mires have become so severely damaged that hardly any pristine examples remain, as a basis for developing an appropriate approach to their rehabilitation.

## STUDY AREA

### Geology and topography

The Maluti Mountains of Lesotho (Figure 1) are divided into three ranges, namely: the Quathlamba Range (Drakensberg Range) stretching from north-west to south-east in the north-western part of the country, which is the highest of the three ranges and forms a massive escarpment on the South African

side; the Thaba-Putsoa Range stretching from west to east; and finally the Central Range which is located in between the other two ranges. Basaltic lava 1500 m deep covers 73 % of the landscape and is underlain by, among other deposits, the whitish sandstone of the Clarence formation which separates the lowlands from the foothills (Backéus 1988). In the early Jurassic, basaltic lavas extruded through earthquake-induced fissures in the sandstone. During and after the lava flow, intrusions occurred forming dolerite and gabbro dykes followed by kimberlite pipes.

The land rises steadily to the north-west, with the foothills forming a narrow strip between 1800 and 2300 m a.s.l. and the actual mountainous region of the Maluti, starting from approximately 2200 m a.s.l., dominating most of the country. Highlands comprise 80 % of Lesotho's surface area and

include Thabana Ntlenyana (3482 m a.s.l), the highest mountain in southern Africa (Grab *et al.* 2009). The mountainous area is characterised by valleys with flat floors and steep sides, and level platforms on top of the steep lava slopes. Soils are shallow or absent, especially on the slopes.

Lesotho's largest river, the Senqu, rises in the Central and Quathlamba Ranges. Its tributaries have cut deep valleys in the basalt lavas, and the lowlands in the south-western part of the country are covered by alluvium, colluvium and aeolian deposits (Backéus 1988). As it leaves the Maluti Mountains, flowing west towards the Atlantic Ocean, the Senqu is re-named the Orange River.

### Climate

The interior uplands receive much less rainfall than the surrounding ridges because they lie in the rain

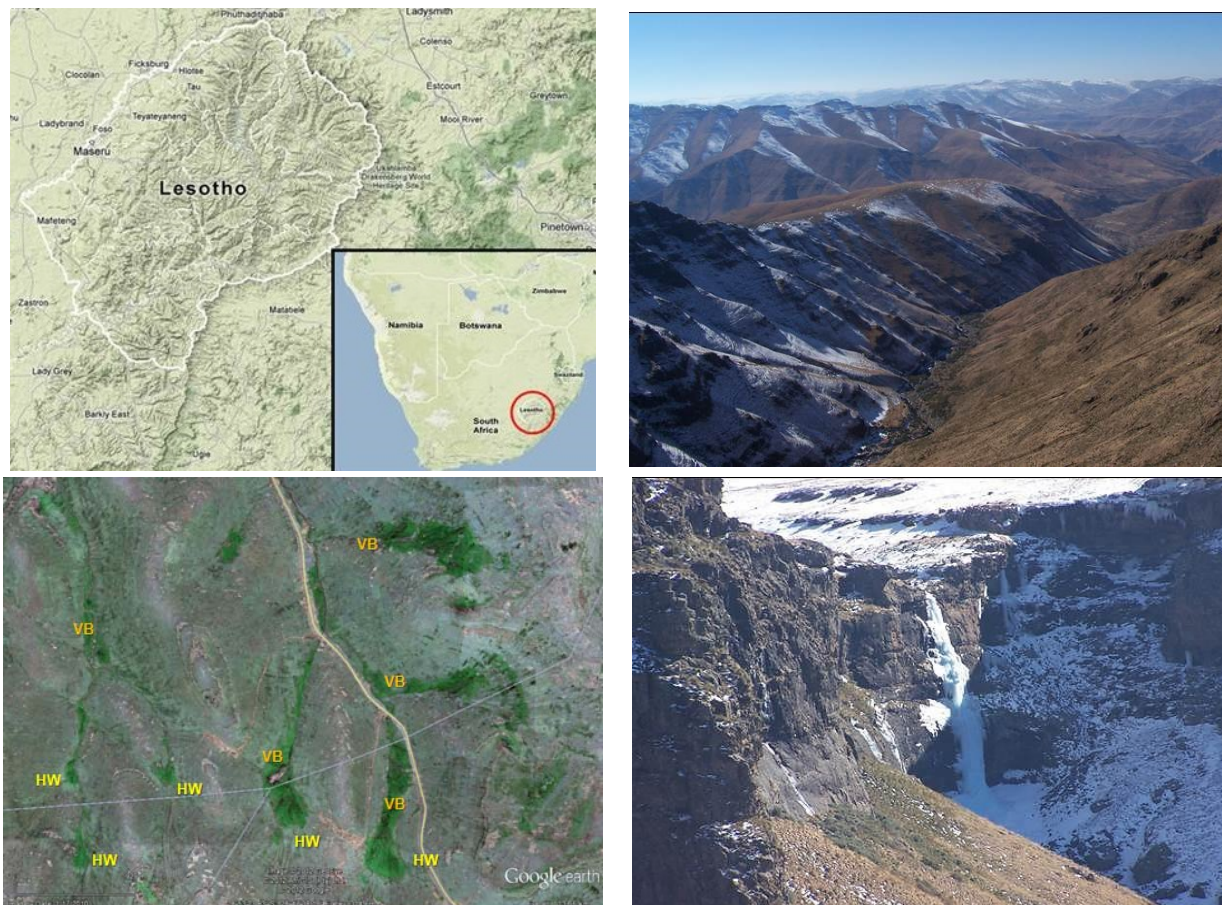


Figure 1. Upper left: maps showing the location of Lesotho, which is a landlocked country within the borders of the Republic of South Africa. Upper right: a winter view of the Maluti Mountain landscape. Lower left: satellite image (Google Earth 2010) of the upper tributaries of the Maliba-Matšo River showing the drainage pattern and occurrence of small peatlands (green) in the landscape; HW=headwater mire, VB=valley-bottom mire. Lower right: an outcrop of the basaltic lava which forms the weathering- and erosion-resistant cap of the Maluti Mountains, with frozen waterfall.

shadow of the mountains. High rainfall occurs especially on the high Quathlamba Range, which helps explain the prominence of mires in this part of Lesotho. The rainfall characteristically arrives in the form of very heavy thundershowers delivering high-intensity precipitation over short periods of time, the result being an environment prone to erosion. Annual rainfall can be as high as 1600 mm at Oxbow (2630 m a.s.l.) in the north-east, with the largest portion falling during the summer months (Van Zinderen Bakker & Werger 1974). Between May and September, heavy snowfall occurs occasionally over the entire country. In the mountain zone there are, on average, eight snowfall days per year with snow depths ranging from < 5 to 120 cm (Grab & Linde 2014), representing an average of about 100 mm of precipitation per year (Nel 2009).

Temperatures above 2500 m a.s.l. are typically cool (not exceeding 16 °C) during the summer months and cold in winter with snow that can persist especially on the southern slopes. The temperature at the soil surface remains below freezing point throughout the year (Van Zinderen Bakker & Werger 1974). The high daytime temperatures are caused by the high degree of insolation, resulting in strong diurnal temperature differences, particularly in the mountainous area (Backéus 1988).

### Vegetation

Mountain grasslands cover most of the subalpine belt, which lies roughly in the altitude range 2290–2900 m a.s.l. (Backéus 1988, Acocks 1988). Two main types of grassland can be distinguished: (i) ‘seboko’ (*Themeda triandra* grassland) and (ii) ‘letsiri’ (*Festuca caprina* grassland). True alpine mountain grassland occurs above 2900 m a.s.l. (altimontane or alpine zone). The vegetation here consists of species that are common in sclerophyllous heath communities, such as *Erica dominans*, *Erica glaphyra*, *Helichrysum trilineatum*, *Passerina montana* and *Inulanthera thodei*. This vegetation type extends to the summit of Thabana-Ntlenyana.

## THE MIRES

In Lesotho’s highland region, flat tracts of land at the top ends of valleys (or headwaters) are commonly and extensively occupied by treeless mires. Sloping mires are much smaller, occur mostly on the footslopes and midslopes of north-facing gradients, and are commonly clustered together to form composite wetland systems. The

wetlands in lower-lying areas below 2750 m a.s.l. are usually marshes (called “vleis” in southern Africa; not peat-forming). These are known as ‘valley bottom wetlands’, often flank stream channels, and are dominated by tall grasses and sedges.

### Vegetation

In the subalpine zone mires are typically infrequent, small and mostly dominated by *Merxmuellera macowanii* (moesha grass), which is unpalatable to livestock and forms tall tussocks. In very wet parts of such mires the sedge *Isolepis fluitans* dominates the vegetation and forms lawn-like swards that are heavily grazed (Backéus 1989).

Mires are more frequent from 2750 to 3300 m a.s.l. within the alpine zone, and *Isolepis fluitans* dominated mires are also more common here. Otherwise, the vegetation of these mires consists of a mixture of aquatic plants (including *Crassula natans*, *Lagarosiphon muscoides*, *Limosella capensis*, *Nitella* sp. and *Colpodium hedbergii*) and terrestrial plants (with species like *Ranunculus meyeri*, *Scirpus fluitans*, *Limosella longiflora*, *Agrostis subulifolia*, *Haplocarpha nervosa* and *Aponogeton junceus*). Rosette plants such as *Senecio cryptolanatus*, *Cenia hispida*, *Helichrysum bellum*, *Athrixia fontana* and the mat-forming *Trifolium burchellianum* occur on areas of drier mire (for an overview, see Van Zinderen Bakker & Werger 1974). Most of the species present are not restricted to mountain mires (Van Zinderen Bakker *et al.* 1974) but some of them, like *Haplocarpha nervosa* and *Athrixia fontana*, occur only in the Lesotho alpine zone.

The vegetation on the slopes and plateaux surrounding the mires is characterised by the small tussock grass *Koeleria cristata*.

### Microtopography

Microtopography is a common and interesting feature of the Lesotho mires. Hummocks (Figure 2), called “thúfur” by Van Zinderen Bakker & Werger (1974), are structures of diameter of 50–70 cm and height 20–30 cm that cover extensive parts of several mires above 2800 m a.s.l. (Grab 2005). The general consensus is that these hummocks are formed as a result of a combination of factors, including surficial frost-sorting, wind erosion and peat deposition. Their vegetation consists of *Merxmuellera macowanii*, *Lobelia galpinii*, *Carex flava* and *Helichrysum flanaganii*, species which are not restricted to mires (Van Zinderen Bakker & Werger 1974). Earth hummocks can be damaged, especially if their surfaces are exposed to the



Figure 2. Hummocks, called thúfur, are common microtopographical features on the mires of the Lesotho mountains (upper left). The mires are fed by springs that discharge groundwater from underground flow paths (upper right). Sometimes the discharge of groundwater is so strong that a small fountain emerges (middle left). The middle right photo shows very shallow stream patterns that transport surface water without causing peat erosion. However, when groundwater levels in the mire drop the thúfur dry out (bottom left) and eventually break open (bottom right).

elements by removal of the vegetation. When the peat is desiccated it can crack (Figure 2), allowing rainwater to infiltrate (Van Vliet Lanoë 1988).

### Peat formation

Members of the 2004 IMCG field excursion described peat profiles in several mires in the headwaters of the Maliba-Matšo, Motete and Motsoku Rivers and in the Mokhotlong and Butha-Buthe Districts. They generally found rather well-decomposed radicell peat, which is formed from the roots of vascular plants with few bryophytes present (Figure 3). Backéus & Grab (1995) found that, moving from middle to high altitudes, the thickness of the peat layers in mires gradually increases from less than 10 cm to several metres (up to 4 m of peat was noted in eroded gullies during the IMCG field symposium in 2004). This increase in peat thickness can be related to the increase in rainfall with altitude in the Maluti Mountains (Schwabe 1995). The stratigraphy of mires in the Lesotho alpine areas often consists of peat with interbedded gravel layers, which points to the regular occurrence of alluvial fans (Figure 4) arising from erosion of the surrounding landscape, particularly on the steeper slopes. Grundling & Marneweck (2003) pointed out that these fans deposit eroded gravels onto the

surfaces of mires and that with time these gravels become incorporated into the peat layer as part of the sediment accumulation process.

It was noted during the various field visits that small peat domes often occur at breaks in slope within or on the edges of the mires. These domes typically rise to 0.5–1 m above the surrounding landscape and their areas do not usually exceed 500 m<sup>2</sup>. Water was often seen discharging at low rates from these domes in the wet season and augering into their cores confirmed that the peat was underlain by unsorted and coarse gravel (Figure 4).

### Bogs or fens?

Early authors agreed that the peatlands of the Lesotho mountains should be classified as bogs (Guillarmod 1963, Van Zinderen Bakker & Werger 1974, Schwabe 1995), with the last of these authors defining a bog as a peatland with an isolated hydrological system and no major streams entering or leaving. The low pH values (between 4 and 5) measured in the topsoils of the peat (Van Zinderen Bakker & Werger 1974) appeared to support this idea. However, such a definition of a bog is not generally accepted. Most authors define bog as a mire type whose vegetation is exclusively influenced by precipitation water (Wheeler *et al.*



Figure 3. Radicell peat, which dominates the stratigraphy of the Lesotho mires. Photos: Olivier Olgiati.

1995, Succow & Joosten 2001). Backéus & Grab (1995) realised that these mires are influenced by surface water that regularly floods the mire: “after rains, which are often extremely heavy, muddy water flows onto the mire, thus preventing the development of ombrotrophic mires”.

The mires of the Lesotho mountains are, in essence, relatively small sloping mires. Peat formation can be sustained under such conditions only if there is a regular supply of groundwater in addition to precipitation, and artesian springs are the only possible source. The groundwater is usually rich in minerals, since the underlying basalt is rich in CaO, K<sub>2</sub>O and P<sub>2</sub>O<sub>5</sub> and has a pH of about 8. Mires may also occasionally receive runoff water from the steep slopes after heavy rains. This water is often very muddy and, therefore, influences the nutrient conditions of the mire (Backéus & Grab 1995).

An interesting observation from the IMPESA study (Sliva & Grundling 2002) and the 2004 ICMG

field symposium was that none of the investigated mires (50 examples in three parts of Lesotho, two northern and one southern) could be classified as bogs. The mires sampled during the field assessments were classified as fens because they were in the headwaters of various drainage lines with clear evidence of groundwater discharge (e.g. iron precipitation, seepage zones and artesian springs) or open-ended wetland systems that received some inflow from surrounding catchments and streams flowing through them. Therefore, perhaps the non-rainwater-fed “bogs” of Lesotho should be termed fens in future.

## THREATS

### Human activities

Many wetlands in Lesotho have been degraded as a result of human activities (Figures 4 and 5) ranging from agricultural practices (mainly livestock



Figure 4. Upper left: a typical mire in the headwaters of a tributary, which looks pristine but note the erosion gully at the left and right sides of the photo. Upper right: close-up of the upper left photo, showing a surface-water feeder channel and an alluvial fan on the mire. Lower left and right: severe erosion of peat exposing gravel beds, which are highly permeable to water.

husbandry; Hall & Lamont 2003) to infrastructure development, damming and diamond mining (Backéus & Grab 1995). The Lesotho Highlands Water Project flooded fertile valleys, displacing grazing pressure onto (especially) communal alpine areas. In any case, increasing demand for grazing land and pasture degradation at lower altitudes have increasingly disrupted the traditional transhumance system during recent years (c.f. Grab & Nüsser 2001) with the result that many livestock herds nowadays spend the winter months on high-altitude ‘summer’ pastures, despite the greater exposure to snow and cold (Grab & Linde 2014). Sedge-grass headwater mires offer some of the most desirable grazing in Lesotho’s highland region, and the very high grazing pressure has now turned these mires into the most degraded of all wetlands in Lesotho.

**Erosion**

The regular occurrence of gravel layers in the peat indicates regular disturbance of the hydrological

conditions, most probably by severe flooding from the mountain slopes. Thus, a question remains as to whether the erosion processes that can now be observed in almost all of Lesotho’s peatlands are natural (climate-induced) or human-induced phenomena. Under natural conditions a mire recovers from such severe erosion events, leading to renewed development of fine-grained to medium-fine-grained peat layers, as can be seen in almost all of the peatlands studied. The layers of new peat cover the gravel layers and prevent the rapid release of groundwater from these tiny aquifers. However, when human-induced erosion starts cutting through the peat layers, the gravel layers are re-exposed and can start discharging groundwater again, thus accelerating the erosion process (Figure 4). In such cases, direct on-site management measures are urgently needed to curb further deterioration of the wetlands, especially by storm water runoff from new tar roads (Backéus & Grab 1995) and overgrazing by livestock.



Figure 5. When surface water erosion has lowered groundwater levels (upper left), precipitation water can directly enter the surface layer of soil and, during frost, needle ice is formed (upper right). The ice needles can crush larger peat particles, which weakens the peat structure (lower left) and makes the mire more susceptible to erosion by surface overflow (lower right).



Small rodents including the African ice rat (*Otomys sloggetti robertsi*) can have a large effect in erosion-impacted peatlands. Such digging rodents create large burrow systems in former mires (Figure 6). This contributes to the process of desiccation (Hall & Lamont 2003). Tunnels that are connected to one another down a slope lead to water being transported faster downhill, and canalisation. Digging loosens the soil, making it less stable, and flowing water can transport loose soil particles. Moreover, these animals eat plants, in particular their roots. The soil around the roots becomes loose and dry, leading to more erosion and reducing the productivity and cover of the vegetation (Hall & Lamont 2003). When the vegetation is gone and bare soil is left, the effect of the roots in binding soil particles together is also lost. Because oxygen can penetrate into deeper layers of loose soils,

decomposition is stimulated by the digging rodents. Furthermore, invasive plant species such as *Chrysocoma ciliata* colonise these desiccated mire areas (Grab & Deschamps 2004), posing a threat to the biodiversity of the alpine region.

When cold rainwater gets into the topsoil, needle ice can form (Figure 5). Needle ice formation occurs above 3100 m and results from the alternation of freezing and thawing processes. The formation of needle ice in earth hummocks can cause 'heaving' of soil particles (frost heaving), which damages the hummocks (Van Zinderen Bakker & Werger 1974, Grab 2002). Also, when needle ice is formed, it can crush the large organic particles that make up the peat, transforming them into smaller particles which can be eroded more easily (Van Zinderen Bakker & Werger 1974).

Gully erosion occurring in mineral soils

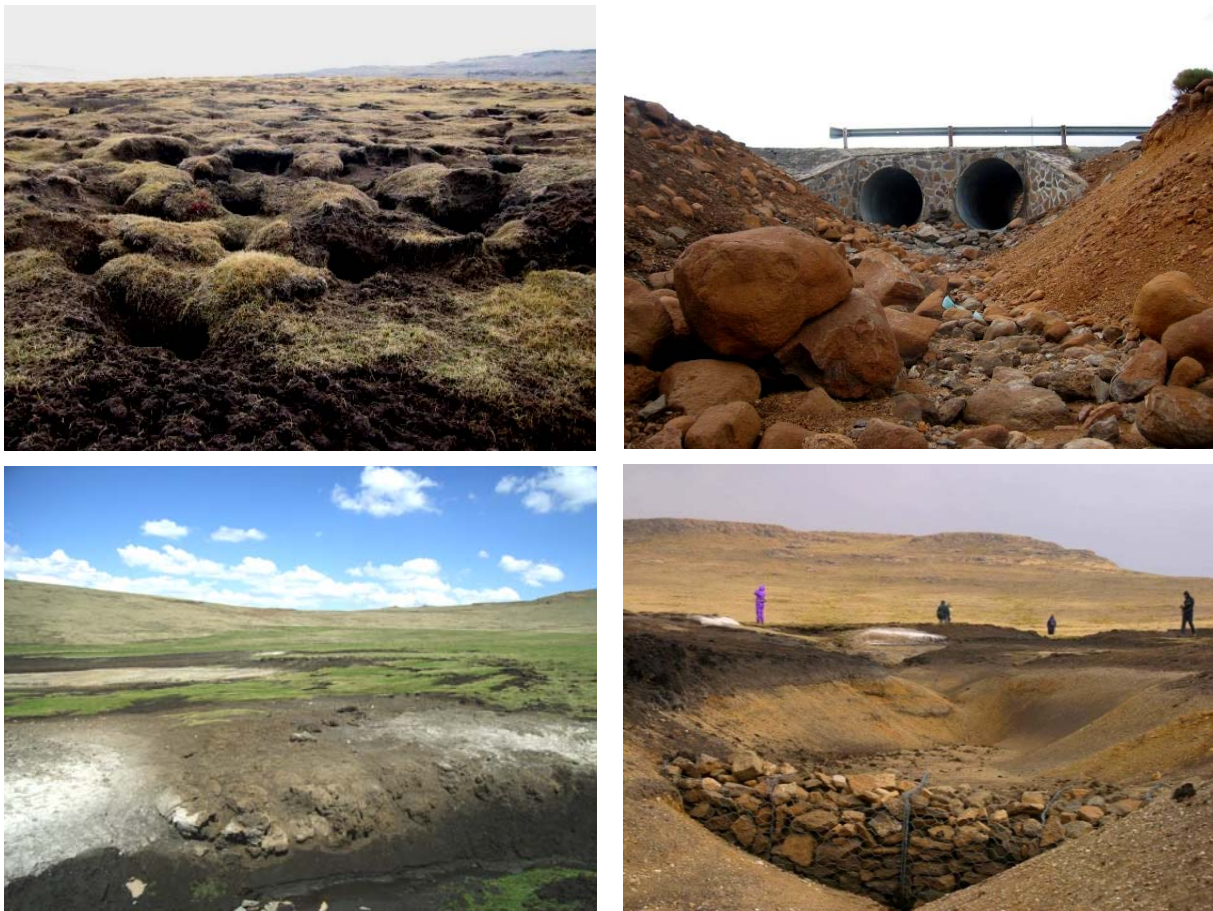


Figure 6. Drying of the peat facilitates invasion by ice rats, whose large burrows may seriously harm the peat (upper left). Erosion is also promoted by the construction of tar roads with culverts that channel storm water from upslope into the peatlands (upper right). Desiccation of the peat may lead to burning (lower left) and consequent large losses of peat soil. Even though not well constructed, rehabilitation measures (lower right) were still successful in arresting erosion and trapping sediment.

upstream of mires is especially significant in causing erosion in the more resilient mires as well. The loss of peat and degradation of the fen structure due to various impacts may, in turn, have serious upstream consequences for flow in the streams, causing flooding in downstream areas. It is also important to consider that peat accumulation rates in the Maluti mountains are slow ( $0.25 \text{ mm year}^{-1}$ ), and degradation of these mires due to erosion causing drainage, desiccation and burning of the peat often results in carbon release.

A summary of the factors influencing peat erosion in these mires is presented in Figure 7. It is disturbing that all of the factors mentioned trigger positive feedback mechanisms that promote and accelerate peat erosion. Thus, it is likely that only substantial human interventions can halt it.

## DISCUSSION

The alpine mires of Lesotho are unlike any other southern African mire type in terms of their landscape setting and the interleaving of peat and gravel beds in alluvial fans. The Maluti Mountains are relatively young in geological terms. Weathering and erosion processes are dominant across most of the landscape, which is in a state of constant change. In contrast, the occurrence of peatlands indicates

that rather stable and low-energy environmental conditions have prevailed over long time periods in some locations. Supporting evidence is available from mires that have been dated as being more than 8000 years old (Van Zinderen Bakker & Werger 1974). Considering the conditions that are required for mires to develop, these ages suggest that there must have been low-energy hydrological regimes in the mire locations over even longer periods of time. Further studies on these relatively small but interesting mires are urgently required.

Because most of the fens occur in the headwaters of major feeder rivers for the Katse Dam, their condition gives cause for concern relating to the long-term supply of good-quality water to the reservoir. It is likely that desiccation and erosion, particularly of the fens in the study area, has affected the carbon and water storage capability of these wetlands.

The loss in wetland function still needs to be determined in full but key benefits such as storage, filtering, erosion control, carbon storage, base flow maintenance, *etc.* have been severely impaired at most study sites. The prospects for the successful halting of further degradation of many of these systems will depend on the development and implementation of a long-term rehabilitation strategy, of which a key component will be on-site management and restoration.

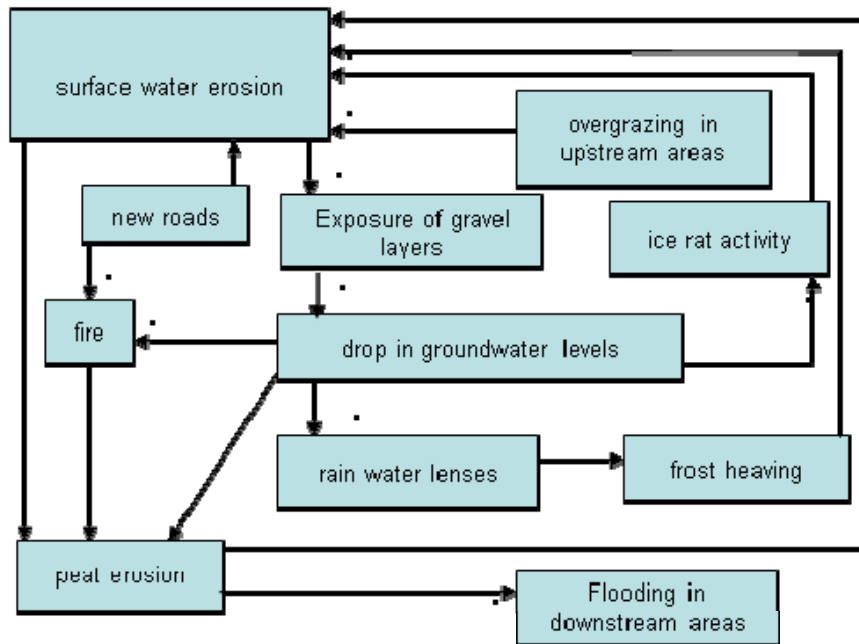


Figure 7. Positive feedback loops operating amongst the factors stimulating peat erosion.

Catchment-scale wetland rehabilitation should be initiated in the alpine zone of Lesotho. Some rehabilitation works did take place before 2004 but they were of poor quality (Figure 6). Rehabilitation focused mainly on arresting erosion and achieving partial re-wetting. Recent initiatives that also involve community education seem more promising, as they are also addressing aspects such as catchment degradation due to overgrazing (Quinlan 1995).

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## REFERENCES

- Acocks, J.P.H. (1988) *Veld Types of South Africa*. Third edition, Memoirs of the Botanical Survey of South Africa 57, Botanical Research Institute, Pretoria, 146 pp.
- Backéus, I. (1988) *Mires in the Thaba-Putsua Range of the Maluti, Lesotho*. Studies in Plant Ecology 17, Almqvist & Wiksell International, Stockholm, 88 pp.
- Backéus, I. (1989) Flarks in the Maluti, Lesotho. *Geografiska Annaler*, 71, 105–111.
- Backéus, I. & Grab, S. (1995) Mires in Lesotho. *Gunneria*, 70, 243–250.
- Grab, S. (2005) Aspects of the geomorphology, genesis and environmental significance of earth hummocks (thufur, pounus): Miniature cryogenic mounds. *Progress in Physical Geography*, 29(2), 139–155.
- Grab, S. & Nüsser, M. (2001) Towards an integrated research approach for the Drakensberg and Lesotho mountain environments: A case study from the Sani plateau region. *South African Geographical Journal*, 83(1), 64–68.
- Grab, S.W. (2002) A note on needle-ice mound formation in the High Drakensberg, Southern Africa. *Permafrost and Periglacial Processes*, 13, 315–318.
- Grab, S.W. (2010) Alpine turf exfoliation pans in Lesotho, southern Africa: Climate-process-morphological linkages. *Geomorphology*, 114(3), 261–275.
- Grab, S.W. & Deschamps, C.L. (2004) Geomorphological and geocological controls and processes following gully development in alpine mires, Lesotho. *Artic, Antarctic and Alpine Research*, 36, 49–58.
- Grab, S.W. & Linde, J.H. (2014) Mapping exposure to snow in a developing African context: implications for human and livestock vulnerability in Lesotho. *Natural Hazards*, 71(3), 1537–1560.
- Grab, S.W., Mulder, N.A. & Mills, S.C. (2009) Spatial associations between longest-lasting winter snow cover and cold region landforms in the High Drakensberg, southern Africa. *Geografiska Annaler*, 91A, 83–97.
- Grundling, P., Grootjans, A.P., Price, J.P. & Ellery, W.N. (2013) Development and persistence of an African mire: How the oldest South African fen has survived in a marginal climate. *Catena*, 110, 176–183. DOI: 10.1016/j.catena.2013.06.004.
- Grundling, P-L. & Marneweck, G. (2003) The alpine mires and Northern Lesotho. *International Mire Conservation Group (IMCG) Newsletter*, 2003/2, 4–7. Online at: <http://www.imcg.net/media/newsletter/nl0302.pdf>, accessed 05 May 2015.
- Guillarmod, J.A. (1963) Further observations on the bogs of the Basutoland Mountains. *South African Journal of Science*, 59, 115–118.
- Hall, K. & Lamont, N. (2003) Zoogeomorphology in the Alpine: Some observations on abiotic-biotic interactions. *Geomorphology*, 55(1), 219–234.
- Matete, M. & Hassan, R. (2005) An ecological economics framework for assessing environmental flows: The case of inter-basin water transfers in Lesotho. *Global and Planetary Change*, 47(2), 193–200.
- Nel, W. (2009) Rainfall trends in the KwaZulu-Natal Drakensberg region of South Africa during the twentieth century. *International Journal of Climatology*, 29(11), 1634–1641.
- Nüsser, M. (2003) Political ecology of large dams: a critical review. *Petermanns Geographische Mitteilungen*, 147(1), 20–27.
- Quinlan, T. (1995) Grassland degradation and livestock rearing in Lesotho. *Journal of Southern African Studies*, 21, 491–507.
- Schwabe, C.A. (1995) Alpine mires of the eastern highlands of Lesotho. In: Cowan, G.I. (ed.) *Wetlands of South Africa*. Department of Environmental Affairs and Tourism, Pretoria, 33–40.
- Sliva, J. & Grundling, P-L. (2002) *Identification and Mapping of Peatlands in South Africa (IMPESA): Evaluation of Resources*. IMPESA, Pretoria and Freising, 440 pp.

- Succow, M. & Joosten, H. (eds.) (2001) *Landschaftsökologische Moorkunde (Landscape Ecology of Peatlands)*. Second edition, Schweizerbart'sche Verlagsbuchhandlung (Nägele und Obermiller), Stuttgart, 622 pp.
- Van Vliet Lanoë, B. (1988) The genesis of cryoturbations and their significance in environmental reconstructions. *Journal of Quaternary Science*, 3, 85–96.
- Van Zinderen Bakker, E.M. (1955) A preliminary survey of the peat bogs of the alpine belt of northern Basutoland. *Acta Geographica*, 14, 413–422.
- Van Zinderen Bakker, E.M. & Werger, M.J.A. (1974) Environment, vegetation and phytogeography of the high-altitude bogs of Lesotho. *Vegetatio*, 29, 37–49.
- Wheeler, B.D., Shaw, S.C., Fojt, W.J. & Robertson, R.A. (eds.) (1995) *Restoration of Temperate Wetlands*. John Wiley & Sons Ltd., Chichester, 13–14.
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