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• Land degradation – High mountains – Southern Africa – Pastoral ecology

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Land Degradation and Soil Erosion in the Eastern Highlands of Lesotho, Southern Africa

Landdegradierung und Bodenerosion im östlichen Hochland von Lesotho, südliches Afrika

With 6 Figures, 2 Tables and 5 Photos

The high-altitude grasslands and wetlands of eastern Lesotho (Maloti-Drakensberg) have been transformed by livestock grazing, burning and fuelwood collection over the past decades. Multifunctional utilisation of vegetation resources contributes to contemporary land cover changes in the peripheral high mountain region of southern Africa. The sustainability of regional land use patterns has been challenged by ongoing grassland degradation and accelerated soil erosion as a result of a generally high and continuous anthropo-zoogenic impact. A better understanding of recent landscape changes and land degradation in pastorally transformed environments requires an assessment of natural resource potentials, vegetation status and erosion processes.

1. Introduction

Mountain systems should be considered to be among the most important of the world's ecosystems as they are often sources of water, energy and biological diversity (Messerli and Ives 1997). In order to understand contemporary change and persistence of mountain environments, aspects of resource utilisation and resource potentials need to be analysed through integrated research approaches. Over the past 120 years, the high-altitude grasslands of eastern Lesotho (Maloti-Drakensberg) have been used as a valuable pastoral resource for the subsistence of the local Basotho population (Quinlan 1995, Nüsser 2001, 2002a). In addition, the eastern highlands of Lesotho serve as an important hydrological reservoir and watershed for much of southern Africa,

contributing water to the Senqu (Orange in South Africa) drainage basin with a yield of 112 m³/s (Makhoalibe 1999). The Lesotho Highlands Water Project (LHWP), one of the largest civil engineering and most massive infrastructure projects in sub-Saharan Africa, has now completed the first phase of a major water diversion project. By damming the headwaters of the southwest-flowing Senqu River, the inter-basin transfer scheme is designed to divert approximately 70 m³/s of water northwards into the Vaal River. The water transfer scheme intends to supply water for the Gauteng province, the metropolitan and industrial heartland of South Africa, including the major cities of Johannesburg and Pretoria (Gleick 1998). A regular supply of clean water from the catchment areas is a crucial precondition for this hydrological project. In order to secure perennial run-

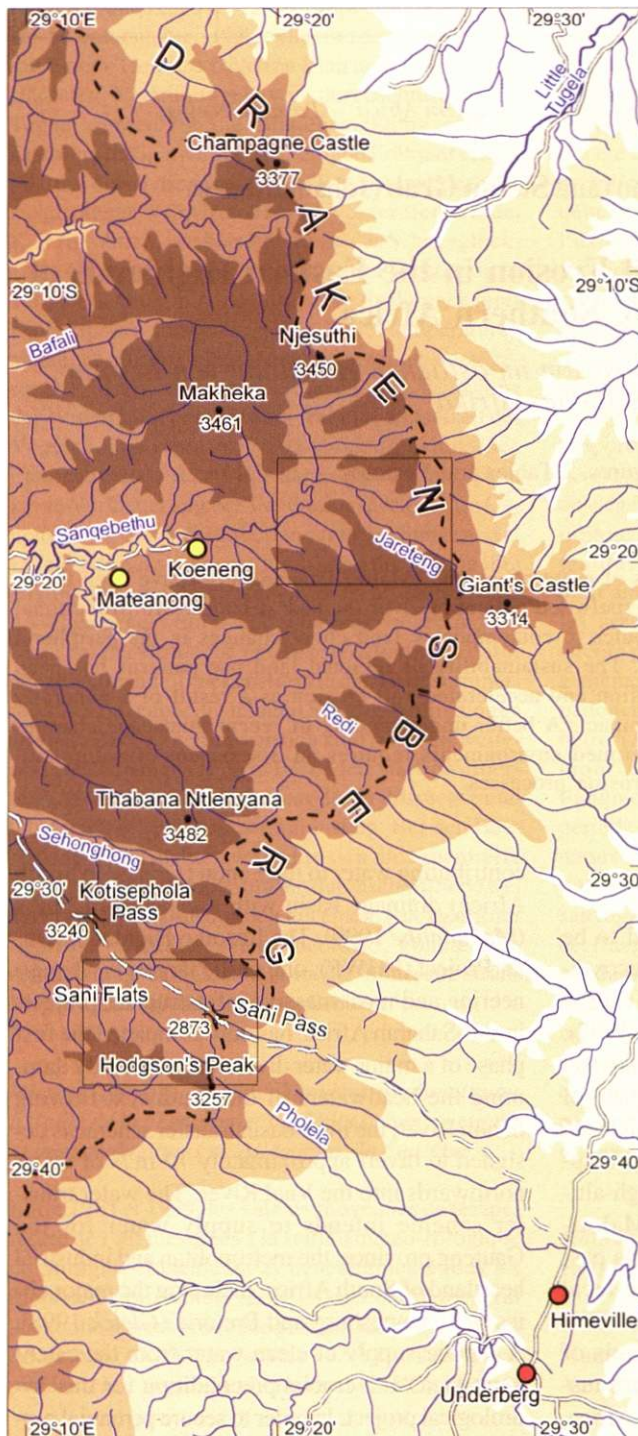


Fig. 1 Location of study areas in the eastern highlands of Lesotho / Lage der Untersuchungsgebiete im östlichen Hochland von Lesotho

Source: Southern Africa 1:500 000, 2928 Durban (1994)
Draft and Cartography: M. Nüsser



Photo 1 The wetlands are used as valuable pastures for livestock. In flat areas, these wetlands contain small pools and silty depressions which are waterlogged in summer (Sani Flats, 9.3.2000, M. Nüsser)
Die Feuchtgebiete dienen als wertvolle Weideflächen. In flachen Bereichen steht das Wasser im Sommer in kleinen Mulden (Sani Flats, 9.3.2000, M. Nüsser)

off with low sediment yields, the ecological integrity of the wetlands in the upper tributaries is vital. Important hydrological functions of these wetlands include water storage, water discharge and recharge, flow attenuation, sediment retention and organic material production and export (Grobelaar and Stegmann 1987). The environmental conditions of the upper catchments have been challenged by ongoing grassland degradation and accelerated soil erosion as a result of a generally high and continuous anthropozoogenic impact. Since colonial times the mountain Kingdom of Lesotho, formerly the British protectorate of Basutoland, has held a well established reputation for extensive land degradation (Showers 1989, 1996).

Despite several botanical studies in the Maloti-Drakensberg region (e.g. Killick 1963, 1978, van Zinderen Bakker and Werger 1974, van Zinderen Bakker 1981, Hilliard and Burt 1987), little quantitative work has been undertaken on applied geoecological issues, such as impacts of grazing and livestock trampling within the catchments, with the notable exception of the studies by Morris et al. (1989, 1993). There is insufficient knowledge regarding processes of soil loss and land degradation in this mountain region. While studies have explored the dynamics of soil loss in the western lowlands of Lesotho (e.g. Rydgren 1988, 1993, Stromquist 1990, Turner 1996) and at lower altitudes in the montane belt to the east of the Drakensberg escarpment (e.g. Everson and

Tainton 1984, Everson et al. 1985, Watson and Poulter 1987), little detailed research has been undertaken on erosion patterns and processes in the high-altitude grasslands of eastern Lesotho.

According to Everson et al. (1989), annual winter burning does not result in accelerated soil loss. Yet, more recently, Bird (1996) concludes that winter burning in the montane belt causes significant sediment losses. No research has focused on soil loss caused by the consequences of fire, especially uncontrolled grassland burning and subsequent wind action on the summit plateau in the Maloti-Drakensberg alpine belt. Given the occurrence of strong winds and the widespread practice of burning rangelands to stimulate new growth of vegetation (Nüsser 2002b), it is likely that the role played by these two processes is more important than has previously been ascribed. The forms of erosion that have been most commonly identified in the alpine belt are gully and surface/sheet erosion (Quinlan and Morris 1994, Backéus and Grab 1995). Most accelerated erosion has been attributed to a variety of synergistically operating factors such as overgrazing, animal trampling, needle ice action, desiccation cracking, deflation, animal burrowing and surface/subsurface water flow (Grab and Morris 1999). To this end, it is an objective of this article to highlight the key issues of pastoral utilisation, grassland and wetland conditions, secondary fire successions and soil erosion in the mountains of eastern Lesotho. The paper presents case studies from the Sanqebethu Valley and from the Sani Plateau region, based on the results from a collaborative research project investigating natural resource management and land cover change (Grab and Nüsser 2001). In order to understand the complexity of the issues, the assessment of environmental degradation needs to integrate the intensity of pastoral utilisation and current changes in regional transhumance patterns (Nüsser 2002a). Land degradation and accelerated soil erosion must therefore be interpreted as a result of changing socio-economic conditions and re-

gional livelihood strategies. This holds true, especially, within the analysis of community-based natural resource management.

2. Study Area: Environmental Setting

Lesotho is a landlocked country consisting predominantly of high mountain plateaus dissected by deeply incised fluvial networks such as the Senqu and its tributaries. Three prominent mountain plateaus stretch across the small Kingdom, with the highest elevations in the eastern region bordering the KwaZulu-Natal province of South Africa (Fig. 1). This northern and easternmost highland plateau is commonly known as the Maloti-Drakensberg mountain system, which comprises two thirds of the 30 355 km² land area of Lesotho (Makhoalibe 1999).

During the Jurassic period, the region was a large inland lake, which was gradually filled with sediments, forming the Clarens Formation Sandstones found predominantly at altitudes below 2000 m in Lesotho (Eriksson 1983). Subsequent fissure lava flows, about 187 million years ago (Fitch and Miller 1971), produced a capping of basalt with a thickness of 1500 m (King 1982), which constitutes the dominant geology throughout the Lesotho highlands (Viljoen and Reimold 1999). The northern and eastern parts of these fissure lava flows are marked by the Great Escarpment, which forms a part of the main watershed between the Indian and Atlantic Oceans.

Climate records for the subalpine and alpine belts in Lesotho, the latter in particular, are scarce. The best air temperature record is that from Letseng-La-Draai (3050 m) which has data spanning from 1965 to 1975. According to this record, mean January (mid-summer) air temperatures approximate 11°C and mean July (mid-winter) temperatures about 0°C on the high plateau (Grab 1994). An absolute minimum temperature of -20.4°C was recorded on 12 June 1967 at this station (Grab

1997a). About 70% of the total precipitation falls during the vegetation growing season between November and March, while less than 10% is recorded between May and August (Tyson et al. 1976, Tyson and Preston-Whyte 2000). Annual amounts of precipitation are highest along the eastern escarpment where up to 1600 mm may be received (Killick 1963, 1990). Recurrent thunderstorms and fog periods contribute largely to the humid conditions. However, the high escarpment is an effective topographically-induced rain-shadow producer, so that precipitation is reduced westwards of the Drakensberg escarpment, amounting to only about 600 mm in the central plateau area. Light snowfalls may be expected during the colder months and ground freezing is estimated to occur on about 200 days per annum (Grab 1997b). In exceptional years (e.g. in 1964, 1987 and 1996), snow cover may last for several weeks on the summit plateau, especially on southern aspects (Mulder and Grab 2002).

Arranged along altitudinal gradients and modified by aspect and microclimate, the vegetation of the summit plateau comprises grassland, dwarf scrub, and open scree and rock communities. Ecological conditions, spatial distribution and species composition of these vegetation types have been changed as a result of anthropo-zoogenic impact. The prevailing rangelands above approximately 2900 m are usually dominated by the grasses *Merxmuellera disticha*, *Festuca caprina*, *Pentaschistis oreodoxa* and *Harporchloa falx*. Large areas are occupied by dwarf-scrub communities, composed of *Helichrysum trilineatum*, *Erica dominans*, *Chrysocoma ciliata* and *Pentzia cooperi* (Nüsser 2002a). Due to the absence of trees on the summit plateau, dwarf-scrubs are used for heating and cooking purposes by the local herders. Sharply delimited wetlands form habitats for grasses (*Agrostis lachnantha*, *A. subulifolia*, *Poa annua*) and sedges (*Scirpus falsus*, *S. ficinioides*, *Isolepis fluitans*, *Schoenoxiphium filiforme*) and serve as important pastures (Photo 1).

The distinctive wetland ecosystems are the only wetlands in southern Africa in which recently forming peat has been found, which has resulted in their classification as mires (Backéus and Grab 1995, Schwabe 1995, Morris and Grab 1997). Schwabe (1989) defines hydrologically isolated wetlands (having no drainage into or out of them) as bogs and most of the wetlands in Lesotho are considered as bogs (van Zinderen Bakker 1955, Jacot Guillarmod 1962, 1963, Meakins and Duckett 1993). These bogs typically have organic soils with a high water table and upraised peat landforms such as thufur and flarks (Grab 1994). The flarks occur where the minerogenic water is poorly drained, forming steep-sided depressions (20-60 cm) (Backéus 1989). Several hypotheses have been considered for their formation, including cryogenic, hydrological and bio-chemical processes. Although it is recognized that turf exfoliation is an important contemporary process in the development of such wetland depressions (Grab 2002), their origin still remains unknown.

3. Methods

Vegetation status and range conditions were studied using the metric belt transect method (Schmutz et al. 1982) at the end of the vegetation growing period of 1999. The method is capable of concurrently determining crown cover, species composition, relative species abundance, phytomass production and forage production estimation in plant communities composed of a mixture of grasses, forbs and shrubs (Range Management Division 1988, Morris et al. 1989). The metric belt transect method has the advantage of requiring a minimum amount of equipment. It utilises a tape stretched along the ground to mark the length of the sample plot and a frame of the size of the tenth of a square metre to outline the plot width. The frame, with a side length of 31.6 cm, is divided into two halves; one half is further divided into fifths to facilitate estimation

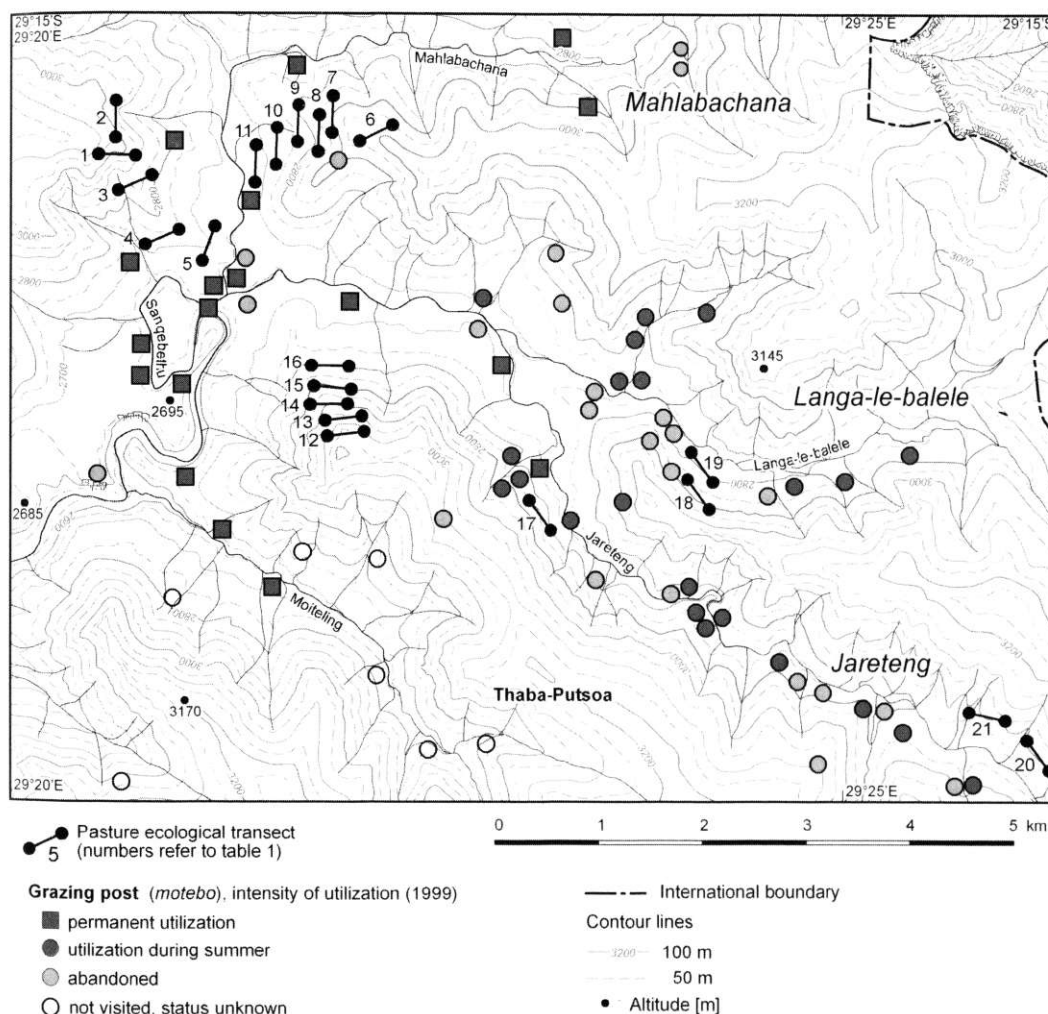


Photo 2 Patches of Merxmüllera drakensbergensis are a conspicuous feature of the high-altitude grasslands. This example shows frozen foliage of the large tussocks after a minimum temperature of -9°C . The Escarpment is visible in the background (Sani Pass, 12.9.1998, M. Nüsser) / Bestände des großen Tussock-Grases Merxmüllera drakensbergensis bilden ein auffälliges Merkmal des Höhengraslandes. Die Aufnahme zeigt die Situation nach einer Minimumtemperatur von -9°C . Das Escarpment ist im Hintergrund erkennbar (Sani-Pass, 12.9.1998, M. Nüsser)

of smaller units of crown cover area. Transects were set along ecological gradients, determined by altitudinal zonation, aspect and distance to grazing posts. To assess the floristic composition of the various pasture ecotopes, a collection of plant species was made for determination by botanical taxonomists. Although the method is frequently used for repeat analysis, in monitoring vegetation one has to consider that the amount of standing phytomass does not only depend on the time of the vegetation period, but also on often uncertain or unknown factors such as previous intensity of grazing and grassland burning as well as inter-annual climatic differences. Therefore, the assessment of range conditions does not allow for any isolation of dis-

tinct grazing impact, as it may represent a variety of influencing factors. In order to assess the dynamics of the secondary fire succession on freshly burnt slopes, selected sites were chosen for repeat photography. Visual interpretation of multitemporal remote sensing data, such as Landsat TM imagery and aerial photography, has been integrated for monitoring of vegetation status, regional land use and land cover change.

In order to isolate the impact of wind-induced erosion, deflation was measured in a degraded wetland and on a burnt slope during the winter period (June-August) of 1999. Given that precipitation and ground moisture were largely absent during the recording period, wind was assumed



Sources: Lesotho 1:50 000, sheet 2929 AD (39). Thabana Ntlenyana, 1982

Draft: M. Nüsser; Cartography: G. Bräuer-Jux, M. Nüsser

Fig. 2 Location of pasture ecological transects and intensity of pastoral utilisation in Sanqebethu Valley
Lage der weideökologischen Transekte und Intensität der Weidenutzung im Sanqebethu-Tal

to be the primary geomorphic transporting agent. Thirty erosion pins per site were placed along the slope contour and inserted to 30 cm depth to avoid possible frost heave. Vernier calipers were used to undertake initial and repeat measurements from the top of the erosion pin to the nearest ground contact point along the pin. The measurements have a resolution of 0.5 mm. Adjoining wetland

sites at approximately 2930 m were selected, one exposing peat and the other mineral sediment. A southeast-facing slope which had recently been burnt, consequently exposing the ground surface, was divided into an upper (3020 m), middle (2980 m) and lower (2940 m) section. Sediment samples were collected at each monitoring site for testing in the laboratory. Sampling took place two

Tab. 1 Rangeland transect data from Sanqebethu Valley (1999) / *Ergebnisse weideökologischer Transekte aus dem Sanqebethu-Tal (1999)*

Transect No.	Valley / Area	Altitude [m]	Aspect	Range quality
1	Sanqebethu	2975	S-facing (180°)	20,2
2	Sanqebethu	2975	E-facing (90°)	64,0
3	Sanqebethu	2875	SSE-facing (170°)	85,7
4	Sanqebethu	2725	spur, flat	100,3
5	Sanqebethu	2700	valley floor, flat	6,1
6	Sanqebethu	2980	NNW-facing (340°)	28,1
7	Sanqebethu	2900	W-facing (280°)	99,1
8	Sanqebethu	2825	W-facing (270°)	129,8
9	Sanqebethu	2775	W-facing (280°)	108,4
10	Sanqebethu	2725	W-facing (280°)	51,5
11	Sanqebethu	2690	valley floor, flat	60,6
12	Langa-le-balele	3025	N-facing (350°)	44,6
13	Langa-le-balele	2975	N-facing (360°)	16,5
14	Langa-le-balele	2900	N-facing (360°)	62,1
15	Langa-le-balele	2825	N-facing (10°)	85,5
16	Langa-le-balele	2720	N-facing (360°)	74,0
17	Jareteng	2750	NE-facing (40°)	40,2
18	Langa-le-balele	2875	NE-facing (45°)	87,5
19	Langa-le-balele	2800	NE-facing (50°)	48,3
20	Jareteng	3030	SW-facing (230°)	17,5
21	Jareteng	3030	S-facing (190°)	33,8
22	Jareteng	3140	E-facing (100°)	171,0
23	Jareteng	3080	SE-facing (150°)	133,9

Classes of range qualities according to the Belt Transect Method:

188-250: excellent, 125-187: good, 63-124: fair, 0-62: poor, less than 0: very poor

years after the latest burn, so as to obtain a better representation of the *in situ* sediment properties, as ash and burnt soil residue may give anomalous values. Samples were oven-dried at 105°C and sieved for particle size analysis. Organic matter content was obtained through loss of weight by incineration at 700°C.

4. Results

4.1 High-altitude grasslands: ecological conditions and degradation

The evolution of transhumance patterns and subsequent expansion of pastoral land use in the high altitude grasslands of Lesotho com-

menced in the 1880s, owing primarily to increased environmental degradation in the lowlands (*Staples and Hudson 1938*). Livestock grazing in Lesotho is integrated into community-based resource management and pastures are generally used as common pool resources. Scattered grazing posts are used by individual shepherds to provide shelter for sheep and goats. The development of pastoral utilisation shows an increase in grazing post numbers between the 1930s and the 1980s (*Quinlan 1989, Morris et al. 1989*). The expansion of pastoral utilisation in the upper ecological belt has been reinforced by the trend to extend the grazing period in the high-altitude grasslands due to degradation of winter pastures in the village environs below (*Quinlan and Morris 1994*).

The case study from the upper Sanqebethu Valley illustrates that the high-altitude grasslands show a slight reduction of vegetation cover, although the intensity of both summer and winter grazing decreased significantly between 1988 and 1999 (Nüsser 2002a). Corresponding results from 23 pasture ecological transects presented here reveal a wide variety of rangeland conditions in the Sanqebethu Valley (Fig. 2, Tab. 1), which can be related to the intensity of pastoral utilisation. The most valuable pastures are occupied by *Themeda triandra* grasslands (in Sesotho: *seboku*), which are usually confined to the warmer north-facing slopes below 3000 m. These grasslands are considered to decrease in abundance as grazing intensity increases (Staples and Hudson 1938). In contrast, the dwarf scrubs *Chrysocoma ciliata* and *Pentzia cooperi* show a distinct increase in abundance with high grazing pressure (Morris et al. 1989, 1993).

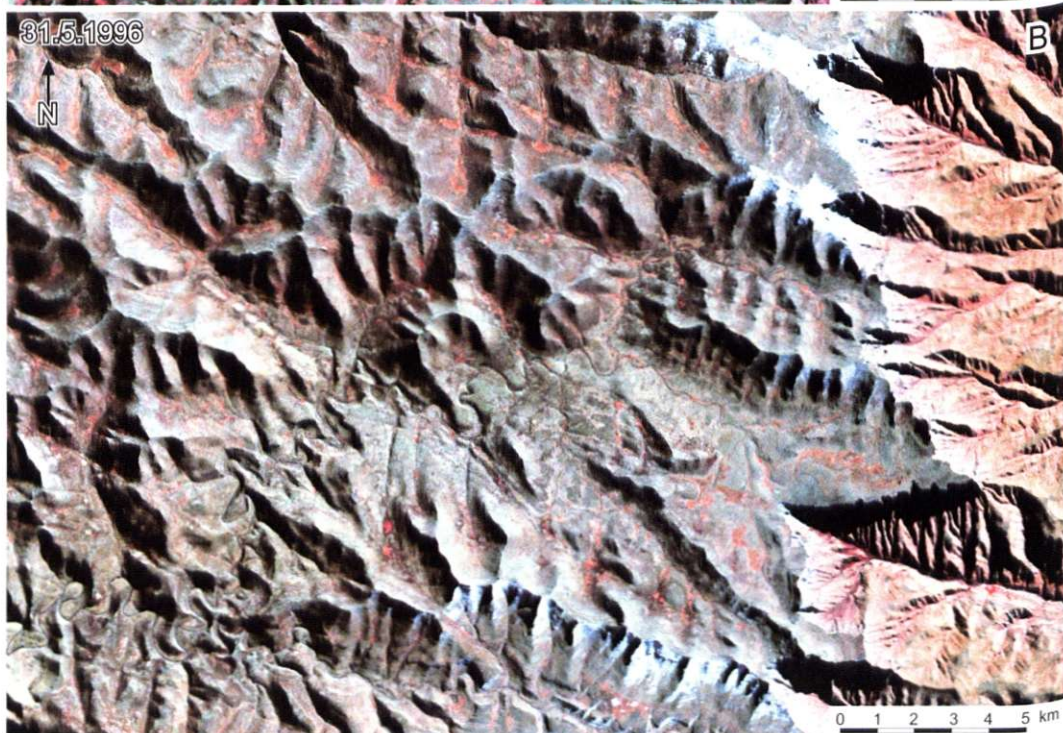
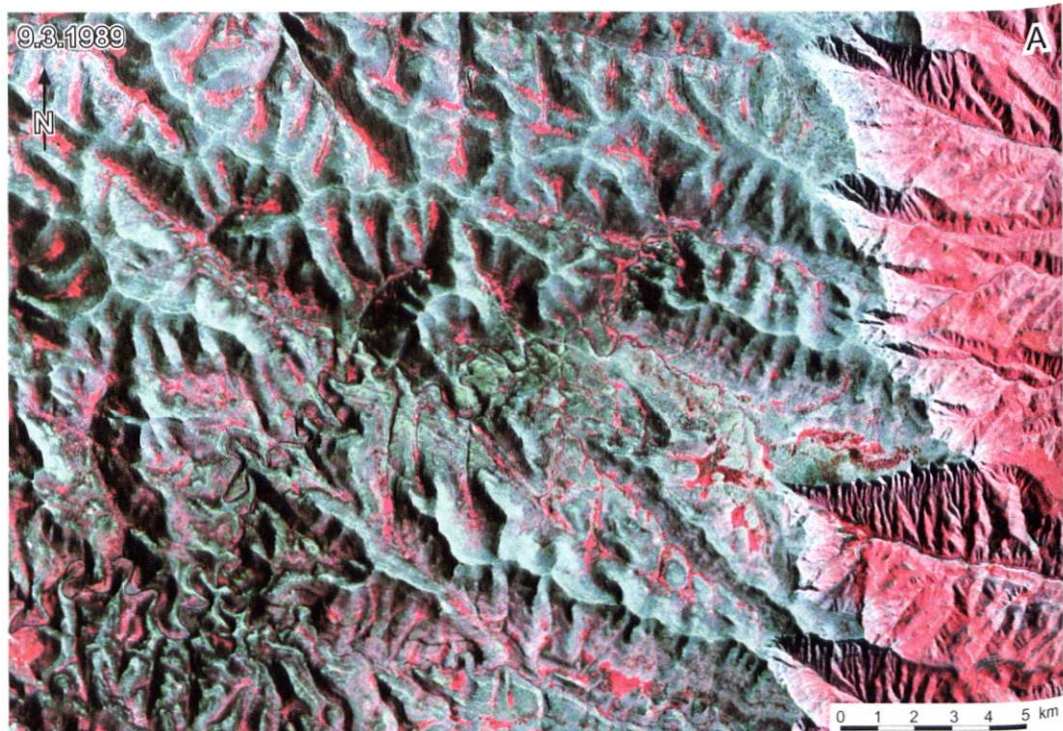
According to the transect data, the slopes of the main Sanqebethu Valley between 2690 and 2980 m (transects 1-11; Tab. 1) reveal poor to fair range conditions as a result of continuous overgrazing. The open grasslands between basalt outcrops are generally characterised by moderate to heavy grazing impact with a relatively high intensity of winter grazing and single stands of burnt grassland patches. Only one transect, dominated by the fodder grasses *Merxmuellera disticha*, *Harporchloa falx* and *Themeda triandra*, shows good rangeland conditions. The majority of the predominantly north-facing transects from the Langa-le-balele and Jareteng valleys (transects 12-23) show poor to fair range conditions. The pastures in these upper tributaries are heavily grazed, especially in the vicinity of grazing posts in the more accessible areas near river junctions which are used throughout the year (Nüsser 2002a). In contrast, as indicated by transects 22 and 23, more positive rangeland conditions occur in the upper valley heads and in close proximity to the escarpment (outside the map, Fig. 2). Rangeland conditions in the vicinity of the Sani

Pass show similar results. Based on 21 transects between 2870 m and 3175 m, the pastures show heterogeneous rangeland qualities with fair conditions on average (according to the rangeland quality classes, Tab. 1). In general, both study areas are characterised by fair rangeland conditions, probably due to decreasing animal numbers and stocking densities, which are documented for the Sanqebethu Valley (Nüsser 2002a). However, bare patches and soil erosion indicate land degradation on a more localised scale.

4.2 Wetlands: seasonal dynamics and degradation

In order to detect contemporary changes in the areas around Sani Pass, multi-temporal Landsat images from the end of the vegetation periods in March 1989 and March 1999, and a third image from May 1996, form a suitable data source (Fig. 3). Visual comparison of the two images from March reveals a certain increase in phytomass over the interim decade. The wetland areas can also be recognized during the drier season in the image from May. The flat areas in the western vicinity of the Sani Pass, and the wetlands in particular, are used as annual pastures (Grab and Nüsser 2001, Nüsser 2002b).

The dominant cause for visible gully development on some of the wetlands is not always clear as this may be related to a number of factors such as trampling pressure, livestock grazing, rodent burrowing and, in several areas, the continuation and convergence of rills above the wetlands. Any soil formed in these types of wet conditions, especially peat, is easily broken up and tremendously vulnerable to the formation of bare patches (Evans 1998, Hall et al. 1999). The hoof pressure of the livestock walking in the wetland leaves depressions in the matrix of the wetland. This exposes soil to rapid aeration and desiccation, which breaks down the bonds in the soil. The flow of water along grazing tracks, combined with the presence of bare patches, increases the likelihood



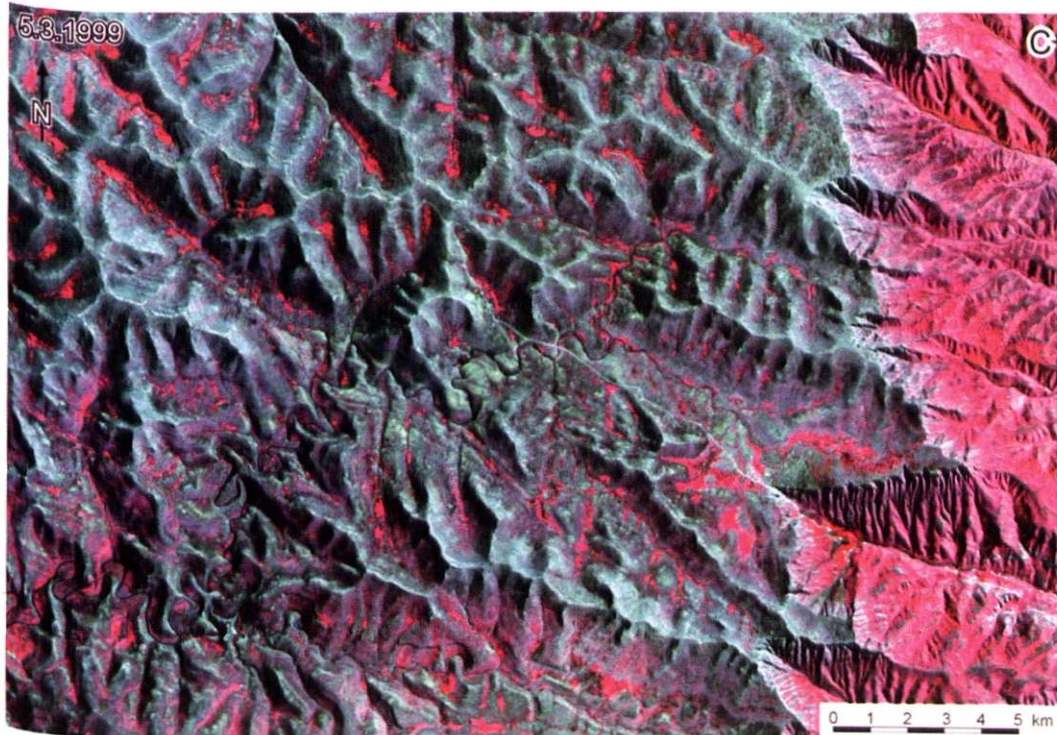
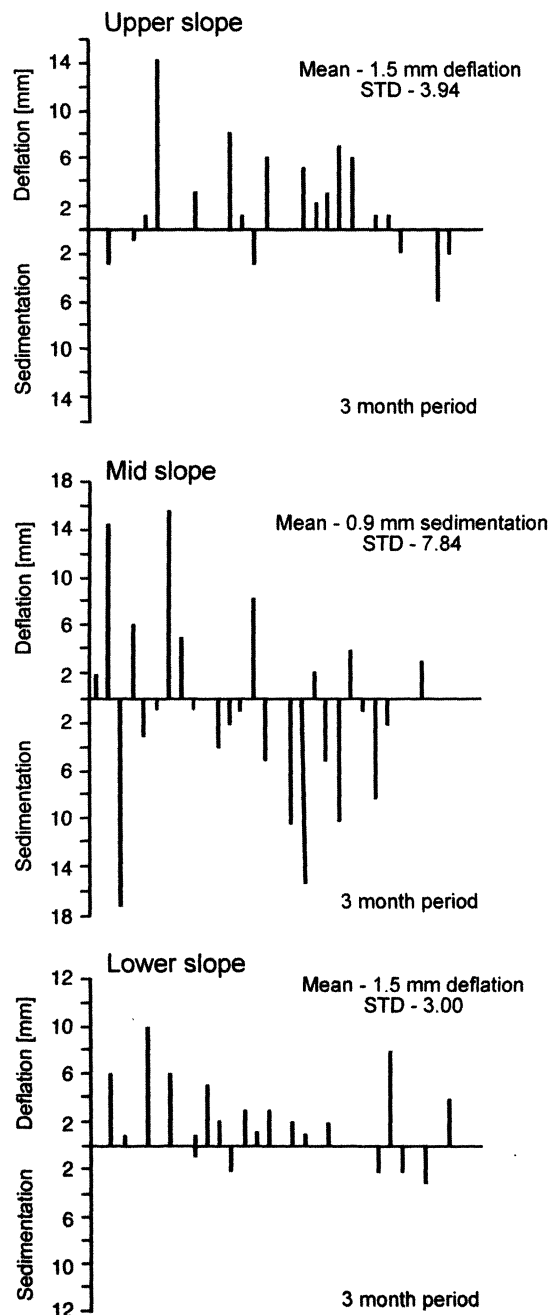


Fig. 3 Geo-referenced subsets of Landsat TM imagery (169/80) showing the summit plateau in the vicinity of Sani Pass and part of the Great Escarpment between Hodgson's Peaks (3257 m) in the southern and Thabana Ntlenyana (3482 m) in the northern part. The first image (March 1989; a) and the third image (March 1999; c) show the moist period of late summer. In both images the wetlands and dense grassland vegetation in the upper tributaries and in the flat areas around Sani Pass (2873 m) as well as the protected mountain savannas of the South African uKhalamba Drakensberg Park can be identified by their intensive red. The second image from May 1996 (b) shows first snowfall on the summits at the escarpment, preceding the extreme winter snow of that year. Colour composites, 4,3,2 = RGB / *Georeferenzierte Ausschnitte von Landsat TM-Bildern (169/80) des Hochlandes von Lesotho im Bereich des Sani-Passes und der Randstufe zwischen den Hodgson's Peaks (3257 m) im südlichen und dem Thabana Ntlenyana (3482 m) im nördlichen Bereich. Im ersten (März 1989) und dritten (März 1999) Bild aus dem feucht-warmen Spätsommer lassen sich die Feuchtgebiete und das dichtere Grasland in den oberen Tributären in Form scharf abgegrenzter roter Areale erkennen. Im Bereich des südafrikanischen uKhalamba Drakensberg Park sind die geschützten Bergsavannen weitflächig durch hohe Deckungsgrade gekennzeichnet. Die zweite Aufnahme (Mai 1996) zeigt in den höchsten Lagen eine beginnende Schneebedeckung am Anfang des extremen Schneewinters 1996. Farbkompositen, 4,3,2 = RGB*

of headcut development. Wetlands below north-facing slopes are particularly susceptible to gully erosion. It is on these warmer north-facing slopes where most grazing posts are located, and the frequency of livestock movement and grazing

around these posts has caused the surrounding slope areas to become denuded of vegetation. An added consequence is that the eroded sediment is subsequently deposited onto the wetland, producing alluvial fans across the wetland turf.



4.3 Soil erosion: the impact of fire and wind

Accelerated soil erosion is partly related to the illegal practice of grassland burning, which becomes more frequent during the dry winter period in order to stimulate renewed growth and more nutritious forage for livestock. In some cases, entire slopes in the area around Sani Top have been burnt, resulting in bare patches, erosion and subsequent soil loss. In particular, stands of the large tussock grass *Merxmuellera drakensbergensis* (Photo 2) are frequently burnt (Nüsser 2002b). The practice of uncontrolled burning of these tussocks is also considered a method to scare away jackals from sheep and goats occupying the grazing posts. The fires are extremely damaging; they do not only destroy the vegetation to the roots but also the organic material binding the soil. Accelerated erosion is a consequence of unconsolidated earth material being exposed to high energy summer rainfall. The example of repeat photography below Hodgson's Peak (Photos 3a, 3b and 3c) demonstrates the secondary succession and erosion dynamics following the fire of September 1998. The second photo from March 1999 was taken on the same day as the satellite image (Fig. 3c). These replicates, taken after approximately 6 months (Photo 3b) and one year respectively (Photo 3c), show an increase in bare patches.

It is widely known, but not always acknowledged, that as vegetation cover declines due to overgrazing or burning, the severity of wind and water induced erosion increases (Evans 1998). Given the nature of the Maloti-Drakensberg climate (i.e. strong and long-lasting winds) and the practice of burning rangelands,

Fig. 4 Sedimentation and deflation values for a burnt upper slope, mid-slope and lower slope near Sani Pass; data from constructed erosion pin transects, for the period June-August 1999 / Sedimentation und Deflation auf dem oberen, mittleren und unteren Abschnitt eines gebrannten Hangs in der Nähe des Sani Passes für den Zeitraum Juni-August 1999

it is likely that these two factors are more important than has previously been ascribed. Vegetation in windy environments may protect the surface by direct cover of a portion of the surface, trapping particles already moving and extracting momentum from the airflow (Wolfe and Nickling 1993). In addition, and important in the context of this study, dead or partially defoliated vegetation also acts to inhibit the action of wind erosion (Wolfe and Nickling 1993). However, most of the alpine vegetation exhibits a low level of defoliation and thus burning in the alpine belt leaves no substantial protective vegetational layer.

Results from the investigation of wind erosion indicate considerable variation in denudation rates between the various slope positions, despite a uniform recording period and all sites having been burnt at the same time. The upper and lower slope positions both reflect a mean deflation value of 1.5

mm/3 months, with standard deviations of three to four (Fig. 4). However, the mid-slope position indicates a positive sediment budget with a mean accumulation of 0.9 mm/3 months and a standard deviation of 7.84, which is double that for the upper and lower slope positions. Several factors may account for this, including particle size and vegetation distribution per site. Lancaster and Baas (1998) observe that the presence of vegetation on sand sheet surfaces acts to increase the threshold wind shear velocity for transport by a factor of two compared to unvegetated surfaces. Similarly, Wasson and Nanninga (1986) suggest that sand transport may occur even with a vegetation cover of 45%. It emerges that isolated but relatively large clumps of grass/shrub act to increase wind erosion in intervening areas, while smaller but more evenly distributed vegetation may decrease the erosional potential of wind throughout the area. After the burning of the three sites it was noted that whilst

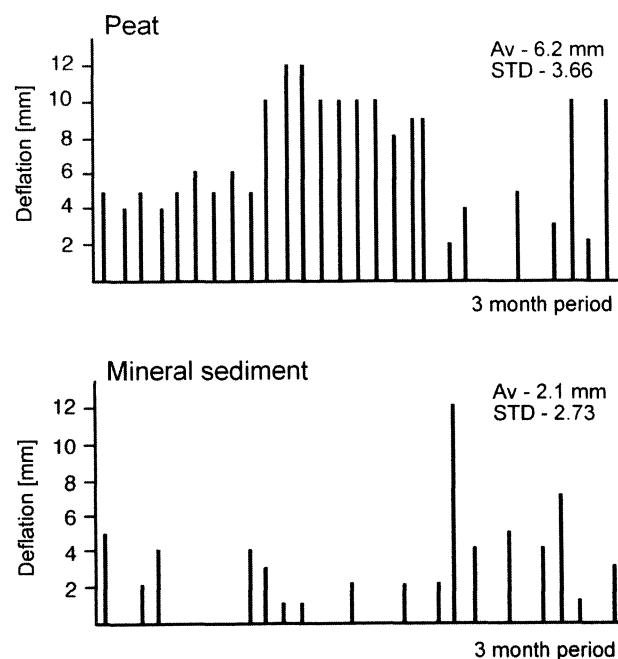


Fig. 5 Deflation values on a degraded wetland near Sani Pass. Data from constructed erosion pin transects, for the period June to August 1999 / Deflationswerte in einem degradierten Feuchtgebiet in der Nähe des Sani-Passes für den Zeitraum Juni-August 1999

*Photo 3a**Photo 3b*



Photos 3a, 3b, 3c Repeat photography of a secondary fire succession below Hodgson's Peak / Multitemporaler Bildvergleich einer sekundären Brandsukzession unterhalb des Hodgson's Peak – M. Nüsser, Photo 3a: 9.9.1998, Photo 3b: 5.3.1999, Photo 3c: 30.8.1999

Photo 3c

the upper and lower slope positions experienced a more complete burn, there was still an abundance of partially burnt vegetation clumps in the mid-slope locality. These clumps are irregularly spaced, so that in places the wake left by the clumps would

protect the surface on the downwind aspect. However, other parts of the site have bare and unprotected surfaces, thus permitting for substantial variations in deflation and sedimentation (deposition) (Fig. 4). It is evident that deflation values were

Tab. 2 Substrate characteristics for various sites of the wind erosion investigation / Substratcharakteristik verschiedener Untersuchungsflächen zur Winderosion

	Altitude [m]	Slope angle Degrees	% Organic material by weight	Particle size class		
				% Gravel	% Sand	% Silt/clay
Degraded wetland						
Peat	2930	3	36,3	0	89	11
Mineral sediment	2935	3	6,6	47	50	3
Burnt slope						
Upper slope	3020	26		28	64	8
Mid slope	2980	19		46	48	6
Lower slope	2940	16		31	63	6

much higher over the bare peat (6.2 mm/3 months) and mineral sediment (2.1 mm/3 months) surfaces than on the burnt slope (Fig. 5). Further to this, there was no evidence for localised sedimentation within the degraded wetland, which may be accounted for by the absence of vegetation. Perhaps the most notable difference between the sites is the particle size distribution at the surface (Fig. 6, Tab. 2). The peat exposed site, without a pro-

TECTIVE gravel lag, encountered a substantially higher rate of deflation than the adjoining site, which had a 47% protective gravel component, reducing potential deflation. Similarly, at the burnt slope sites, the mid-slope position containing a high percentage of gravel (46%) encountered less deflation than the upper and lower slope positions where the percentage of gravel was lower (28 and 31% respectively).

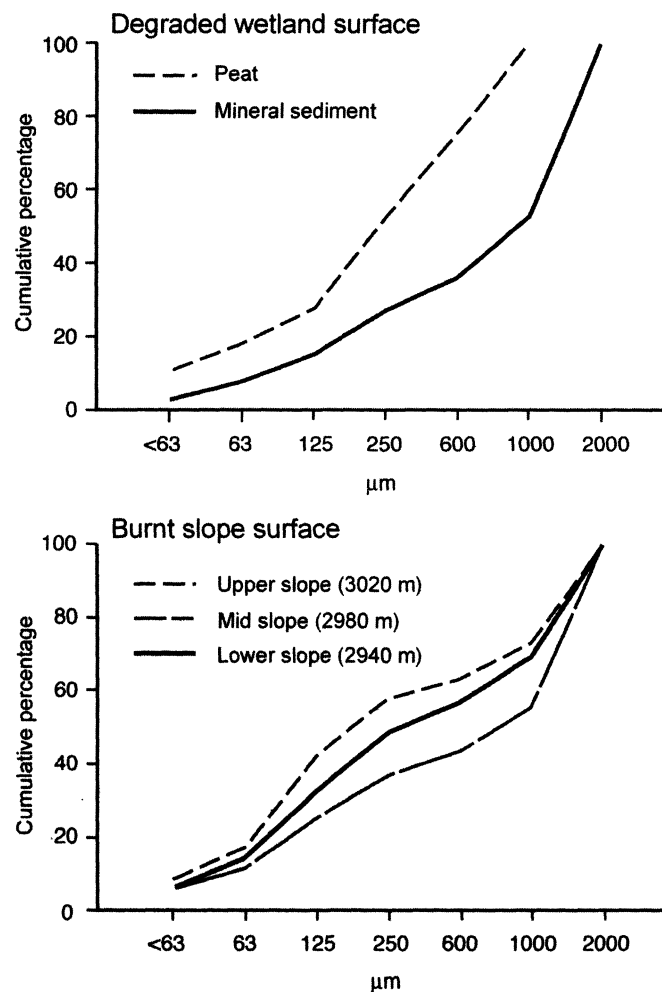


Fig. 6 Particle size distribution on a degraded wetland and for upper, mid and lower burnt slope positions
Korngrößenverteilung in einem degradierten Feuchtgebiet und auf unterschiedlichen Abschnitten eines gebrannten Hangs

5. Discussion and Conclusions

A variety of factors influence soil erosion in the eastern highlands of Lesotho. Whilst rill and gully erosion have frequently been implicated as the primary erosion processes (van Zinderen Bakker 1981, Grobbelaar and Stegmann 1987, Grab and Morris 1999), there has been little recognition of the significance of fire and wind. The findings of this study have demonstrated that both vegetation cover (also controlled by fire) and ground particle size distribution are controlling factors for wind-induced erosion. Given the dominance of coarse textured soils on hill slopes, deflation will be minimal, thus burning early in the winter season is not particularly critical to wind erosion. Autumn burns around the periphery of wetlands or within dryland areas of the wetland would, however, have serious environmental implications. Generally, such burns enhance wetland desiccation through the exposure to more direct insolation and rodent burrowing. During winter, the dry westerly winds further desiccate the exposed surface and cause significant deflation (particularly on peat surfaces), as is indicated by the results. Owing to the short growing season, the burnt tussocks are slow to recover and thus invader species such as *Pentzia cooperi*, *Chrysocoma ciliate* and *Selago flanaganii* rapidly establish themselves at such burnt sites. Wetland grazing and water resources are thus the most vulnerable of the alpine landscape components to the ill effects of fire and wind erosion. The extent of uncontrolled burning patterns has to be analysed thoroughly in order to develop more effective communal regulations for natural resource management.

Regional transhumance patterns have transformed grazing resources over the last century. Not only does the number of livestock in a given pasture play an important role, but also the time and duration of utilisation. The recent decrease in animal husbandry may be interpreted as a response to the ongoing depletion of grazing re-

sources and a corresponding decline in livestock health and quality of livestock products. Furthermore, traditional resource utilisation in Lesotho is characterised by indigenous knowledge of botanical resources and multifunctional utilisation of plants.

Improving our understanding of the driving forces behind grassland degradation and related landscape dynamics remains an ambitious goal requiring integrated human-ecological research approaches. A further challenge is to share such research findings with local and national stakeholders and to devise a suitable plan of action which will promote long-term environmental sustainability in the mountain region. A primary objective for the planned Transfrontier Park development would thus be to ensure ecological and hydrological functioning of the alpine wetlands, which are crucial to the local stockholders and a precondition for water supply for much of southern Africa.

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Summary: Land Degradation and Soil Erosion in the Eastern Highlands of Lesotho, Southern Africa

Vegetation surveys and studies on erosion processes are combined with an assessment of the intensity of resource utilisation in order to analyse contemporary rangeland conditions and land degradation in the eastern highlands of Lesotho (Maloti-Drakensberg). The high-altitude grasslands and wetlands of the study area have been transformed by livestock grazing, burning and fuelwood collection over the past decades. The extent of anthropo-zoogenic transformation of resource potentials varies on a local scale. Grazing pressure due to overstocking is indicated by accelerated soil erosion in all altitudinal belts. Results from pasture ecological transects show a wide range of ecological conditions with distinct changes in floristic composition and various degraded sites. Especially the scattered wetlands are prone to overgrazing and subsequent degradation. Additional important factors for land degradation are the common practice of uncontrolled grassland burning as well as the collection of dwarf scrubs for fuelwood. Given the dominance of coarse textured soils on hill slopes, deflation values are relatively low here, making burning early in the winter season not particularly critical. However, autumn burns

around the periphery of wetlands and within dry-land areas of the wetland will have serious environmental implications. The integrated research approach should stimulate further human-ecological monitoring for the eastern highlands of Lesotho. The applied challenge is to share knowledge and devise an action plan which will promote livelihood development of local mountain dwellers and sustainable utilisation of environmental resources.

Zusammenfassung: Landdegradierung und Bodenerosion im östlichen Hochland von Lesotho, südliches Afrika

Zur Analyse der gegenwärtigen Bedingungen des Weidelandes und der Landschaftsdegradation im östlichen Hochland von Lesotho (Maloti-Drakensberg) werden Vegetationsaufnahmen und Arbeiten zu Erosionsprozessen mit der Intensität der Ressourcennutzung in einen Zusammenhang gestellt. Durch Beweidung, Brand und Brennholzsammlung wurden das Höhengrasland und die Feuchtgebiete im Untersuchungsgebiet über die vergangenen Jahrzehnte verändert. Das Ausmaß anthropo-zoogener Transformation der Ressourcenpotenziale ist lokal verschieden. Der Weidedruck aufgrund hoher Tierzahlen zeigt sich in Form verstärkter Bodenerosion in allen Höhenstufen. Die Ergebnisse der weideökologischen Transekte sind stark gestreut und zeigen deutliche Unterschiede in der floristischen Komposition und im Degradationsgrad. Insbesondere die vereinzelt Feuchtgebiete sind durch hohen Weidedruck und nachfolgende Degradation bedroht. Zusätzliche Faktoren, die wesentlich zur Landdegradation beitragen, bestehen in den weit verbreiteten Praktiken des unkontrollierten Brennens von Grasland sowie im Sammeln von Zwergsträuchern als Brennmaterial. Aufgrund der vorherrschend groben Bodentextur sind die Deflationsbeträge in den Hangabschnitten relativ gering, wodurch Brände im frühen Winter nicht besonders kritisch sind. Dagegen ergeben sich bei Herbstbränden in der Umgebung und in trockenen Bereichen von Feuchtgebieten ungünstigere Auswirkungen. Der integrierte Forschungsansatz kann als Anregung für ein humanökologisches Monitoringprogramm für das östliche Hochland von Lesotho

dienen. Die anwendungsorientierte Herausforderung besteht in der Umsetzung der Ergebnisse und in der Formulierung von Handlungsanweisungen, die die Entwicklung der Existenzsicherung der lokalen Gebirgsbevölkerung und eine nachhaltige Nutzung der Umweltressourcen fördert.

Résumé: Dégradation et érosion du sol dans le Haut-plateau est du Lesotho, Afrique du Sud

Pour analyser les conditions actuelles des pâturages et de la dégradation du pays dans le Haut-plateau du Lesotho (Maloti Drakensberg), les relevés de végétation et les travaux concernant les processus d'érosion ont été mis en relation avec l'intensité de l'utilisation des terres. De par le pâturage, les incendies et le rassemblement de brindilles, la végétation de la région étudiée a changé au cours des décennies précédentes. L'ampleur de cette transformation anthropo-zoogène des ressources naturelles varie selon les lieux. L'excès de pâturage, dû au nombre élevé des animaux, se manifeste sous forme d'érosion intensifiée à tous les niveaux. Les résultats des analyses concernant les effets de pâturage varient considérablement et témoignent des différences évidentes quant à la composition florale et au degré de dégradation. Notamment les quelques régions humides sont menacées par le pâturage excessif et la dégradation qui en résulte. D'autres facteurs contribuant con-

sidérablement à la dégradation du sol sont la carbonisation incontrôlée des prés ainsi que la récolte de jeunes arbustes pour en faire du feu. Grâce à la texture rugueuse du sol, la déflation dans les parties en aval est relativement peu importante, c'est pourquoi les incendies en début d'hiver ne sont pas trop problématiques. Les incendies automnaux par contre ont un impact négatif sur les alentours, notamment sur les régions arides ou desséchées. Les travaux de recherche intégrante peuvent servir de source d'inspiration pour un programme de monitoring anthropo-écologique pour le Haut-plateau du Lesotho. Le défi concernant les moyens d'application consiste à rendre utile les résultats et à formuler des directives d'action garantissant l'existence de la population locale et favorisant l'exploitation durable des ressources naturelles.

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