Sustaining Life and Livelihood along an Ephemeral River

The Example of the Kuiseb River/Namibia

Namibia is the driest country in sub-Saharan Africa. The extremely arid Namibian interior is drained by ephemeral rivers that briefly flow only after heavy rains have fallen in their catchments. Of the rain that does fall, most water evaporates, and only 17 % becomes part of the ecosystem of ephemeral river basins. With 25 such ephemeral river basins covering Namibia, their effective management is the key for sustaining life and livelihood in this arid country.

Photos: J. Henschel

Photo 1: The Kuiseb river flowing past Gobabeb. In the Nama language "Nomabeb", corrupted to Gobabeb, means "Place of the Fig Tree"

The Kuiseb River is a typical Namibian ephemeral river (*Jacobson* et al. 1995) and is the one best studied with flood records dating back to 1837. Since 1962 research coordinated by the Gobabeb Training and Research Centre, located on the banks of the Kuiseb, has resulted in a significant accumulation of knowledge (*Koch* 1963, *Seely* 1973, *Henschel* et al. 2000).

The Kuiseb River which has its origins in the hills west of Namibia's capital city Windhoek crosses the Great Escarpment into the hyper-arid Namib Desert and ends at the port city of Walvis Bay *(Figure 1)*. Its basin covers 15,500 km^2 and ranges from an altitude of 2,347 m above sea level down to the Atlantic Ocean. Along the 420 km length of the river, mean annual rainfall decreases from 350 mm in the highland interior to 10 mm at the coast (Meteorological Services of Namibia). Annual run-off from of the upper catchment is highly variable (minimum–median–maximum = 0.007–10–220 million m^3 per year; *Huntley* 1985, *Slabbert* 1991). At Gobabeb 80 km from the coast, the Kuiseb flows for an average of 15 days per year (range 0–102; *Photo 1*) and rarely reaches the coast. Even with this little water the natural resources of the basin support more than 70,000 people including commercial and traditional farmers, towns, mines, tourism enterprises and conservation areas.

Kuiseb basin sections

The upper section of the basin, where run-off is generated, is thorn tree savanna on freehold land in the hilly Khomas Hochland. It extends to the base of the Great Escarpment. Numerous shallow drainage lines join and deepen as more and more tributaries connect. Residents in this section (*Gruntkowski* 2001) farm mainly with cattle – part of the prime Namibian beef industry – and some keep sheep and goats. This area is rich in game such as kudu, oryx, Hartmann's mountain zebra, springbok and ostrich. Many landowners have converted their farms to cater for tourists in response to demand and difficult farming conditions. Others do not try to farm commercially on this marginal land but own it as an asset or for recreation.

The middle section of the Kuiseb basin is located in the Namib-Naukluft Park west of the escarpment and the 50 mm rainfall isohyet. The Park focuses on conservation and tourism and engages in environmental work at the Gobabeb Training and Research Centre. In the eastern part of this section, the river channel is located in a 100–200 m deep, narrow canyon. From Homeb westwards this opens into a 200–500 m wide valley that extends to Swartbank. Across the middle section the river separates the northern gravel plains and rocky gullies from the 20,000 km^2 Namib Great Dune Sea to the south. Despite the steady northward transport of dune sand, sporadic flows of the Kuiseb erode away the sand and maintain the stark separation *(Figure 1C)*. The Topnaar people are resident along the riverbed. They farm communally with goats, donkeys and a few cattle and harvest indigenous !Nara fruit (*Henschel* et al. 2004).

In its lower section beyond Swartbank, the river dissipates and splits into several channels as it crosses the Kuiseb delta. Flows are not adequate to prevent the movement of sand across the channels in this section, and dunes of 10 m height cross the delta at a rate of 5–10 m per year (*Lancaster* 1989). The delta incorporates the city of Walvis Bay and the Walvis Lagoon - a wetland according to the "Ramsar Convention" of 1971 – where 70,000–250,000 shorebirds feed. A flood diversion wall was built in 1962 *(Photo 2)*. It has been effective in confining floodwaters to the southern part of the delta so that they do not inundate the town as happened a few times prior to 1962. It is in the lower section of the Kuiseb where bulk water is abstracted from the alluvial aquifer to feed into the Central Namib Regional Water Scheme which also receives water from the aquifer of the ephemeral Omaruru River. This water scheme

Figure 1: Perennial rivers of Africa cross Namibia (A), which is covered by ephemeral river basins (B), including the Kuiseb (C)

Source: adapted from Mendelsohn et al. 2002

Infrastructure for bulk water abstraction was installed in the Rooibank area in 1923 and steadily developed over the next five decades. In 1975 the current Swartbank-Rooibank-Dorop system was established following a high demand for water by the Rössing Uranium Mine and abstraction increased dramatically to 14.6 million m^3 per year (*Slabbert* 1991). The water table dropped from the surface or a few metres deep (reachable with *gorras*) to the current level of 15–17 m deep (NamWater 2001). Water contained in palaeo-channels under the dunes was investigated as a possible additional source, but it was recommended not to mine the widely dispersed weakly-flowing channels due to high abstraction and ecological costs (*Sengspiel* and *Siemon* 1995). Instead, seawater desalination is envisaged to supplement available water and relieve pressure on the Kuiseb-Omaruru (*Slabbert* 1991).

Sustainable yield

Estimates of sustainable yield have varied over the years from 5.1 to 13.0 million m^3 per year and are currently considered to be 7.4 million m^3 per year. Recent calculations (NamWater 2001) take into consideration variable surface flood volumes from recent records as well as groundwater exchange between the riverbed and palaeochannels while maintaining slight positive outflow to the sea. Assumptions in the calculations include the frequency of rare, large floods, and geohydrological factors affecting water infiltration and groundwater movements.

However, these calculations are crude because the geohydrology is complex and not well understood, and infiltration may be different than assumed (*Schmitz* 2004). Furthermore, ecological requirements and effects are considered to be too complex or inadequately known to incorporate into the recharge/abstraction calculations currently being used. As these are important aspects of the "sustainability" question, scientists are challenged to fill this knowledge gap (*Jacobson* et al. 1995). Scientists have recently teamed up to examine the "long-term flood Water recharge and management of shallow alluvial Aquifers in Dryland Environments" (WADE). This project entails characterizing the geophysical features of the Kuiseb, examining the current and historical behaviour of water on the surface, its infiltration, its subsurface progress, and how this relates to biological and anthropogenic features.

Riparian forest

The green belt lining the riverbed along its whole length is a conspicuous feature of the linear oasis. Productivity in and near the riverbed is many times higher than in the surrounding landscapes. The long-term monitoring of riparian vegetation as an indicator of environmental health was initiated in 1978 with aerial and ground surveys (*Theron* et al. 1980, *Seely* et al. 1981, *Huntley* 1985) that recorded species diversity, abundance, size distribution, health and recruitment. To this end, the Gobabeb Centre has established long-term monitoring of the riparian forest at sites differing in groundwater depth. Simultaneously the understanding of the relationships between riparian forests, floods, groundwater, people and animals as well as the dynamics of each of these features is being refined through detailed studies.

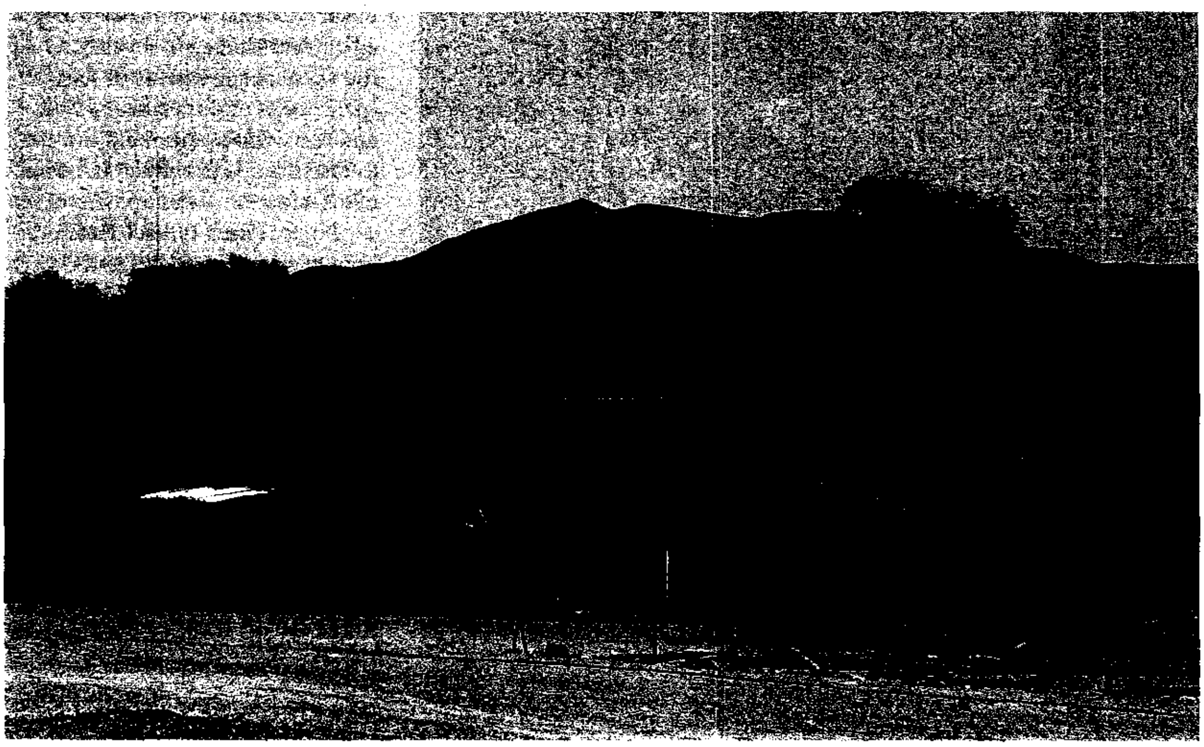

Photo 3: Since 2002 the borehole pump at the Soutrivier village is solar-powered

Photo 2: The flood diversion wall in the Kuiseb Delta has to date withstood all floods, including March 2000, the highest flood since its construction

supplies the towns of Walvis Bay, Swakopmund, Henties Bay, Arandis, and the Rössing and Langer Heinrich Uranium Mines and several smaller settlements.

Physical development of the Kuiseb river

The early formation of the river valley in the Namib (*Ward* 1997) dates back to the middle Miocene, ca. 15–17 million years ago (Ma). At this time there were several channels going towards Sandwich Bay which gradually filled with dune sand and pushed the course of the river northwards to its present mouth at Walvis Bay. After a period of continental uplift around 2–4 Ma (Tertiary-Pleistocene transition), the canyon became deeply incised and breached the escarpment to capture the current headstream. A succession of aggradational and erosional events occurred in the Early-Middle Pleistocene, ca 1–0.5 Ma (*Ward* 1987), and in the Late Pleistocene, 23000–19000 B.P. (= before present; *Smith* et al. 1993), around 5300 and 300–600 B.P. (*Yamagata* and *Mizuno* 2005). Hydrologic influences on soil properties in the riverbed (*Jacobson* et al. 2000) enable one to trace recent flood events and are invaluable for the understanding of Kuiseb hydrology and productivity.

The pattern of large floods has changed during the past two centuries (*Stengel* 1964). Between 1837, when documentation started, and 1942, the Kuiseb reached the Atlantic Ocean on 14 occasions. In the 63 years since that period, it has done so only twice – in 1963 and 2000, marking the longest recorded intervals between big floods. It appears to be more difficult for floods to reach the ocean. This could be due to physical changes in the Kuiseb delta, e.g., the flood diversion wall and steady accumulation of sand, or due to changes in surface water hydrology (*Slabbert* 1991).

Water uses and management

The method of accessing Kuiseb water differs along the river. In the Khomas Hochland numerous farm dams are employed to temporarily store flood water for farming and domestic purposes. The retention of about 16 million m^3 water in the upper catchment is believed to significantly reduce the volume of small floods but appears to have little effect on larger floods and the recharge of groundwater in the lower Kuiseb in wet years (Department of Water Affairs). The small, shallow dams greatly enhance evaporative water loss and silt up in just a few years. By contrast sand storage dams retain the benefits in terms of local groundwater recharge (*Heyns* et al. 1998).

Some natural pools persist permanently in the deeper river gullies of the upper section and in the canyon making this a linear oasis in an otherwise parched environment. This water attracts many birds and mammals, some of whom regularly undertake movements over tens of kilometres from their feeding grounds to these pools (*Kok* and *Nel* 1996). Zebra trails criss-crossing the precipitous canyon walls attest to these movements. Some of the pools are kept open by animals digging.

Digging of wells several metres down to shallow groundwater, so-called *gorras*, was the method employed in the past by the Topnaar people. Variable resource availability stimulated a semi-nomadic way of life (*Kinahan* 2001) and until a few decades ago Topnaar groups moved between 27 places along the river (*Ward* 1985). In the late 1970s,the government installed boreholes at twelve places that became permanent settlements. Later solar pumps were installed by the Directorate of Rural Water Supply at villages upstream of Swartbank *(Photo 3)*. Water point committees are responsible for borehole maintenance and water distribution. Downstream NamWater (a company that supplies bulk water on behalf of Government) provides water to the rural Topnaar for a service fee. However, cash payment for public services is a novel feature, and the water point committees have a difficult task keeping this basis of village economy going (*Werner* 2003). The provision of tourism services by Topnaar may in future provide more income to pay for the water services.

Of 128 plant species in the riverbed (*Henschel* et al. 2006), 11 are trees, and it is in particular these that enable many non-desert-adapted animals and people to live in the area. Some key questions have focussed on the relative importance of the different species in terms of abundance, their importance as natural resources, their population dynamics, especially age structure, recruitment and mortality, and how these trees are affected by floods and connected to the groundwater. The underlying question is how water abstraction and use of plant products affect the tree communities and their dependants. These questions are being examined in several doctoral and undergraduate studies by students from the Polytechnic of Namibia, the WADE team and researchers of the Gobabeb Centre.

Photo 4: A healthy anaboom tree next to the river channel produces 175 kg of pods

The two largest trees have garnered most attention, namely the anaboom, *Faidherbia albida (Photo 4)*, and the camelthorn, Acacia erioloba, both also being the most important producers of fodder in terms of their prolific seed pods and leaves from low branches (*Seely* et al. 1981). Anaboom are more tolerant of the effects of floods but are also more dependent on good access to water, and thus these trees typically grow in and alongside the river channel. Their productivity declines with distance from the channel and depth of groundwater as does that of camelthorns, although the latter are more tolerant of declining water levels and also occur far from the river channel. When the Kuiseb river failed to flow past Gobabeb between 1980–1985 and groundwater level dropped, the condition of anaboom declined and many old trees collapsed (*Ward* and *Breen* 1983, *Mizuno* 2005; *Photo 5*). Concern over the knock-on effects of such extensive changes prompted current studies to investigate the water requirements of several tree species and specifically how and from where they obtain water. Recruitment is examined in terms of germination, development of seedlings *(Photo 6)*, factors affecting survival of juveniles and the conditions and processes by which juveniles become established as trees (*Moser* 2005). These studies contribute to our understanding of how tree life history and demography are affected by numerous factors, such as moisture conditions, the energy of floods, soil properties, herbivory and frugivory.

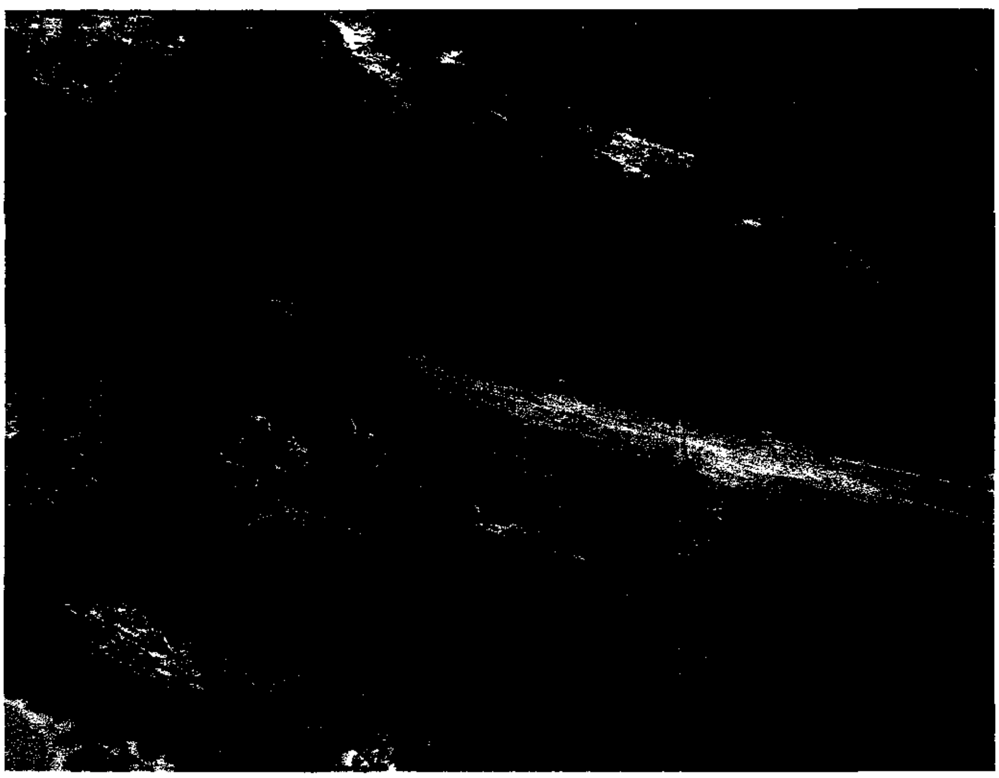

Photo 5: When the river failed to flow in the early 1980s, many old anaboom suddenly collapsed

River basin management

Namibian ephemeral river basins are being recognized as dynamic, keystone systems depending on and affecting integrated economic,

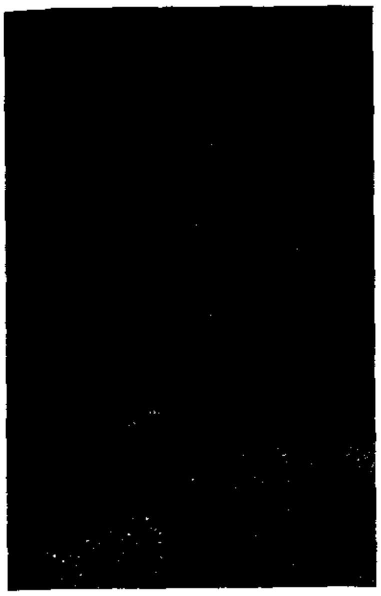

Photo 6: The future of the river's health may be affected by how well anaboom seedlings become established

social and ecological processes that are intimately linked to sustainable development (*Huntley* 1985, *Jacobson* et al. 1995, *Heyns* et al. 1998, *Seely* et al. 2003). This recognition is reflected in the Water Resources Management Act 24 of 2004, which outlines the role of Basin Management Committees in advising Government on issues relating to water management on the basis of economic, social and ecological factors. The project "Environmental Learning and Action in the Kuiseb" (ELAK) responded to this development and facilitated the establishment of the Kuiseb Basin Management Committee (KBMC) by the Minister of Agriculture, Water and Forestry as the first such committee in Namibia. The KBMC grew out of a Forum in which all major stakeholder groups in the Kuiseb basin were represented. In effect, this river basin is regarded as a province that manages its natural resources, with water being the bond and defining the limits for development. The "Profile of the Kuiseb River Basin" being prepared for publication by the Desert Research Foundation of Namibia will be an important information source to guide planning.

The Kuiseb is a model system for the development of economic-social-ecological modelling and application to facilitate sustainable development in arid lands. ■

References:

Gruntkowski, N. 2001: Landschaftswahrnehmung und Ressourcennutzung verschiedener kultureller Gruppen am Kuiseb, Zentralnamibia. Diploma thesis, University of Cologne, Germany

Henschel, J.R., ***R. Dausab, P. Moser*** and *J. Pallett* 2004: !Nara, fruit for development of the !Khuiseb Topnaar. Namibia Scientific Society, Windhoek

Henschel, J.R., M.K. Seely, J. Zeidler 2000: Long-term ecological research at Gobabeb: gaining and applying knowledge about a highly variable environment. Journal of the Namibia Scientific Society 48, pp. 89–115

Henschel, J.R., J. Pallett, C. Berry, M. Griffin, B. Hachfeld, O. Makuti and *M.K. Seely* 2006: Checklists of the flora and vertebrates of Gobabeb. Journal of the Namibia Scientific Society, in print

Heyns, P., S. Montgomery, J. Pallett and *M. Seely* 1998: Namibia's water, a decision makers' guide. Department of Water Affairs and Desert Research Foundation of Namibia, Windhoek

Huntley, B.J. (ed.) 1985: The Kuiseb environment: the development of a monitoring baseline (South African National Scientific Programmes Report 106)

Jacobson, P.J., K.M. Jacobson, P.L. Angermeier and *D.S. Cherry* 2000: Hydrologic influences on soil properties along ephemeral rivers in the Namib Desert. Journal of Arid Environments 45, pp. 21–34

Jacobson, P.J., K.M. Jacobson and *M.K. Seely* 1995: Ephemeral rivers and their catchments. Desert Research Foundation of Namibia, Windhoek

Kinahan, J. 2001: Pastoral nomads of the central Namib Desert. Windhoek

Koch, C. 1963: An illustrated account of a major flood in the Kuiseb River. Der Kreis (2/3), pp. 39–51

Kok, O.B. and *J.A.J. Nel* 1996: The Kuiseb River as a linear oasis in the Namib Desert. African Journal of Ecology 34, pp. 39–47

Lancaster, N. 1989: The Namib sand sea. Rotterdam

Mendelsohn, J., A. Jarvis, C. Roberts and *T. Robertson* 2002: Atlas of Namibia. Cape Town

Mizuno, K. 2005: Environmental changes in relation to tree death along the Kuiseb River in the Namib Desert. African Study Monographs Suppl. 30, pp. 27–41

Moser, P.M. 2005: Regeneration and utilization of Faidherbia albida and Acacia erioloba along ephemeral rivers of Namibia. PhD thesis, University of Bonn, Germany

NamWater 2001: Re-assessment of the long-term sustainable yield of the lower Kuiseb aquifers. Namibia Water Corporation Ltd. Windhoek

Schmitz, A.U. 2004: Transmission losses and soil moisture dynamics in the alluvial fill of the Kuiseb river, Namibia. Diploma thesis, University Freiburg, Germany

Seely, M.K. 1973: Kuiseb River life sustaining barrier. South West African Annual Yearbook 1973, pp. 153–157

Seely, M.K., W.H. Buskirk, W.J. Hamilton III and *J.E.W. Dixon* 1981: Lower Kuiseb River perennial vegetation survey. Journal of the South West Africa Scientific Society 35, pp. 57–86

Seely, M., J. Henderson, P. Heyns, P. Jacobson, T. Nakale, K. Nantanga and *K. Schachtschneider* 2003: Ephemeral and endoreic river systems: relevance and management challenges. In: *A. Turton, P. Ashton* and *E. Cloete* (eds.): Transboundary rivers, sovereignty and development. African Water Issues Research Unit, Pretoria, pp. 187–212

Sengpiel, K.-P. and *B. Siemon* 1995: The BGR geophysical helicopter survey in the Kuiseb dune area (Central Namib Desert), Bundesanstalt für Geowissenschaften und Rohstoffe, Hannover (. German-Namibian Groundwater Exploration Project Report B-III)

Slabbert, A. 1991: Water resource development for Walvis Bay. Department of Water Affairs and Forestry, Walvis Bay

Smith, R.M.H., T.R. Mason and *J.D. Ward* 1993: Flash-flood sediments and ichnofacies of the Late Pleistocene Homeb Silts, Kuiseb River, Namibia. Sedimentary Geology 85, pp. 579–599

Stengel, H.W. 1964: The rivers of the Namib and their discharge into the Atlantic, Part I: Kuiseb and Swakop. Scientific Papers of the Namib Desert Research Station 22, pp. 3–50

Theron, G.K., N. van Rooyen and *M.W. van Rooyen* 1980: Vegetation of the lower Kuiseb River. Madoqua 11, pp. 327–345

Ward, J.D. 1987: The Cenozoic succession in the Kuiseb Valley, central Namib Desert. Windhoek (Geological Survey of Namibia, Memoir 9)

Ward, J.D. and *C.M. Breen* 1983: Drought stress and the demise of Acacia albida along the lower Kuiseb River, central Namib Desert: preliminary findings. South African Journal of Science 79, pp. 444–447

Ward, J.D. and *A.J. van Wyk* 1985: Topnaar (#Aonin) place names along the Lower Kuiseb River, Central Namib Desert. Namib Bulletin 6, pp. 3–8

Werner, W. 2003: Livelihoods among the Topnaar of the Lower Kuiseb. Desert Research Foundation of Namibia, Windhoek

Yamagata, K. and *K. Mizuno* 2005: Landform development along the middle course of the Kuiseb River in the Namib Desert, Namibia. African Study Monographs Suppl. 30, pp. 15–25

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