Table 1. Shows a shift in attitude to climate change issues if communication is effective

Present situation	Expected outcomes
Communities/farmers lack knowledge on causes of climate change and do not understand what needs to be done to tackle it.	Communities/farmers clearly understand climate change and what is causing it.
Communities/farmers think that climate change will not affect them.	Communities/farmers understand the impact climate change may have on their daily activities.
Communities/farmers do not include climate change as an important matter when making decisions.	Communities/farmers include climate change when making their decisions and embrace the positive changes that result.
Communities/farmers think climate change is a depressing and negative issue.	Communities/farmers feel empowered and positive about tackling climate change.

groups do you want to influence (target audiences), what do you want to say (key messages) and who or what are the most effective messengers or champions (community leaders; political leaders or farmers themselves).

TARGET AUDIENCES AND RELATED PERSUASIVE MESSAGES

It is always important to segment the target audiences during communication. Consequently, developing a profile of the audience is needed to answer questions such as: how do they prefer to get information (written, audiovisual, face-to-face etc.)? What is the age range of your audience? Are they mostly men or women? And how do they make a living?

Once the audience segments have been determined, develop messages to address them. A good message addresses a particular objective and should be specific. It communicates clearly to that particular audience, links to something they care about and should be believable and backed up by facts or evidence. Messages about climate change should convey a sense of urgency and emphasise the benefits of making the changes being advocated. Therefore, the messages should show that these changes will build resilience, sustain livelihoods and reduce vulnerability. At the end, request feedback from the communities or farmers which could assist in improving and enhancing the message for the future.

CONCLUSION

To ensure effective communication about climate change, make sure that you understand the issues and concepts before trying to communicate them to others. Speak in plain language; do not use technical, climate change jargon. Keep your messages clear, accurate and simple. Link climate change with other environmental and social issues that might be familiar to people, so that they can understand how the issues are connected. Show the history of climate change, if any, through visuals such as videos, maps, satellite images and pictures to emphasise the importance of this global phenomenon. Last but not least, encourage the audience to integrate climate change into their development goals in order to remain focused, or to take climate change into consideration during the implementation stage of their projects or daily activities.

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ACCELERATING LANDSCAPE INCISION AND THE DOWNWARD SPIRALLING RAIN USE EFFICIENCY OF NAMIBIAN RANGELANDS

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ABSTRACT

In response to rapidly degrading rangelands there is an urgent need to precondition the land for extremes of weather conditions, which will both mitigate locally against climate change and offer better rain use efficiency and better primary and secondary productivity. Mainstream principles of rangeland management tend to overlook levels of ecological organisation above the "veld type" as well as dehydration caused by landscape incision and the impacts of infrastructure that initiate and accelerate many erosion processes. Dongas erode soil, but far more ecologically significant is their dehydrating impact on affected surrounding landscapes and their sub-catchments. Prior to incision by dongas, the affected landscapes were usually the most productive in their wider catchment context, staying green longer than adjacent run-off and run-through landscape elements and responding rapidly to local rainfalls. Examples are presented from Farm Krumhuk, approximately 20 km south of Windhoek.

INTRODUCTION

Rangelands globally face many challenges, not least of which are increasing costs and declining real prices on produce. Climate change is another challenge which appears certain and predictable at a global and continental level, but little real progress has been made to adapt to likely changes for most regions.

Whatever the impacts of climate change, we argue that preconditioning the land for extreme weather conditions will not only mitigate locally against climate change, but also offer better rain-use efficiency and better primary and secondary productivity. In other words, this work should be done, irrespective of climate change scenarios. Such preconditioning aims to get rainfall into the ground as locally as possible and minimise run-off. For both extremes of weather, the conventional strategy is to have high ground cover at a fine scale to capture raindrops into the soil locally, minimise run-off and protect against soil erosion. We argue that it is equally important to restore base levels, where water is held back in the landscape, at a drainage ecosystem level. The purpose of these inter-dependent strategies are to withstand major rainfall events and make best use of small falls of rain in prolonged dry periods. (Base levels are the lowest part of a drainage system beyond which erosion cannot occur. When base levels are incised, for instance when a sandy sill of a wetland is breached by animal paths, then a new phase of erosion is initiated upslope).

While standards of grazing management can certainly be improved and systems such as Savory's Holistic Management (Savory and Butterfield, 1999) and Riaan Dames' Fodder Flow Grazing Management Strategy (Dames, 2009) offer great opportunities, as well as the older Acocks model (Acocks, 1964), they are fundamentally captured in the traditional, local focus (perhaps obsession) with "veld type" dynamics. What all of these models share is a focus on biologically strategic rest (mainly for grasses), an important but inadequate approach to be truly "holistic". That lack of holism is in the sense of levels of ecological organisation above the "veld type" (or "ecological site" in the USA), which is partly our focus in this article. Of particular concern is the increasing incision of catchments and their landscape sequences from valley floor to upland headwaters. These processes do not start and stop in a veld type, but transcend them and thus require a higher level of appraisal than conventional in situ veld management.

Two key additional issues need to be considered along with conventional veld management and like all else, interact as factors determining habitat quality for both livestock and wildlife locally. These are i) landscape incision and dehydration and ii) the impacts of infrastructure that initiate and accelerate many of the former degradation processes. We see these three strands of physical land management as prerequisites to ecosystem ("ecologically") sustainable land management, whatever the land use, culture or location (Pringle and Tinley, 2003; Pringle *et al.*, 2003; Shamathe *et al.*, 2009).

LANDSCAPE INCISION, INITIATED BELOW AND ACCELERATED ABOVE

Gully or "donga" erosion is often blamed on poor ground cover in the hinterland catchment above. This is not generally correct; increased run-off certainly causes sheeting and extension of erosion cells (Pickup, 1985), but dongas generally need a "nick point"; a cut in the landscape to get started. This may be a track graded below the land surface by just a few centimetres, or a cattle or wildlife pathway. In Mozambique's Gorongoza National Park, it was the hippo that caused the spread of dongas into the Urema Lake wetlands system (Tinley, 1977).

Easily overlooked, but fundamental to understanding incision-based dehydration of landscapes, are the following key sequences of processes:

- Water usually flows downslope with gravity.
- Erosion headcuts progress upslope at all scales, micro to macro, cutting into adjacent intact soil surfaces.
- Detached soil is entrained by the flow and also moves downslope.

There are exceptions, but they will confuse the key message here. What is critical for land managers and their technical supporters is that any donga has come from and been initiated downslope. Increased run off in headwaters acts as an accelerator pedal, not an initiator of donga development. Thus any restoration needs to address:

- Stabilisation of the aggressive headward cutting "head";
- calming the hinterland, and
- restoring as best as possible the initial "nick point".

Most importantly, once a head is initiated, it needs to be identified and halted before it splits, as heads will always retreat back into areas from which they receive strong flow. Thus dongas may incise upslope as a simple head initially, but if any tributary flows are encountered on this course, the head will split and cut back into them too. Thus dongas draw exceedingly more water into their channel ("canal") system at the expense of the surrounding "robbed" landscape. Dongas erode soil, but far more ecologically significant is their dehydrating impact on affected surrounding landscapes and their sub-catchments (Pringle and Tinley, 2003; Tinley, 2001; Tinley, 1982).

Dongas siphon landscapes dry and lead to lower and more intermittent soil moisture balance regimes

Dongas are usually discussed in terms of soil erosion, which is correct and obvious. What is not often appreciated is the wider impact dongas have on the distribution of soil moisture in time and space. Dongas drain away surface water that has not infiltrated the soil, exporting this critical resource from the landscape in which it fell as rain. Dongas effectively "pull the plug out of the bath" leading to shorter periods of positive soil moisture balance. This in turn degrades the rain use efficiency of affected landscapes and their sub-catchments with subsequent rainfalls. Dehydration becomes a positively reinforced downward spiral; the more water is lost, the faster and wider the incision process and so on. Once erosion patches enlarge and link up reaching a critical dimension of increased runoff volume, this results in ongoing self-generated expansion of eroded terrain that no amount of rest will heal without intervention at key sites.

It is imperative that dongas be seen as desiccators of affected landscape complexes and not just as a soil erosion problem. Prior to incision by dongas, the affected landscapes were usually the most productive in their wider catchment context, staying green longer than adjacent run-off and run-through landscape elements and responding rapidly to local rainfalls.

Donga heads not only lower the local base level and thus drain surface water passively; as flows fall over the rim of the gully head, they accelerate. This acceleration acts as a strong physical "pulling" force within the surface water above; the heads of dongas really do "suck" landscapes dry. Thus as donga heads cut back and split upslope; they are effectively becoming increasingly efficient at sucking suites of landscapes dry.

"Spikier" soil moisture balances favour different plant species and vegetation

The export of surface water is particularly profound and problematic in seasonally inundated landscape elements such as upland valley floors, valley-side floodouts, floodplains and swamps. The incision of the ecological and commercially critical landscapes reduces the time they are waterlogged and thus species sensitive to water logging are no longer drowned. Many of these key landscapes were once open hydromorphic (water loving) grasslands and sedgelands (according to farmers of the Auas Oanob Conservancy and various historical accounts and photographs). However, they are now bush encroached because bush seedlings in these previously seasonally inundated landscapes are no longer drowned effectively before they can grow to a size where they can survive water logging during parts of the rainy season, and also because of the opposite dry season conditions of compact cement-like clay or gilgai-cracked desiccated soils that are inimical to scrub seedling survival (Tinley, 1982; 1977). This component of the wider Namibian bush encroachment story is largely unknown and overlooked in the most recent major review (De Klerk, 2004). It is emphasised that this cause of bush encroachment is specific to seasonally inundated landscapes within wider catchment systems in which other factors are usually predominant (Joubert, Zimmermann & Graz, 2008; De Klerk, 2004).

Not only can bush species survive when seasonally inundated surfaces are "unplugged", hydromorphic grasses become more stressed and lose their habitat-specific competitive advantage over more xeromorphic species in a positive feedback loop resulting in successively greater landscape dehydration and increasing xeromorphic vegetation (grass as well as bush species). Overgrazing might accelerate the process through reduced local infiltration as well as consequent faster landscape incision due to greater run-off.

These major changes also have cascading ecological effects, including favouring browsers (e.g. goats, impala and kudu) over ecotonal or grassland favouring grazers (e.g. hippo, roan and sable antelope) or mixed feeders (e.g. cattle and eland) (Tinley, 1977). As a general rule, the species favoured by landscape dehydration are more generalist and may be of lesser commercial and/or conservation value.

The major changes are also potentially catastrophic for landholders, both commercial and traditional, as they try to adapt to an increasingly inefficient rain use landscape that is more drought and flood prone. In a climate change context, these changes are likely to make adaptation ever more challenging at a local level. This issue is too important to remain overlooked or treated as a side issue. We must stop the decline and start rehydrating the rangelands (Shamathe, Zimmermann & Pringle, 2008a) for a complex variety of interlinked reasons.

INFRASTRUCTURE CAUSES MANY OF THESE INCISION PROBLEMS

As previously discussed, dongas almost always start at some local landscape incision ("nick point") receiving concentrated flow from above. The most common causes of dongas across southern African and Australian rangelands include:

- Old wagon tracks cut into the landscape, particularly where they traverse narrow valley floor gaps in mountainous terrain or follow valley floors (Cooke and Reeves, 1976).
- Modern access tracks that are aligned to some extent (not necessarily directly) up and downslope and have been cut (perhaps only a few centimetres) into the landscape in construction or maintenance (e.g. with a grader blade) or been used when the landscape is still wet following rain.
- Fence lines running to some extent up and downslope that have concentrated animal traffic along them and thus are prone to incisions of animal pathways.
- Watering points in areas of concentrated flow which typically have animal pathways radiating out from them (Pringle and Landsberg, 2004); the worst of these are where they are located at the "key line", where flow should switch from tributary to distributary as flows emerge from uplands into flatter country (Pringle *et al.*, 2006). Once incised by a donga, the water flow no longer spreads out at the keyline, but instead gushes down the donga.
- Main road culverts, which are usually set below the surrounding landscape level to facilitate the rapid flow of water below and not over the road surface.
- Excavations with steep slopes (e.g. "borrow" pits for road building).
- Any other source of landscape incision likely to receive substantial run-on.

A keyline (see fourth point above) is the change in slope from uplands to flatter ground. In uplands drainage channels usually come together (the tributary phase), straighten, accelerate and are effective at eroding disturbed soil. Below the keyline channels should start to split up (the distributary phase), slow down and deposition should dominate over erosion. In severely damaged drainage ecosystems, the distributary phase is replaced by channels that keep the water in them like downpipes on a roof, drying out previously hydrated landscapes of whole drainage systems (Pringle & Tinley, 2003).

In the past, wells and even bores were generally sunk where underground water supplies were shallowest and had the best quality and supply. These were often (even usually) in positions in the landscape least suited to intense traffic of animals and humans. However, with reticulation technology (e.g. plastic pipes), it is no longer necessary for watering points to remain in these highly unsuitable locations. Even dams can be fenced and the water reticulated to hydrologically "quieter" and more stable landscape positions. This cannot be done at once, but through a triage process, a long term programme can be affordable and effective. Fence lines causing problems can also be prioritised and gradually relocated or removed.

With machinery, "track creeks" are also repairable by flattening out windrows to allow natural cross flows. Where the "creeks" have been incised too deep and there is not enough material in windrows to flatten them out effectively, strategically placed small banks can be installed to encourage harvested water to return to its natural course.

Floodways at landscape level are far more ecologically appropriate than culverts, but engineers (and the public) often want non-stop traffic flow along main roads. The heads cutting back upslope from road culverts should be stabilised to allow water to flow over them with no further erosion (if the culvert cannot be removed or replaced at natural landscape level). This can be done by flattening down the head's "cliff" and then armouring it with stones (preferably limestone which sticks together when wet) or geotextiles. This should be a standard practice in main roads management, but is very rarely observed. Flows from culverts should be checked with a short solid bank as close to the road as is allowable to "take the hit" and then spread the water more serenely back out into the landscape.

CASE STUDIES ON FARM KRUMHUK

Landscape incision and dehydration, and their initiation by infrastructure, are captured in photographs from Farm Krumhuk, in the Auas-Oanob Conservancy nearby Windhoek. A sketch of the broader study area appears in Figure 1. Satellite images from Google Earth show the broader area where two case studies are located (Figure 2). Figure 3 focuses on the case study area around Vlagte Dam. The coordinates for the dam appear on Google Earth as 22° 46' 03" S, 17° 05' 05" E. Photographs of this case study appear in Figures 4 to 8. The other case study of water capture by a track is illustrated by photographs appearing in Figures 9 to 13.

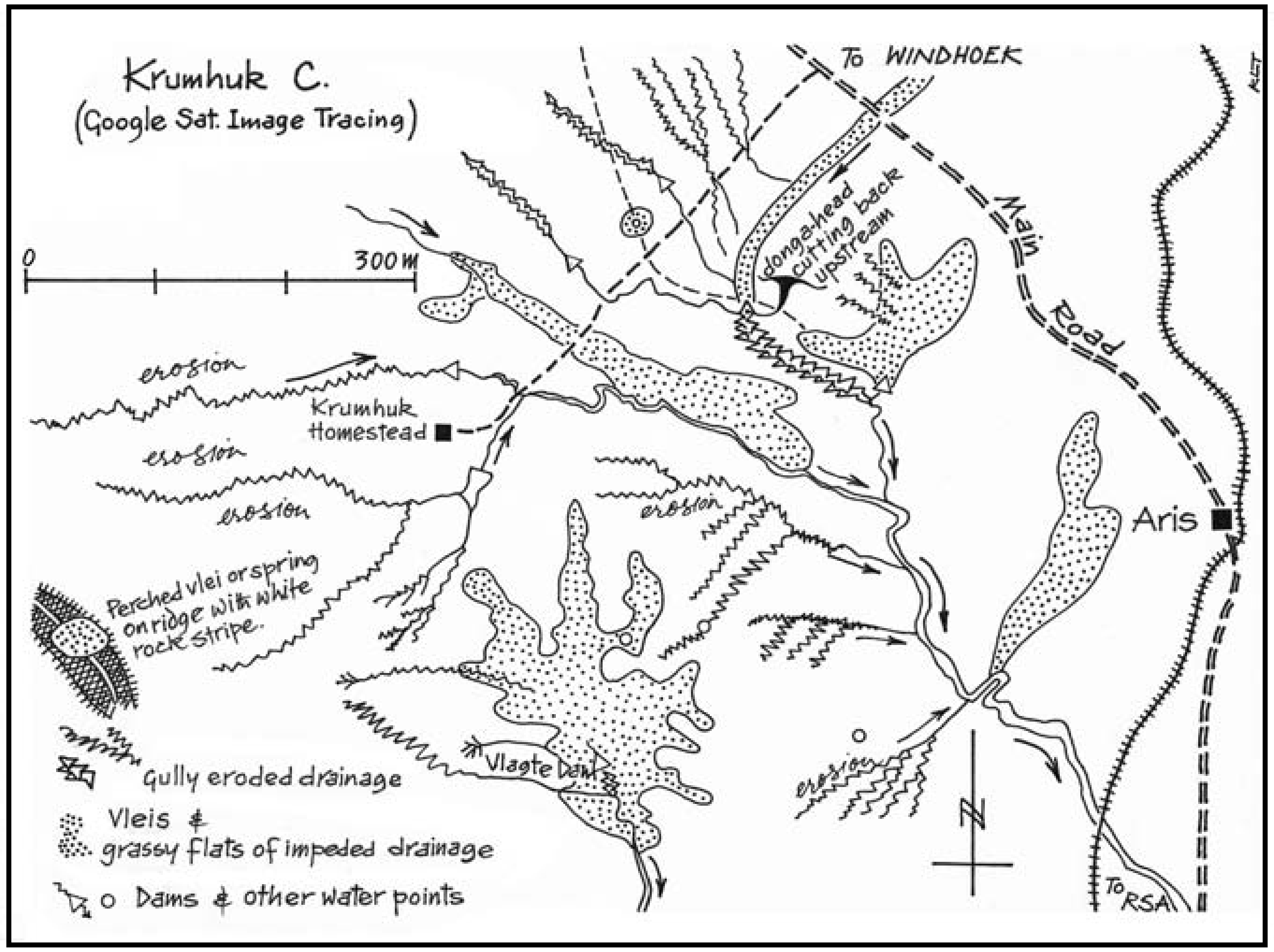

Figure 1. Tracing from Google Earth satellite images of main landscape features in the northern part of Farm Krumhuk, south of Windhoek.

Figure 2. In this example on Farm Krumhuk, a creek flowing out of the mountains (outside and to the left of the Google image) floods out when it meets flat terrain and then splits its sheet flow because of subtle slopes in the plain below. Some goes north-east to a dam near the homestead and some flows down to the vlagte (seasonally inundated wetland) blocked by Vlagte Dam. We know the floodout fan splits because of the distinct donga heads eating back towards the creek's floodout point from different directions. The "track thief" may well have pulled water towards it and an animal path would have been enough to start the donga head upslope (left). Wherever you see sections of track broader than others on Google Earth (which is free), it is likely they are cut down and cutting back laterally (sideways) to drain landscapes. Should either of the donga heads in the case study of the track creek (Figures 9 to 13) reach the floodout point, there will be a downpipe from the mountains to the nearest major channel and that creek's contribution to soil moisture balance of the plain will be totally lost (as has already happened with other creeks).

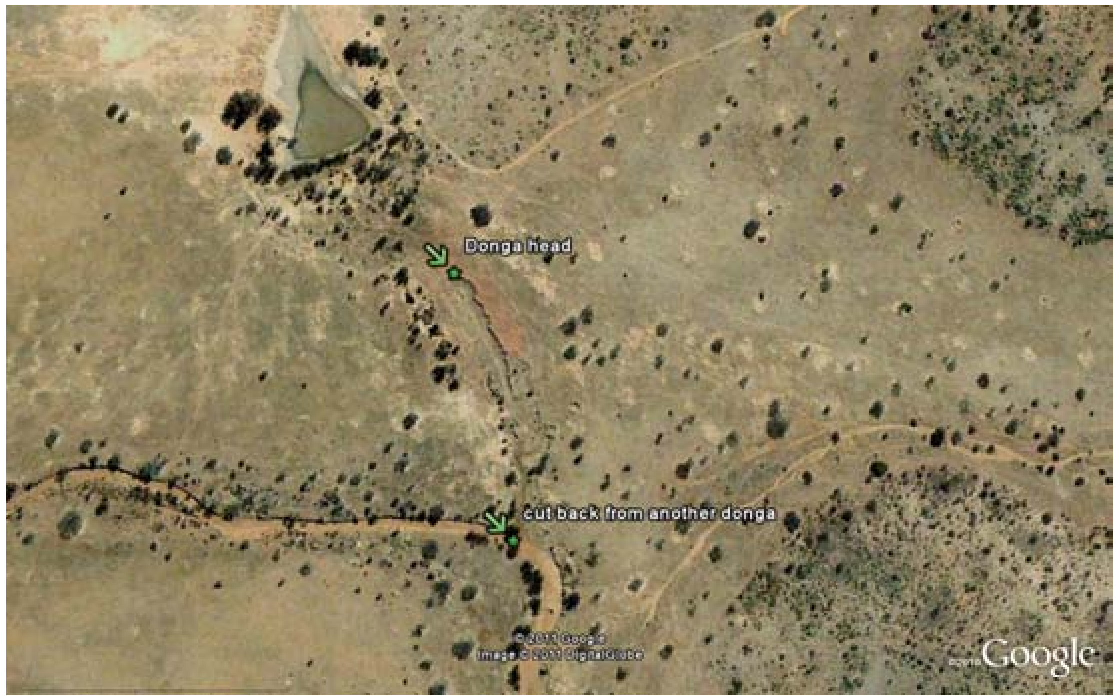

Figure 3. The donga head cutting back towards the Vlagte Dam on Farm Krumhuk has cut back from a more deeply cut down channel that turns sharply west. This deeper channel also ends upslope in gully heads indicating that it is not a natural drainage feature either. The concentrated overflow from Vlagte Dam has spilled over into the incised channel and set off the current donga head cutting back to the dam's spillway. The old, unchanneled water course is parallel to the donga, as indicated by the line of trees.

Figure 4. A major donga is cutting up towards the Vlagte Dam overflow alongside a cut off natural watercourse on Farm Krumhuk. The donga is draining a broad seasonally inundated plain. Younger and smaller Acacia karoo trees higher in the channel indicate this is a donga, not a natural creek.

Figure 5. A cattle path helps the head of the donga actively pull water towards it. Water flowing over the head's "waterfall" accelerates, thus exerting a sucking force on the water behind. This is how donga heads actively drain landscapes upslope of them. Thus dongas are a major ecological issue, not just a soil conservation problem.

Figure 6. Water actively sucked into the donga quickly finds its way out of the system, thus reducing the landscape's ability to turn rainfall into grass and leading to soils drying out more quickly.

Figure 7. Once the storms were over, it was clear that the donga head had eaten its way back into the healthy ground – up to five metres in places. Well after the rain stopped, the waterfalls continued sucking the plain dry, with the central, lowest waterfall stopping last, leaving no more surface water upslope.

Figure 8. Young *Acacia karoo* plants establish above the rim of the donga head where they are no longer drowned at seedling size. Unlike their counterparts in the most recently formed part of the donga below them, these bushes are doomed, as the donga head will, in the next big storm, erode the soil that now supports them. A larger plant can be seen in the foreground. This plant dates back to an earlier season than the two smaller ones in the background. It may survive until the next major head retreat. Then the two smaller ones will in turn be "hanging on the edge".

Figure 9. This is an example of how poorly located and constructed access tracks can drain landscapes as effectively as any true donga. In this case a creek from the mountains in the background has flooded out in a fan when it has hit flat ground, depositing rich alluvium in a highly productive system. The track is cut into the land and has started micro-terraces (broad, small water fall heads) cutting back into the floodout fan. The track starves areas of the fan below it.

Figure 10. The waterfall face of these micro-terraces may be less than an inch high, but is very effective in draining areas upslope as the water accelerates over the edge.

Figure 11. As the micro-terrace faces cut up-slope they often become shallower and get broken up by stable mounds making a pattern of stable islands and stripping rills out of a once water-soaked fan system.

Figure 12. The track is capturing almost all of the sheet flow from the left side and the lower, right hand side of the photograph is now effectively dehydrated by the "track creek".

Figure 13. A head is cutting back up the track towards the area of the previous photographs. This head is creating a new, deeper base level below the natural landscape and thus helping the existing track "sucking" the landscape above dry and when it gets back to the area above, it will probably set off a new series of micro-terrace faces to accelerate the drying of this fan and virtually cut off flow to the area of the fan downslope.

ADDRESSING LANDSCAPE INCISION TO REHYDRATE RANGELANDS

Soil conservationists have been addressing donga systems for several decades and the techniques they have developed generally work well, but are now often cost prohibitive in terms of the price of concrete to build various check structures or weirs. Alternative, less costly approaches using machinery to build banks have also been successful (but again, not always) (Bastin, 1991). Bush packing has also been successful, such as seen/demonstrated/observed in another part of the Auas-Oanob Conservancy (Kauatjirue *et al*., 2010; Shamathe *et al*., 2008b). At Londolozi in South Africa, trees were used to fill dongas; these have vanished and have returned to being productive grasslands (Ken Tinley, personal communication). There are many other approaches to rehydrating incised and dehydrating rangelands and local creativity and innovation is often required to make use of what is at hand.

What is not common, is a systems view to be implemented so that a carefully planned and sequenced set of interventions can be implemented to address the causes as well as the symptoms, and thus turn the system back to better functioning (Whisenant, 1999). Too much attention has been paid to techniques and not enough to systems in restoration planning. Through the Ecosystem Management Understanding (EMU) Project™, we have developed a sequence of key steps in planning repair of an incised and dehydrating rangeland system (Tinley and Pringle, 2006). Key to this approach is to map key landscape patterns and processes (particularly hydrological ones), incisions and their heads and implicated infrastructure, *before* planning interventions that are sequenced and support each other. What is primarily important, is identifying what has to be achieved at each intervention point, not the technique used. This allows for creativity and innovation to overcome resource limitations.

CONCLUSION

Downward spiralling rain use efficiency is being driven by landscape incision processes globally in rangelands with effective overland flow, and Namibia is no exception. In fact, this issue is possibly the most critical overlooked environmental problem in the country and it affects many aspects of Namibia's human ecosystems from wildlife conservation and traditional land use to commercial farming. Without being recognised and addressed strategically, the future is one of increasingly long droughts and damaging floods, as well as far greater vulnerability to climate change. Most distinctive and drought buffering landscapes and plants and animals that are specifically adapted to them, will be lost and replaced by bare earth and/or bush encroachment. This issue is too important to be ignored, as the cost of not addressing it will be extremely high for wildlife and human inhabitants of Namibia.

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