TOWARDS AN UPDATED CARRYING CAPACITY MAP FOR NAMIBIA: A REVIEW OF THE METHODOLOGIES CURRENTLY USED TO DETERMINE CARRYING CAPACITY IN NAMIBIA.

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ABSTRACT

Global warming and land reform are amongst the issues that have pushed rangeland degradation in Namibia to the fore once again. It should be realized that the application of realistic grazing capacities (GC) holds the key to sustainable rangeland utilization. A realistic grazing capacity map could play a major role in aiding policy makers towards informed and responsible decisions regarding land reform issues.

However, it is just about impossible to accurately establish the GC of an area, based on the large number of variables influencing it. This does not mean, however, that one should stop attempts to do so.

Currently, three methods of determining GC are being either applied or investigated by researchers in the Ministry of Agriculture, Water and Forestry. These are: the quantitative yield method (measuring grass and animal biomass, and matching animal requirement to the amount of plant biomass available), remote sensing, and generating grazing index values for plants based on their biomass production, nutritive value and palatability.

Although the quantitative yield method, or clipping of quadrats, remains one of the most accurate methodologies available to determine grazing capacity in Namibia's heterogeneous rangelands, calculated GC values are still subject to a statistical error of 20%. Compiling photo guides based on the clipping of quadrats could be a valuable tool to assist farmers in the sustainable use of their rangelands. Remote sensing is best suited to areas with a homogeneous vegetation. Although real time data can be acquired through remote sensing, images still need to be validated through the time consuming process of ground truthing. The heterogeneous nature of Namibia's rangelands does not lend itself readily to this advanced technology. The Grazing Index Value project will be launched at the beginning of 2006. Due to the agronomic traits to be included in the establishment of a grazing index value, it is believed that more accurate grazing capacities for the south of Namibia, with its strong dwarf shrub component, can be established.

In order to establish accurate grazing capacities over the long term, whichever methodology proves to be the most appropriate in terms of accuracy, time, manpower and finances, will have to be repeated over a number of years to capture all variation inherent to GC determination. In order to overcome the time constraint here, it might be meaningful to adapt the current grazing capacity map in terms of structural problems that exist (e.g. bush encroachment), "officialise" the map and use it in future land reform policy decisions.

INTRODUCTION

The deterioration of Namibia's rangelands is an issue that has been under discussion for a long time. In a Report of the Drought Investigation Commission of South West Africa (1924), it is stated: *"Soil erosion has commenced in South West Africa"*. More recently, Loubser (1987), refers to an increase in bush over the past three decades due to overgrazing. This aspect, together with a prolonged drought during the years 1980-1987, resulted in a continuous deterioration of the grazing. As a result, a conference was held in Windhoek in 1987, which was attended by the representatives of the various agricultural authorities in South West Africa/Namibia. Participants at that conference were sufficiently convinced to take the decision that there was a need for entering into a land reclamation phase, and that a strategy should be implemented as soon as possible in an effort to stop and reverse the land degradation process. Summarily to the land reclamation phase, Le Roux (1988) stated the attitude of man towards the soil, overestimation of the grazing capacity of the land, structural problems such as bush encroachment and uneconomical farming units as the major reasons for the overall degradation of Namibia's rangelands.

In Namibia today, the issue of land deterioration is becoming even more pronounced, especially as land expropriation, global climate change and increased living costs are real issues, which, together with those concerns raised by Le Roux, should define the research focus of those qualified in these fields. Against this background, it is foreseen that the natural veld in Namibia will increasingly come under pressure. Judicious use of this natural resource cannot be over emphasized, and pasture researchers in Namibia have been working with this as a given for a long time. Various articles have been written by these researchers with sustainability as the basis and a number of articles on the vitally important aspects of grazing capacity and stocking rate have been published over the years (Visser and Van Wyk, 1986; Kruger *et al.*, 1988; Van Wyk, 1988; Bester and Reed, 2003; Bester, 2003; Bester *et al.*, 2003). A considerable amount of information regarding the extent of and the possible reasons for bush encroachment, ways of dealing with it and financial analysis on various aspects of bush encroachment have also been published by local researchers, and have been consolidated in a recent document titled "Bush Encroachment in Namibia" by J.N. de Klerk (2004).

Currently, an issue which has become of real importance in the land reform context is the creation of an updated version of the existing grazing capacity map of Namibia. Although such an updated map could be instrumental in the taking of responsible land reform policy decisions regarding valuation and the redistribution of land, the primary objective should still be to make guidelines available which would enhance the chances of the sustainable use of natural grazing. Various approaches and methodologies can be used in the determination of grazing capacity, each with its own strengths and weaknesses. However, all of these require time and therefore it cannot be expected that a national grazing capacity map be generated overnight.

Meissner (undated) states that the term "carrying capacity" has different meanings for different people, and this is indeed illustrated by the number of different definitions that exist. In this paper, carrying and grazing capacity is understood to be as follows (after Trollope *et al.,* 1990): Carrying capacity: the potential of an area to support livestock through grazing and/or browsing and/or fodder production over an extended number of years without deterioration to the overall ecosystem; Grazing capacity: the productivity of the grazeable/browsable portion of a homogeneous unit of vegetation expressed as the area of land required to maintain a single animal unit over an extended number of years without deterioration to the soil.

Schmidt *et al.* (1995), states that it is impossible to accurately determine the grazing capacity of an area simply because of the large number of influential variables. When one factor changes, grazing capacity also changes to a greater or lesser extent. A simple example is the effect of rainfall on grazing capacity especially in an arid country like Namibia. Be that it as it may, it remains essential to continue attempting to estimate grazing capacity, as it forms a strong basis for sustainable rangeland utilization (Van der Westhuizen *et al.*, 2001).

Following is a review of the current methodologies either being applied in Namibia, or in the process of being developed in order to create more accurate information on grazing capacity.

THE METHODOLOGIES

The quantitative yield method (clipping of quadrats)

Up until fairly recently grazing capacity in Namibia has been based primarily on estimations by experienced farmers and extension officers and was expressed as ha/Large Stock Unit (LSU) or Small Stock Unit (SSU). The subjective (but not necessarily totally incorrect) nature of this method was realized in the late 1980s and a more scientific approach, based on the biomass principle, was then developed by Namibian researchers. This approach is based on the objective measuring of plant and animal biomass. Plant biomass is determined by the clipping of quadrats, while animal biomass is determined through regular weighing of animals. By setting the daily Dry Material (DM) intake of an animal at 3% of liveweight and matching the amount of DM needed to the amount of available grass material, it is possible to determine the yearly grazing capacity of an area.

An article on the quantitative yield methodology to determine plant biomass was published by Bester (1988), showing the process step by step. Grass biomass is calculated from the yield of forty 1 m^2 quadrats, on a transect starting at the watering point in a camp (mostly situated in one corner of a camp) and ending at the opposite corner of that camp. In doing so, it is argued that any variation that might exist in terms of botanical composition as well as grass yield is captured. This is based on the assumption that grazing closest to the watering point, where animals usually concentrate, would be in the most degraded state, while the grazing which occurs furthest from the watering point would be the least degraded. Thus, variation in both aboveground biomass and botanical composition can be expected as one moves further away from the water point. Fourie (1989) showed that a minimum of 40 one meter square quadrats per transect are needed for a statistical error of ≤ 20%. To decrease error to 10% would

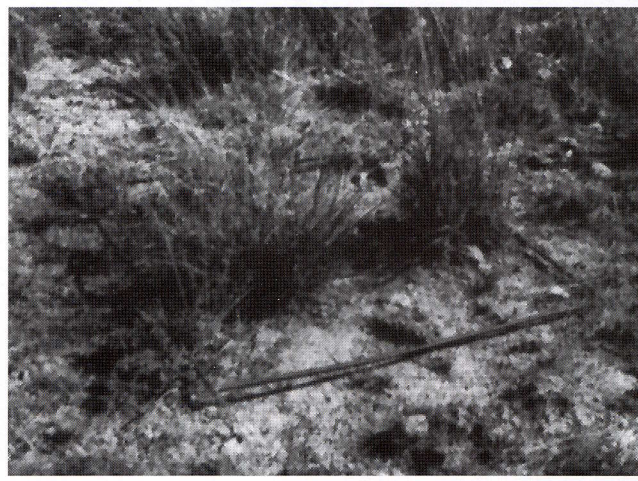

Figure 1. Grass tufts in a quadrat before clipping (Bester, 1985).

require a total of 153 quadrats per transect which, although possible, would be too time consuming to execute. Clipping less than 40 quadrats per transect would extend the statistical error to an unacceptable level.

Another application stemming from this method is the compilation of a photo guide showing pictures of areas in which the grazing capacity was determined using the clipping method (NAPCOD, 2003). This could guide farmers towards more sustainable use of their land.

Remote sensing

The Ministry of Agriculture, Water and Forestry's Agricultural Laboratory has the capability to acquire and analyze SPOT (*Satelite Pour l'Observation de la Terre*) VEGETATION satellite imagery with a resolution of 980 x 980 m. These images, together with SMAR (Satellite Monitoring of Arid Rangelands) software developed by the French Agency GDTA (*Groupement pour le Développement de la Télédétection Aérospatiale*), a subsidiary of the French Space Agency CNES (*Centre National d'Etudes Spatiales*), have been used to estimate Total Seasonal Biomass Production over a period of twenty years in Namibia. This is a project of the Agro-Ecological Zoning (AEZ) program in collaboration with the

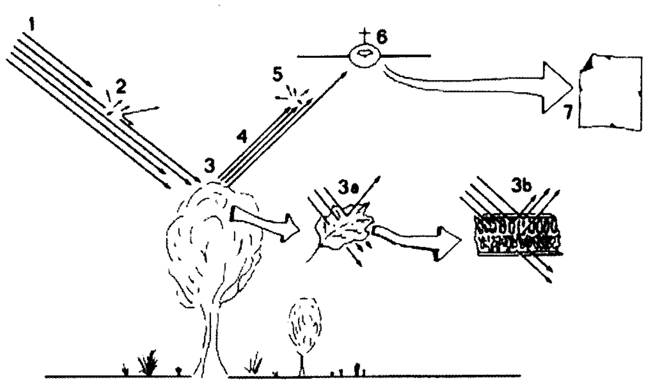

Figure 2. Idealized overview of the acquisition of a remotely sensed image.

This schematic view of some elements in the acquisition and interpretation of a remotely sensed image illustrates kinds of knowledge that constitute the field of remote sensing. This image is derived from solar radiation. A portion of the incoming solar radiation (1) is scattered or attenuated by the earth's atmosphere (2). The remaining energy reaches the earth's surface and interacts with features in the landscape, for example a tree (3). Much of the reflection of energy from the tree is controlled by interaction with individual leaves (3a), which selectively absorb, transmit and reflect energy depending on its wavelength (3b). The reflected energy (4) is again subject to atmospheric attenuation (5) before it is recorded by an airborne or satellite sensor (6). The results of a multitude of such reactions are recorded as a photograph-like image (7), or as an array of quantitative values. The image is then available for interpretation and analysis (Campbell, 1987).

Agencia Espanola de Cooperation Internacional as well as the Cartographic Institute in Catalunya, Spain. The ultimate goal of the AEZ program is the mapping of areas in Namibia with similar combinations of climate and soil and with similar biophysical potential for agricultural production.

With this capability, the question arises as to whether it is not possible to use remote sensing data to determine grazing capacities, and to what extent it can be applied to compile the much needed updated grazing capacity map of Namibia. In a fairly recent exercise (20 – 30 June 2005, the period coinciding with the observation platform passing over Namibia), coordinated by the National Botanical Research Institute, various staff members within the Ministry of Agriculture, Water and Forestry embarked on clipping grass biomass in 200 transects spread as widely as possible over the whole of Namibia. The methodology required that:

- the sites to be selected should be such that they contain only grass;
- a GPS (Global Positioning System) reading be taken at the beginning and end of each transect so that pasture spectral signatures could be calibrated with satellite images;
- a minimum of 40 quadrats be clipped per transect;
- the transects be at least 800 m long and that all grass within the quadrat be clipped and collected.

With information thus obtained, attempts will be made to delineate grassland areas based on this component's spectral signature and to link a total grass biomass yield/ha to these delineated areas.

Grazing index values (GIVs)

Researchers within the Ministry of Agriculture, Water and Forestry have embarked on a project in which the grazing index value methodology, as developed by Du Toit (1996) for the South African Karoo veld, is investigated as a possible approach to determine objective, realistic grazing capacities for the southern region of Namibia. This has become imperative as grazing capacities in Namibia are, to a large extent, based on estimation and expert opinion. At more than one Farmers' Association meeting which the author attended over the past 10 or so years, concerns were raised on a regular basis as to the applicability of the quantitative yield method to determine grazing capacities in the south (with its strong small shrub component) as this method is *grass biomass yield* orientated. The major concern was that the grazing capacity over much of Namibia's southern rangelands is, to a large extent, determined by and dependent on dwarf shrubs, and not on grass.

The GIV project aims to calculate a grazing index value (based on agronomic traits) for those plant species which appear to be the most dominant on selected sites in the commercial as well as the communal southern farming areas. The area targeted in the first phase of the project is the Swartrant, from Maltahöhe to Bethanie, as well as the communal farms Ubiams and Kinachas situated in the same area. The Swartrant was chosen due to its relative homogeneity with regard to topography, rainfall and vegetation.

Grazing index values are to be calculated on dry material yields and chemical values of individual dominant species at the observation sites, put together in a formula of the following form:

$$GIV = \frac{(\text{Available forage} + TDN + \text{Cover} + [K/Ca:Mg]) \div \text{ether extract})}{100}$$

Where: TDN = Total Digestible Nutrients
Cover = canopy cover

A number of important variables needed to determine grazing capacity are incorporated in this formula: Plant biomass (amount of material available to the grazing animal), quality aspects (for example TDN – because of the prominence it receives in animal feeding rations – coupled to the requirements for growth and production) and palatability (covered by the ether extract of plants: ether extract in karoo shrubs influences palatability negatively; in grasses, ether extract enhances palatability) (Du Toit, 1996). The parameters included in the Index Value model of Du Toit (1996) were determined and selected using multiple stepwise regressions.

Figure 3. Measuring canopy cover for inclusion on GIV calculation.

The project, which is to commence during February 2006, will attempt to collect data on available forage and chemical properties of the dominant species at the selected sites at least twice during the growing season and once during the off-season for at least three consecutive years. It is hoped that this frequency will ensure acceptable average GIVs for a given species. Once such index values have been generated, they will be used in the calculation of veld condition scores. Sites at which veld condition has been determined will then be subjected to grazing trials in order to determine grazing capacities. Hopefully the first reliable GIV data (depending on rainfall) should be available by the end of 2008, from where the next relatively homogeneous farming area will be identified and the same process repeated (phases 2, 3 and so on). This is necessary simply because of the diverse nature of Namibia's southern rangelands and acceptance of the fact that grazing capacity differs widely over that region.

DISCUSSION

Quantitative yield method

Although proven to be relatively accurate in grass dominated veld, there are still a number of shortcomings in the quantitative yield method of determining grazing capacity. Probably the most important one is that it measures only grass production, while the vegetative production of herbs, dwarf shrubs, tall shrubs and trees is excluded. Currently, the occurrence of these components in the veld is treated as a "bonus" additional to the calculated grazing capacity on grass. This brings about a degree of conservativeness in the final calculated grazing capacity figures. Although it is possible to determine the yield of these vegetative components, the appropriate methodologies are time and labour consuming and therefore expensive.

Secondly, the figure of 3% of liveweight is a very rough estimate and considered by Meissner (1995) to be not scientifically justifiable. He points out that whereas a 200 kg calf may eat 6 kg of DM/day, an 800 kg bull will not eat 24 kg of DM/day. It is shown that the intake for cattle could be much less (2.19 – 2.34% of liveweight), while the intake for sheep may vary from 2.9 – 3.5% of liveweight. This may bring about conservative stocking rates when applied on a cattle farm, while a sheep farm may be somewhat overstocked.

After clipping and drying, the total grass biomass yield is decreased by 50%. This stems from the fact that where more than 50% of the foliage of a grass plant is removed, prolonged or complete root growth stoppage follows, which is reflected in poor shoot development (Crider, 1955; Dahl, 1995). It is a fact that animals select different plants when grazing, and that plants will be defoliated to different levels in the same sward when grazed. In order to more accurately determine the grazing capacity, one should therefore not use 50% across the board for all species but include utilization factors in the grass biomass yield calculation process. For example, Bester *et al.* (1985) found that where a stocking rate of 6 ha/LSU was applied, defoliation at the end of the grazing period for *Schmidtia pappophoroides, Stipagrostis uniplumis* and *Eragrostis rigidior* was 60%, 33% and 17% respectively. Higher stocking rates would bring about higher levels of utilization of the less palatable species, but such stocking rates would invariably exceed the acceptable level of utilization of the palatable species. This indicates that the inclusion of utilization factors will contribute towards more accurate calculation of grazing capacity if sustainability is to be the underlying objective. Although it is quite possible to clip grass on a species basis and apply utilization factors when calculating grazing capacity, it requires specialist knowledge on palatability and the diet selection patterns of domesticated animals.

Remote sensing

Smith *et al.* (1993), as quoted by Gerber (2000), has shown that reflectance measurements of 0.66 – 0.73 μm (visible red light) in the electromagnetic spectrum can be used as an indicator of biomass of homogeneous canopies. Campbell (1987) is of the opinion that discrimination of vegetation classes is sometimes possible using near infrared reflectance (0.72 – 1.3 μm). Gerber (2000) points out that the multi-species, or heterogeneous nature of rangeland vegetation complicates the use of reflectance measurements, and that the accuracy of biomass estimations on some sites in the Kalahari was a function of the grass:dwarf shrub cover ratio. He emphasizes that the spectral reflectance-biomass relationship should be quantified regularly through ground truthing. Ganzin *et al.* (2005) states that remote sensing will lead to overestimation of biomass production when the woody cover proportion is high, as is the case over much of Namibia's rangelands. In the determination of the Total Seasonal Biomass Production Estimation project by the Agricultural Laboratory, it was stated that it is not possible to distinguish between the grazeable and non-grazeable components of the vegetation. This is borne out by the fact that the spectral response pattern of all healthy vegetation in the blue, green and red bands (0.38 – 0.72 μm) of the electromagnetic spectrum is basically the same and is interpreted as such by the remote sensing platform, from where digital images are downloaded.

A prerequisite for distinguishing between the vegetation classes using near infra red reflectance is that the areas for which grazing capacity needs to be determined should have a homogeneous canopy and occur over sufficiently large areas to suit the capabilities of the satellite imagery used. Furthermore, should the area be dominated by grass (which remains an important component of the grazing), remote sensing data, no matter how high the resolution of the satellite image, cannot distinguish between annual and perennial grasses or between known unpalatable and palatable grass species. These aspects need to be taken into consideration when attempting to determine grazing capacities for such areas as accurately as possible over time.

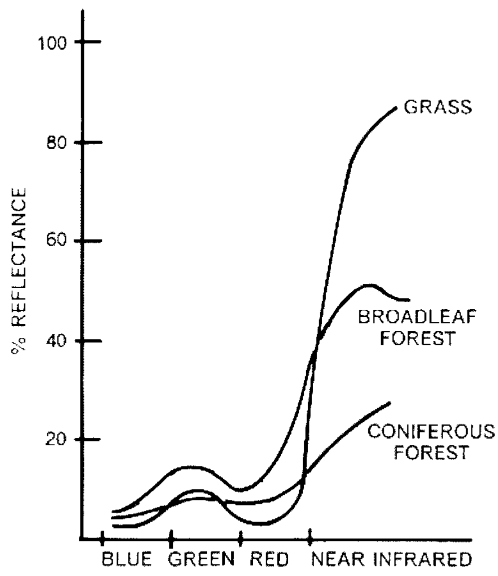

Figure 4. Vegetation class distinction in the Near Infra Red spectrum (Campbell, 1987).

During the clipping of the 200 transects countrywide in June 2005, the annual or perennial nature of the grass clipped, as well as the variations in palatability of the various components, were not taken into consideration. As is the case with the quantitative yield method the yield of trees, bush, shrubs, herbs and forbs was excluded. Ground truthing values derived from the 200 transect clipping exercise must therefore be seen in perspective, that is: values generated could only be linked to grassland biomass and only to a limited extent to grazing capacity. In a paper presented by Ganzin (2005), it was shown that grazing capacities were vastly over estimated in the Nakuru National Park in Kenya when spectral data was not corrected for woodiness, accessibility and palatability. Realistic grazing capacities can only be determined from satellite imagery once real values for each of these components have been obtained.

Grazing Index Values

Although the TDN system of food evaluation, based on digestible and metabolisable energy, remains an important parameter for calculating the energy–supplying power of feedstuffs (McDonald *et al.*, 1973), cognizance must be taken of the fact that this system of feedstuff evaluation contains a number of weaknesses as listed by the NRC (2001), and is therefore considered by some to be too crude for inclusion into a feedstuff evaluation formula (personal communication – Roodt, 2006).

Considering the important role that phosphorus (P) plays in the metabolism of carbohydrates, and the notorious low levels of phosphorus that exist in Namibia's rangelands, and indeed the whole world (McDonald *et al.*, 1973), the question arises as to whether the inclusion of phosphorus in the GIV would not generate a more appropriate grazing index value. Du Toit (1996) excluded phosphorus from the grazing index value formula, based on the high correlation that he found between P levels and TDN during field trials. Considering the weaknesses of using TDN as listed by the National Research Council (NRC) (2001), it may make sense to have plant samples analyzed for P content and somehow include these values in the GIV formula. Should TDN as a food evaluation system be discarded, then consideration should be given to the inclusion of the fibre content of feedstuffs, as this fraction of food has the greatest influence on its digestibility.

CONCLUSIONS

Although the biomass principle is accepted as much more scientifically defendable than the pure estimation of carrying capacity, and has been explained and demonstrated to many farmers in Namibia over the past 15 years, it is still not readily applied. Although it remains one of the most accurate methodologies to determine grass biomass yield (Holechek *et al.*, 1998), it does have some shortcomings, which makes the outcome of any calculated grazing capacity using this approach subject to error. It remains, however, a relatively accurate method in its current form for determining grazing capacity in grass dominated rangelands.

Grazing capacities calculated with SPOT VEGETATION satellite imagery are a real possibility where the canopies of the encountered vegetation are homogeneous. Although such areas do exist in Namibia, the general nature of the vegetation canopy in Namibia's rangelands is heterogeneous. The resolution of SPOT VEGETATION images is too coarse (980 x 980 m) to accurately determine local level grazing capacities for the majority of Namibia's rangelands. Grazing capacity figures generated by using these images should therefore be viewed cautiously. Images with a higher resolution capability, such as 10 x 10 m or less (as the Agricultural Laboratory is currently in the process of acquiring for selected areas in the north and south of Namibia) may generate much more workable figures on a local level based on the assumption that they will have the capability to distinguish between the different vegetation components (grass, shrub, tree). On the other hand, apart from the fact that these images are extremely expensive, the use of high spatial resolution imagery may actually decrease rather than increase accuracy of vegetation mapping (needed for the calculation of carrying capacities) as was found by researchers from the National Training Centre *et al.* (1995) in the Mojave desert in the United States.

The accuracy of the grazing index value as developed in South Africa and to be applied in Namibia's south remains to be seen. The inclusion of such agronomic traits as dry matter production and the chemical properties of species in a methodology where the ultimate goal is an objectively determined grazing capacity makes a lot of sense. It is believed that this project will be quite beneficial to a better understanding of the grazing capacities of the south. However, as is the case with most projects of this nature, it is going to be time consuming and in need of experts in the field. Also, reconsideration should be given to the continual use of the TDN system of feed evaluation, in favour of phosphorus, Crude Protein and Crude Fibre values in the grazing index value.

The calculation of grazing index values for all grazing plants in the south (grass or dwarf shrub), and the comparison of the GIV methodology to biomass methodology, might also prove to be a useful exercise.

It should be clear that there are no quick and easy methods to generating an accurate grazing capacity map. It is complicated by the fact that the grazing capacity of the land changes continuously from area to area, season to season and year to year due to a number of variables. It implies that a grazing capacity map could only be generated if the long term grazing capacity figures of the various farming areas in the country are known. This would enable researchers to apply an average grazing capacity to an area. Although the current grazing capacity map is quite old, (developed in the early 60s by Agricultural Technical Services – Personal Communication. Bester), the information contained therein is based on long-term grazing capacity experience of landowners and agricultural extension officers. Although it is accepted that grazing capacities based on expert opinion and estimation (of subjective nature) might not have any legal status in court cases which might ensue in future, legalizing the current grazing capacity map with adjustment in areas where known structural problems (e.g. bush encroachment) exist, might be meaningful. The current grazing capacity map remains a good source of baseline information which can be utilized by policy makers for the interim until such time that more scientific (objective) data becomes available.

Although it is quite possible to create a grazing capacity map from objectively generated data it will take time, a commodity that is not available in the political timetable of the day. However, hasty decisions based on hastily generated data may prove the hasty downfall of many of those dependent on the health and productive capacity of Namibia's rangelands.

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