Towards an Index of Biological Integrity for habitat assessment in Namibia – developing tools with and for farmers: preliminary assessments

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Keywords: Desertification, biodiversity & ecosystem functioning, participatory research, termites, beetles

1. Introduction

Large areas of Namibia, the most arid country in sub-Saharan Africa, are constituted by rangelands and a majority of the population rely on livestock farming for survival (Marsh & Seely, 1992). Desertification, defined as a "cumulative set of processes leading to land degradation in arid to semi-arid areas (UNEP, 1992), manifests itself in rangelands in several forms including a reduction of secondary productivity. In Namibia, identification of desertification is difficult, because natural variation caused by erratic rainfall is difficult to separate from environmental degradation. It is important to identify the causes of desertification, and understand the underlying processes. Management tools and policy directives to combat desertification need to be based on reliable information.

The aim of this research is to develop reliable and practicable methods for range condition assessment and monitoring by using two complimentary approaches: (a) using locally existing farmers' knowledge, and (b) applying scientific methods to determine range/habitat condition. Additionally existing management and policy constraints leading to desertification in the farming area are investigated. This research explicitly investigates whether and how existing land tenure systems in Namibia affect range condition by applying appropriate approaches to community-based research and information exchange, married with ecological techniques.

Because range condition is determined by the underlying ecosystem function, including crucial soil related processes (e.g. nutrient cycling, organic matter translocation, soil perturbation) (e.g. Anderson, 1988; Behnke & Scoones, 1993), range condition in this study is measured using a composite set of ecological indicators. This is used for assessing the so-called biological integrity of the system (Zeidler et al., 1998; e.g. Karr, 1991).

2. Materials & Methods

a) Study site selection
   Three study farms of similar habitat type but of differing land-use history and under different land tenure were selected in the north-western farming areas of Namibia. Local farmers assisted in identification of two study plots on each farm, reflecting (a) a low and (b) a comparatively high land-use intensity.

b) Measures of biological integrity
   A conceptual model of factors determining and indicating the biological integrity of rangelands in arid Namibia was developed. Termite, tenebrionid beetle and vegetation biodiversity parameters were selected and measured according to a defined quantitative sampling protocol. At each of the six study sites four similar 1ha plots were sampled for the various parameters. Termite diversity was measured by a standard belt-transect method (Zeidler et al., in prep (a).; Zeidler et al., in prep. (b)). Tenebrionid beetle diversity was studied using pitfall traps, mark-recapture methods and standardized transect walks (Parenzee et al., in prep.). Vegetation measures included grass and tree cover and species composition.

c) Soil Parameters
   Selected soil parameters (light fraction, total C, N & P) were measured at study sites mentioned above. The C:N ratio and other indices reflecting on soil processes were calculated following standard procedures. Local farmers assisted in collection of rainfall data.

d) Data on land use practices; farmers perceptions & methods
   Sets of commonly used indicators of rangeland condition and possibly desertification were derived by discussion with farmers from the communal as well as commercial farms. Information on management and policy constraints was collected in a participatory fashion, by applying PRA (Participatory Rural Appraisal) and RRA (Rapid Rural Appraisal) methods, which were extended to serve as land-use planning tools.

e) Analyses
   The preliminary data was analyzed calculating mean values and deriving very preliminary indices for termite and tenebrionid beetle diversity. The later ranking was derived through a K-means clustering exercise. Once the full data set is available more comprehensive statistical and conceptual analyses are to be performed.

3. Results

Table 1: Summary data obtained Oct. '97 – preliminary results: Rangeland condition assessment – insert here -

Farmers assessments: local indicators used
The indicators used are similar amongst all farmers and they are mainly based on rainfall, vegetation cover and the presence and absence of plant invader species. On the communal farm a few additional methods, looking more at the condition of the livestock per se, are used.

Termite diversity
Only one genus, *Trinervitermes*, was detected at the sites. At three sites (Olifantputs low, Weerlig low & high, only one species was found, respectively, calculating a diversity rank of 0. The highest diversity rank was scored at the low land-use intensity site at Halt, where three species were represented.

Tenebrionid beetle diversity
Tenebrionid beetle fauna was more diverse at the low intensity site compared to the high land-use intensity site.

Vegetation
Tree canopy cover is higher at the low intensity sites at all three farms. Woody species composition suggests that the thorny Acacia species commonly known to be encroaching species are present at the higher intensity sites. They are less abundant or not found at the low intensity sites. Dominant grass species are similar at all sites.

Soil parameters
The light fraction component, as well as C:N ration and P content are higher at the low intensity sites compared to the high intensity sites at all farms.

4. Discussion
The preliminary data and results obtained from this research allow for a first qualitative evaluation of possible biological and physiochemical indicators of range condition in north-western Namibian rangelands. From these data a set of metrics is to be derived, an so-called index of biological integrity (IBI), which provide a scale of range/habitat condition. It will hopefully be possible to determine a threshold value of the IBI at which ecosystem function is impaired, thus the system (range/habitat) is truly degraded or desertified. The causes that lead to the 'desertification' of the system are to be differentiated as natural or human induced.
From the obtained data, some interesting observations and conclusions can be made. For instance was only one genus of termites found in the study area, namely *Trinervitermes.* This is a grass feeding and epigeal/hypogeal nesting termite genus. This very "narrow" representation of termite taxa, which supposedly are one of the most common and abundant representatives of the soil macrofauna in the study area, might reflect an extremely narrow representation of functional groups. For example no wood feeding or fungus-growing species were found at sites. However, it is also possible that drawbacks in the methodology lead to unrepresentative sampling results. This is suggested by additional data (Zeidler, unpubl.) which supports the notion that various sampling procedures need to be applied to determine termite species richness reliably in arid environments.
The vegetation data collected may reflect grazing pressure, which seems to be highest at the high intensity site at Olifantputs and lowest at the low intensity site at Halt. The low intensity site at Olifantputs compares to the high intensity sites of the other two farms. However, it grazing potential is possibly a poor measure of range condition other than grazing intensity, not reflecting whether ecosystem functioning is impaired or intact.
The selected soil related measures take into consideration more process oriented connections between soil fauna and the soil/vegetation interface. For example could the ratio of total C : LF reflect the turnover and conversion of the light fraction into C, probably mediated by termites. Therefore this process could be linked to the biological characteristics of termites, including species presence, abundance, diversity etc. However, there are not only termites and other soil fauna; organisms and microbial links are also to be investigated.
In other studies it has been suggested that the C : LF ratio increases under intensified land use (Custers, 1997). Such a relationship needs to be investigated from more in-depth data sets for our study sites in north-western Namibia.
An examination of the C:N ratios at the sites reveals that in the study there is generally more N associated with C than "expected" (10:1 is the norm e,g, for Nylsvlei, a savanna ecosystem in South Africa (Scholes & Walker, 1993). It could be speculated that here nutrients are conserved and C is utilised rapidly, probably by soil feeding organisms. Generally soils in arid areas are known to be low in C content. The P values obtained from our study sites in norht-western Namibia are generally comparable to those of Nylsvlei. However, at the low intensity sites they are always higher compared to the high intensity sites. These findings could indicate that both, P and N, which are nutrients that are generally known to be limiting factors for plant productivity in similar environments, are even more critical under high land-use pressure.
The conducted research is only forming the first steps in establishing an IBI for habitat assessment in Namibian rangelands. It investigates the necessary ecological baseline data, which is crucial for determining suitable indicator

taxa and properties for these particular study sites. Aside the ecological study of effective habitat assessment strategies it is equally important to learn and exchange how local farmers assess their range and how they manage their land. A composite and supplementing approach should be taken to incorporate the identified ecological measures with the common land management practices already in place to achieve adaptive management in a region were rainfall in extremely variable and land use has to be continuously adapted to the condition of the habitat.

5. Acknowledgements

The Desert Research Foundation of Namibia, especially the staff of Namibia's National Programme to Combat Desertification in southern Kunene region are thanked for their guidance and support. This project is financially supported by the Flanking Programme for Tropical Ecology (TOEB) German Agency for Technical Co-operation (GTZ) AA 90.2136.1-03.112 and the Namibian National Biodiversity Programme of the Department of Environmental Affairs (DEA), Ministry of Environment and Tourism (MET). Permission to work in the Namib-Naukluft Park was granted by MET.

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Zeidler, J., Hanrahan, S. & Scholes, M. (2), in prep. Termite (Isoptera) species richness, composition and diversity under differing land-uses in southern Kunene region, Namibia.

Table 1: Summary data obtained Oct. ’97 – preliminary results: Rangeland condition assessment

	OLIFANTPUTS		**HALT**		**WEERLIG**	
Tenure	Communal area since 1898		Since 1960’s communal		Commercial	
Land-use intensity	Low	High	Low	High	Low	High
Coordinates	S20°17.042’ E014°59.599’	S20°16.050’ E014°58.402’	S20°16.653’ E014°54.400’	S20°18.359’ E014°53.524’	S20°02.057’ E014°59.895’	S20°03.470’ E015°01.937’
FARMERS ASSESSMENTS						
Indicators used	Rainfall; increase of invader plants; livestock condition; livestock eat rubbish; milk production; vegetation cover		Vegetation cover; increase of invader plants		Vegetation cover & quality; rainfall; increase of invader plants	
BIOTIC ASSESSMENTS						
Termites[1]	0	1	3	2	0	0
Species numbers	1	2	3	2	1*	1
Species composition	Trineritermes rhodesiensis	T. rhodesiensis T. trinervoides	Termininae (prob.Amitermes) T. rhodesiensis T. trinervoides	T. rapulum T. rhodesiensis	T. rapulum *	T. rapulum
Shannon index Hs (Diversity)	0	0.5	0.87	0.64	0	0
Simpson index D (Dominance)	1	0.68	0.52	0.56	1	1
Tenebrionid[2]	0	1				
Veg. ratio[3]	1:2	1:3	2:1	1:2	1:1	1:2
Tree canopy cover (%)	22	14	11	3	35	17
3 most dominant tree species (% cover)	Catophractes alexandri Colophospermum mopane Tree 1	Colophospermum mopane Acacia tortillis Acacia senegal	Colophospermum mopane	Acacia erioloba Colophospermum mopane	Colophospermum mopane TC1 Boscia albida	Catophractes alexandri Colophospermum mopane Acacia tortillis
3 most dominant grass species (% cover)	Eragrostis porosa Schmidtia pappophoroides Anthepora schinzii	Schmidtia pappophoroides Eragrostis spec. Eragrostis porosa	Schmidtia pappophoroides Eragrostis spec. Eragrostis porosa	Schmidtia pappophoroides Eragrostis spec. Eragrostis curvula	Schmidtia pappophoroides Eragrostis spec. Anthepora schinzii	Schmidtia pappophoroides Eragrostis spec. Eragrostis porosa
PHYSIOCHEMICAL ASSESSMENTS						
Soils						
Light fract.[4]	557	419	383	201	463	293
Total C : LF	8.4	3.3	3.2	5.3	2.8	3.9
C:N	8.1	5.2	16.2	5.7	7.1	5.2
P (ppm)	10.4	7.5	9.8	7.9	9.7	4.7

Establishing methods for range condition assessment in arid north western Namibia - combining ecological and participatory community-based research approaches

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Abstract

Globally, desertification and/or land degradation manifests itself in several forms including a reduction of secondary productivity induced by changes in rangeland condition. Identification of desertification in the Namibian context is difficult, however, because natural variation caused by the variable rainfall conditions is difficult to tell apart from environmental degradation. Unless natural habitat/range condition that maintains all necessary ecosystem processes and the treshold point at which habitat/range function is impaired can be determined reliably, it is impossible to make informed management and policy decisions for the sustainable use of rangelands essential for community survival. The proposed aim of this research is to develop reliable and practicable methods for range condition assessment and monitoring. Two complimentary approaches are investigated: (a) using locally existing farmers' knowledge, and (b) applying scientific methods to determine range/habitat condition.

The Desert Research Foundation of Namibia co-ordinates the research component of Namibia's National Programme to Combat Desertification (Napcod) and has launched a project on range/habitat assessment and possible indicators of biological integrity and ultimately desertification with farmers at Napcod's long-term research (LTR) sites in the southern Kunene region.

Local knowledge is collected in a participatory fashion, by applying PRA (Participatory Rural Appraisal) and RRA (Rapid Rural Appraisal) methods, which are extended in their use to serve as land-use planning tools. Working with farmers from the communal as well as commercial farming areas, sets of commonly used indicators of rangeland condition and possibly desertification, which are often of qualitative nature, are to be derived, tested and compared.

For the scientific approach it is suggested to measure range condition using a composite set of ecological indicators measuring the so-called biological integrity of the system. Quantitative measures of vegetation parameters, soil fertility, soil biota and land uses are incorporated, including aspects of biodiversity and its functional properties. The results will reflect to which extend crucial ecosystem processes are operational. Range/habitat condition is determined by whether crucial ecosystem process are functioning or disturbed. By deriving an index of biological integrity (IBI) as a scale of range/habitat condition it will hopefully be possible to determine a threshold value of the IBI at which ecosystem function is impaired, thus the system (range/habitat) is truly degraded or desertified. The causes that lead to the 'desertification' of the system are to be differentiated as natural or human induced.

The two methods for rangeland condition assessment will be tested at selected sites. The results of the scientific method are to be compared with common local and indigenous practices. The most suitable combination of practical indicators is to be derived from the different approaches.

Introduction

The Desert Research Foundation of Namibia, coordinating the research component of Namibia's National Programme to Combat Desertification (Napcod), has launched a project on habitat assessment and possible indicators of desertification with farmers at Napcod's long-term research (LTR) sites in the southern Kunene region (indicator & monitoring project). The long-term aim is to monitor ecological as well as socio-economic change at the pilot sites in order to collect baseline data as a solid foundation for land-use planning and contributions to policy making. Guiding principles for the research approach of DRFN are to marry ecological with farmer participatory research, to combine research and training efforts and to develop mechanisms for exchanging information between the relevant partners.

Conceptual framework of the indicator and monitoring project

The aim of this particular research project is to develop appropriate methods for rangeland assessment taking into consideration the need to develop indicators that can discriminate between areas that are resting under conditions of natural variability of rainfall versus areas that are truly degraded (Figure 1). This is approached by determining the status of the habitat using (a) local and indigenous practices of land assessment and (b) established scientific methodologies. Both methods are compared. Two main themes have been identified as being important for such assessments: first, current and past land use and, secondly, the status of biological integrity of the system (Figure 2).

Land use

Land use as a theme incorporates research into aspects of current and historical land use practices at the study sites as well as considerations of the land tenure system in place. In the Namibian context a vivid discussion revolves around the fixed notion that communal farming areas are generally more severely degraded than farms under commercial land tenure. This is often attributed to the fact that range management practices on private land are based on an 'exclusive access' right to the range allowing for better control over stocking rates and land use intensity. However, very little data are available to corroborate such statements and it is a main objective of this overall study to test whether land tenure indeed affects the status of the range.

The biological integrity concept adapted to western Namibian rangelands

The biological integrity concept was first developed in the context of aquatic systems in northern America (e.g. Karr et al., 1986; Karr, 1987, Karr, 1991; Angermeier & Karr, 1994), looking as organismic as well as functional aspects of the ecosystem. The concept embodies an approach that aims to provide practicable management tools for habitat condition controls. Indices based on biotic parameters such as species richness and composition, abundance and condition of selected target taxa, as well as trophic composition of the system are being developed, and are thought to indicate different levels of ecosystem disturbance or, vice versa, ecosystem functioning (e.g. Karr, 1991). It was suggested that an Index of Biological Integrity (IBI) (e.g. Karr et al., 1986; Karr, 1987) adapted to Namibian rangelands be developed as part of the Napcod programme (Figure 1). The appeal of applying such a concept to terrestrial ecosystems is the broadly based and functional approach to indicator studies as well as the practicability of its application.

Because there is no such thing as a single most sensitive species that can reflect habitat condition over a broad scale (e.g. Crains, 1986; Noss, 1990), this study takes a multi-factor approach, attempting to establish process oriented linkages between land-use, rainfall, vegetation, soil and particularly soil biota. Figure 3 illustrates the conceptual outline of how selected measures of biological integrity may reflect ecosystem functioning in arid Namibian rangelands.

Land-use

Land-use intensity, reflected through land-use practices (current & historical) as well as land tenure, is studied as possible cause for differences and changes in habitat quality. Impacts such as trampling, excreta and biomass inputs as well as herbivory on soils, vegetation and soil biota are considered.

Rainfall

Rainfall is perceived as the single most important driving force of this ecological system. However, since rainfall is out of our reach for management purposes, it is mainly being dealt with as a co-variable in the scope of this study.

Vegetation

Fodder availability and quality are the two main factors determining range condition and livestock production. The responses of plant species composition and Annual Net Primary Productivity (ANPP) to land use intensity are investigated.

Soils

Soil chemical and physcial aspects such as nutrient and water availability ultimately determine primary and secondary productivity. Various key factors such as C, N and P availability are measured and brought into a process oriented context by looking in more detail in the role termites as abundant soil organisms play in the system.

Soil biota

Soil biota are recognised key actors in maintaining and improving soil characteristics such as nutrient status, organic matter stabilisation and water balance, and protecting against processes such as leaching and erosion (Lee & Wood, 1971a; Lee & Wood, 1971b; Anderson 1988). Generally soil micro-, meso- and macrofauna modulate the chemical and physical attributes of soil through mechanical and physiological processes, ultimately contributing to soil fertility and ecosystem productivity.

In the Namibian context it is relevant to study aspects of termite biodiversity, since termites are thought to form a major part of soil macrofauna in the more arid areas, contributing to various ecosystem processes (Crawford & Seely, 1994). Measured by biomass, termites are the most numerous and predominant herbivores in savanna ecosystems (Wood & Sands, 1978) and most probably also in arid Namibia. Termites have various attributes that possibly make them good indicators for ecological analyses. These are, for example: their taxonomic tractability, the fact that individuals are present throughout the year and their functional importance in ecosystems (Bond, 1993; Soule & Kohm, 1989). However, there are also problems that make termite studies difficult to undertake and the resulting data difficult to interpret (Eggleton & Bignell, 1995). Sampling for termite diversity, for example, remains difficult and time-consuming. Whereas species richness can probably be determined fairly reliably, population parameters and abundance measures are extremely hard to obtain. This is particularly true for arid systems, where many species are subterranean, and populations may spread out over large areas. Also there is little information available on the biology and the role that individual termite species play in ecosystem processes.

However, some soil organisms impact biogeochemical processes more than others (Anderson, 1994). Termites probably play the most significant role in translocating organic matter form the soil surface into the ground. This is an important step in the cycling of nutrients such as C, N and P. The diversity and composition of soil biotic communities, including termites, and the functions associated with them vary within and between ecosystems and may shift under changing land-use regimes (Swift & Anderson, 1993; Anderson, 1994). Similarly, environmental fluctuations, induced for example by global climate change or pollution, may alter naturally established soil biotic structures (e.g. Whitford, 1992). Until today very little is known about the full implications of biological diversity for ecosystem performance per se, although numerous attempts have been made by researchers to elucidate the issue (e.g. Huston, 1994). However, one of the main discussions that also relates to the problem of desertification revolves around the question of whether the loss of particular species and/or communities may disturb or even interrupt crucial biogeochemical processes. If so, this may ultimately lead to an impoverishment of ecosystem functioning and performance (e.g. Naeem et al., 1994). This needs to be critically examined and possible causes that lead to changes in biodiversity are to be clearly identified in order to allow for appropriate resource management. It is the aim of this study to elucidate some of the connections between termite diversity and soil processes.

Farmer participatory research, research & training & information exchange mechanisms

Farmer participatory research is carried out by DRFN at the Napcod LTR sites (Henschel et al., 1998) in western Namibia. In the scope of the indicator and monitoring project, farmers are primarily engaged to inform researchers on how they assess rangeland condition and which indicators they use in these assessments. This is important first because the local farmers might apply particularly useful methods of habitat assessment. These should be included in a final set of indicators and methods applied. Secondly it is important to establish the decision making process farmers engage in to manage their rangelands. Such information is important for developing improved and practicable management tools.
Background data on current and historic land uses are also collected in a participatory manner and emphasis is placed on developing good knowledge transfer systems based on mutual co-operation and understanding.

Capacity building is important for a country such as Namibia and the Convention to Combat Desertification (CCD) in particular supports the integration of research and training efforts. DRFN takes a capacity building approach in all activities. The indicator and monitoring project is persued by three students working on their PhD, MSc and Nature Conservation Diploma, respectively. Other shorter-term trainees from the Polytechnic as well as school leavers are involved in the project as research assistants. Farmers and the staff of Napcod are integrated in an active knowledge transfer exchange and a great effort is placed on maintaining close communication links between all parties.

Information exchange and feedback mechanisms are developed and tested in the scope of this study and by DRFN per se. This particular research is re-integrated with the farmers through holding meetings and PRA workshops and developing targeted and illustrated information materials. Research reports, publications, the degree work are targeted at and made available to the scientific and development communities as well as to Napcod. Integrated in DRFN's ongoing efforts to provide information to decision makers and land-use planners, the research results from this study are made available at the policy and government levels as well.

Summarising comments

This paper outlines an attempt of combining an ecological with a participatory community-based research approach as followed by DRFN in Namibia. This paper, showing examples of combining sound ecological research with a broad community-based involvement in information exchange and training, describes the process and is intended to encourage the replication of the innovative approach.

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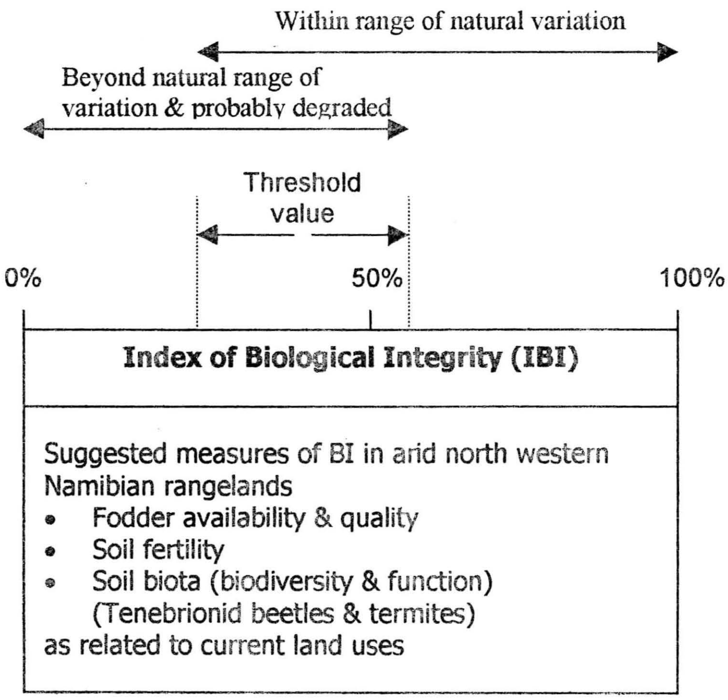

Figure 1: The IBI, which provides a measure of biological integrity, serves as a tool to assess range and habitat condition. By establishing critical threshold values of the IBI, areas that are degraded with impaired ecosystem functioning can be identified. Establishing critical threshold values of the IBI also serves to help differentiate between natural changes or human induced causes for apparent degradation.

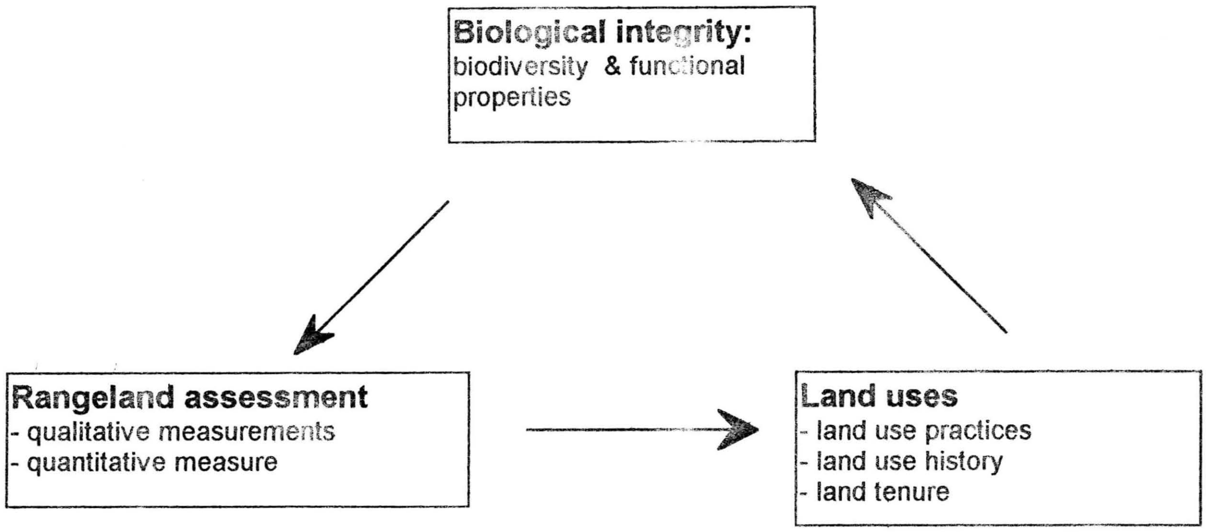

Figure 2: *Conceptual framework for the indicator & monitoring project.* In order to be able to practice adaptive rangeland management, information on the current state of the habitat and various aspects of the use of the land are to be considered. To achieve this, it is important to delineate the most effective and practicable ways of assessing rangeland condition as well as land uses. In the context of this study it is suggested to use measures of biological integrity, looking as aspects of biodiversity and its functional properties, for range/habitat assessment. The results of the scientific method are to be compared with common local and indigenous practices, which are usually qualitative in their nature. A most suitable set of indicators is to be derived from the different approaches.