Part I Rangeland inventory and evaluation techniques

Rangelands of the world; unifying vegetation features

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1. Introduction

1.1. General

Rangeland is defined as a tract of land currently used for grazing by domestic livestock and/or wildlife (van Gils & Zonneveld, 1982), where:

a) no mineral fertilisers are applied;
b) semi-natural vegetation is the main forage resource; and
c) the stocking density is lower than 1 A.U.* per ha per year.

Land – in rangeland – is used in the holistic way (FAO, 1976; Zonneveld, 1972) and therefore includes vegetation, soil, rock and water. This paper will deal with vegetation mainly, since vegetation is by definition the most important land component in rangeland.
Land evaluation in general and rangeland evaluation especially will be dealt with the paper of Zonneveld. There it will become clear that 'land quality' and 'LUT' (Land Utilization Type) are key concepts for land evaluation. The most important land quality for rangeland evaluation is without doubt the forage availability and the quest of this paper is to see which vegetation features influence the forage availability.
The review of rangelands in a world-wide perspective seems useful, before starting to discuss the rangeland evaluation techniques. Each major rangeland type shows his own specific rangeland qualities and (improved) rangeland utilisation types.

The need for an exploratory map of the world, continents and/or countries is also felt both in development projects and education. Such an exploratory rangeland map should be able to answer a question like: 'To which extent is grazing research in place A relevant and applicable to my project in place B?'. Such a question is usually approached by comparing (bio)climatic (e.g. ILCA) or agro-ecological zones; the latter based on climate and soil characteristics related to crops. First of all such an approach does not pay enough attention to vegetation and terrain features and/or does not differentiate sufficiently in rangeland areas. Further climatic and soil requirements for semi-natural vegetation do not play the same role as in the case of crops; the semi-natural vegetation is per definition already suitable for the local climatic and soil conditions.

1.2. Location and extent of rangeland

Rangelands cover major parts of the earth land surface; depending on author and definition of rangeland, one quarter (Shantz, 1954 as cited by French, 1979) to half of the land is used as rangeland.

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* A.U. (Animal Unit) is defined here as 250 kg livestock live weight.

All bioclimatic zones of the world (as defined by Walter, 1973) have rangeland. However the relative proportion of rangeland and the trend in the rangeland/cropland + woodland ratio vary per bioclimatic zone.
A relative high proportion of land is used as rangeland in the subtropical dry zone, the mediterranean (or transitional winterrain) zone and the artics. The continental temperate zone rangelands (Eurasian steppes, South American pampas, USA prairies, South African High veld) have been decreasing since the last century by the extension of cereal cultivation. Rangelands are increasing in the equatorial and tropical summerrain zones at the expense of forest and mainly as by-product of intensification of shifting cultivation.

1.3. Scales in rangeland mapping

Rangeland resource mapping on reconaissance to detailed scales, 1:250.000 – 1:5.000, is carried out on routine base by ITC; standard procedures are available (Van Gils & Zonneveld, 1982). However to attempt rangeland mapping on exploratory scales in the same manner must fail* or at least will show to be ineffective in terms of manpower costs. The amount of field samples for compositional land features (vegetation/soil) is not reduced by using small scale final maps (Van Gils & Zonneveld, 1982). An average african country would need thousands (e.g. Sahel) to ten thousands (e.g. East Africa) field sample plots depending on its complexity and an equivalent period to process such field data. Exploratory rangeland or vegetation maps sofar usually took either the concept of potential 'natural' vegetation or vegetation form as their mapping principle. But for rangeland utilization we are interested in the actual vegetation and not only its form, but also its composition. It is certainly not possible to relate the form to the composition of the vegetation directly, without doing substantial field sampling on the level of reconnaissance scales (Van Gils & Wijngaarden, 1983).

2. Rangeland types on global scale

2.1. Rangeland climatic zones

Rangeland types characterised by climatic features are e.g. 'tropical grazing land' (UNESCO/UNEP/FAO, 1979). I would not know what 'tropical grazing lands' have in common exclusively from their point of view of grazing, besides that their climate is tropical.
Contrary to the generally accepted thesis that a certain climate gives a specific climax vegetation form type* (Walter 1973, Zohary 1973 etc.), recent research shows that substrate (rock) type determines to a large extent also the vegetation form at least within the savannas (Cole, 1982) and the mediterranean scrub-wood-land (Rabinovitch-Vin, 1983).

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* The author carried out an exploratory survey (scale 1:1.500.000) covering 220.000 km in Botswana's Kalahari. However, this is an exceptional homogenous area in terms of vegetation, terrain and climate and therefore the standard ITC approach for reconnaissance rangeland survey could be applied (Van Gils, 1980).

* The monoclimax theory for vegetation composition has been abandoned since long.

2.2. Rangeland vegetation types; a review

Since the main resource of rangeland is per definition their vegetation, it seems necessary to use also vegetation features for the distinction of rangeland types.

Floristic composition of rangeland vegetation.

Attemps to use grass species or grass genera for description of rangelands on small scales (this means country to global wide) failed for East Africa (Pratt & Gwynne, 1977) all together. Another older attempt to describe grassland by their dominant grass genus (Rattray, 1960) or by their grass species composition (Whyte, 1968) are according to our experience not succesful. Important rangeland types found by us (ITC) in the areas covered by the referred authors are not represented in the legend, respectively description.

The phyto-geographical approach to rangeland typification seems not suitable for rangeland types on global scale, since many taxa used in designing plantgeographical regions are rare or absent in rangelands.

Vegetation characters other than floristic composition.

Various rangeland typifications for exploratory scales have been met in literature, and use their own vegetation qualities:

2.2.1 Lifeform

Lifeform features lead to the following rangeland types for the USA (French, 1979):

annual grassland
short grass prairy
mixed short/tall grass prairy
tall grass prairy
shrub steppe
desert

This typification may be reconstructed for global use as follows:

grassland
annual grassland (sparse-closed)
perennial grassland (sparse-closed)
short perennial grassland
mixed short/tall perennial grassland
tall perennial grassland

shrubland
closed shrubland
dense shrubland
open shrubland (approx. shrub steppe of French l.c.)
sparse shrubland (approx. desert of French l.c.)

For the distinction of grassland versus shrubland see Van Gils & Wijngaarden (1984). It is clear, however, that there are, even in the USA, large rangeland areas that are neither covered with grassland nor with shrubland but with, for example, savannas or tundras. This implies that more lifeforms than grass and shrub only should be included in this USA typification for wider use; at least evergreen trees/shrubs should be included since their leaves and twigs

usually have high enough C.P. levels during the dry or cold season to fulfil herbivore requirements and grasses usually have not. Trees may supply pods (*Acacia* spp.), acorns (*Quercus* spp.) or other fruits that offer substantial high quality food in the dry respectively cold season.
The shade under trees results in many areas an extended period of greenness under trees and thus shortening the dry season for grazing.
In cases of rangeland grazed by a wide variety of herbivores three vegetation layers may have to be assessed:
the ground-layer, the lower browse layer (< 2m) and the higher browse layer (> 2m) (elephants/giraffes).
Attempts to design a worldwide vegetation form classifications are numerous, even the best example (UNESCO, 1972; Eiten, 1968) lack in systematics and do not include enough possibilities to include the grass cover into the typification for rangeland studies (Van Gils & Wijngaarden, 1984).
Since herbage and browse may be complementary, improved rangeland LUTs may include introduction or stimulation of browse shrub/trees in grass dominated areas and bush/tree elimination and grass seeding in woodland and bushland areas.

2.2.2 C3 – C4

Photo-synthetic pathway of grass: C3 – C4 are used (Huntley, 1982) to distinguish between tropical and non-tropical rangelands. However, there are also temperate C4 grasslands, e.g. of *Chrysopogon gryllus, Botriochloa ischaemium* and/or *Heteropogon contortus* (Van Gils et al., 1975; Horvat et al., 1974). At least part of the continental temperate rangeland (prairies and pampas) contain a mixture of C3 and C4 grasses. It may be concluded therefore that C4 grasses are not a tropical feature, but that they dominate where high temperatures occur in the growing season, that is in the tropical low altitude summerrain zones and in the continental temperate zones, but not in the zone in between the mediterranean (winterrain) zone.
The important feature of C4 grasses for rangeland utilisation types is their capability to dilute their protein content a factor 2 further* than the C3 grasses. This dilution of C.P. implies that the grass quality decreases below animal maintenance requirements. However, the maximum dilution of C.P. (0.5% N) at maturity is only occurring if the water supply to the grasses is optimal for growth. C4 grasses may therefore show in more arid conditions (that is in arid zones or drought years) C.P. levels at maturity of the same level as C3 grasses.
One of the consequences of relatively high C.P. content of non-growing (dry) C3 grasses is that they are selectively grazed if they occur in a mixture of C3/C4 grasses and easily disappear from such rangeland under grazing pressure.

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* This is the reciprocal of the twice as high water-use efficiency in producing dry matter of the C4 compared with C3 plants (Ludlow, 1976).

2.2.3 *Grass tribes*

Tribes of the grass family are used to characterize major rangeland zones (Whyte et al., 1959; Humphreys, 1981):

Paniceae + *Andropogoneae* = subfam. *Panicoideae**	– tropical, subtropical moist* and continental temperate* rangeland.
Eragrostideae + *Chlorideae** + *Aristideae**	– subtropical dry rangelands.
*Stipeae**	– temperate and mediterranean dry rangelands, tropical dry highland rangelands.
Agrostideae + *Festuceae* + *Hordeae** + *Aveneae** = subfam. *Poacoideae**	– temperate, mediterranean and tropical highland rangelands*.

2.2.4 *Legumes subfamilies*

The legumes are next to the grasses an important component of rangeland, since most (> 80%) of the legumes are able to fix atmospheric N(itrogen) by root nodules. However, nodulation is not equally distributed throughout the legume family. The majority (app. 90%) of the woody *Caesalpinoid* species (subfamily) does not show nodules in Zimbabwe, whereas the species (for more than 90%) of the two other legume subfamilies, the *Mimosoids* (mostly woodly) and *Papilionoids* (herbaceous species in temperate, but many woody species in the humid tropics; the mediterranean is intermediary), may form nodules in the same area (Corby, 1974). It is however of importance to check if any specific legume is actually nodulating in a certain area.

2.2.5 *Sweet veld/sour veld (Accocks, 1953; Walker, 1979)*

Sweet veld savanna grasses maintain some grazing value in the dry season (C.P.** app. 4%), whereas sour veld savanna grasses loose this in the dry season (C.P. < 3%). Both sweet and sour veld savannas consist almost completely out of C4 grasses.

Sweetveld fires at the end of growing season destroy valuable forage. In the sour veld, however, useless biomass is removed and allows grass regrowth if there is still soil moisture available; such fresh green grass regrowth contains sufficient C.P. to meet herbivore requirements. Another implication of the sweet veld/sour veld distinction is that in sweet veld the N.A.P.P. is the key factor to calculate the grazing capacity. In the sour veld, however, the grazing capacity is to be calculated by the N availability (see under 2.2.8). We may try to extend the useful sweet/sour veld concept from Southern Africa over the whole of Africa or even the world. Sweet veld would include than the C3 grasslands, the short annual C grasslands and the relative arid C4 grasslands.

Relatively arid means in Southern Africa a rainfall below 650 mm (Huntley, 1982), but the distinction between arid and moist savanna may be at considerably lower rainfall in the lowland, latosolic savannas in West Africa (400 mm?).

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* Addition by author of this paper.

** C.P. = Crude Protein.

Sweet grasses and sour grasses may grow in a mixture. If this is the case (e.g. Botswana) the sweet grasses are bound to disappear under year-round grazing, since the superior quality of sweet grass in the dry season makes that they will be selectively grazed.
Seeding with sweet grasses may be a major rangeland improvement in such cases; management for preservation of sweet grasses another improvement. Ranching is obviously much more easy to establish in sweet veld areas as compared with sour veld areas.

2.2.6 *Winter green/winter dry grass*

The distinction between wintergreen/winterdry grasses in the temperate zone and high altitude rangeland has some similarity with the sweet/sour contrast of the tropics. Winter green grasses (e.g. *Deschampsia flexuosa* or wavy hair grass occurring in temperate Eurasia and the temperate Americas) have a higher nutritive value as compared with winter dry grasses in comparable habitats (e.g. *Molinia coerulea* or purple Moor-grass).

2.2.7 *Grass growth form*

Grass growth form (syn. lifeform) is used in many grassland typifications. The most common distinction is between short and tall grassland. Both short and tall grasslands grow in Northern America (French, 1979), Africa (Sinclair & Norton Griffiths, 1979) as well as in monsoon Southeast Asia (Sri Lanka, pers. obs.) next to each other in similar habitats.
It seems that if short and tall grassland occur side by side, the short grasslands are preferred for grazing by wildlife (Bell, 1970) as well as livestock.
Another important distinction is between annual and perennial grassland. Perennial grassland may show regrowth after burning in the dry season and gives a cover that reduces erosion at the start of the rainy season. However, perennial grasslands have generally a lower proper use factor as compared with annual grassland. Mixtures of perennial and annual grasses do occur and mostly the perennials are in danger of being eliminated by grazing because of their lower proper use factor.
Another grass lifeform feature is the shape of the grass: tussock (or tufted) grassland, hummock grassland, sod grassland or mat grassland (rhizomatous/stoloniferous) and bunch grassland. Tufted, hummocky and tussock grasses defend themselves against grazing by retreat. Some green biomass may escape grazing in the centre of the tussock. Sod or mat grasses retreat by having a larger proportion of biomass underground.

2.2.8 *Quantity versus quality of grass (N.A.P.P. and C.P. content)*

Quantity (N.A.P.P.) and quality (C.P.%) of grass are negatively correlated throughout most of the year in rangelands (see Figure 1); from 2-3 weeks after the start of the growing season during several weeks plentiful grass of good quality may be available. Management may stretch the period of availability of considerable quantities of good quality grass.

Global classifications of vegetation on base of N.A.P.P. (e.g. Lieth, 1975) are not applicable to rangeland survey and evaluation since the quality of the N.A.P.P. for livestock production is not considered in such global primary production models.

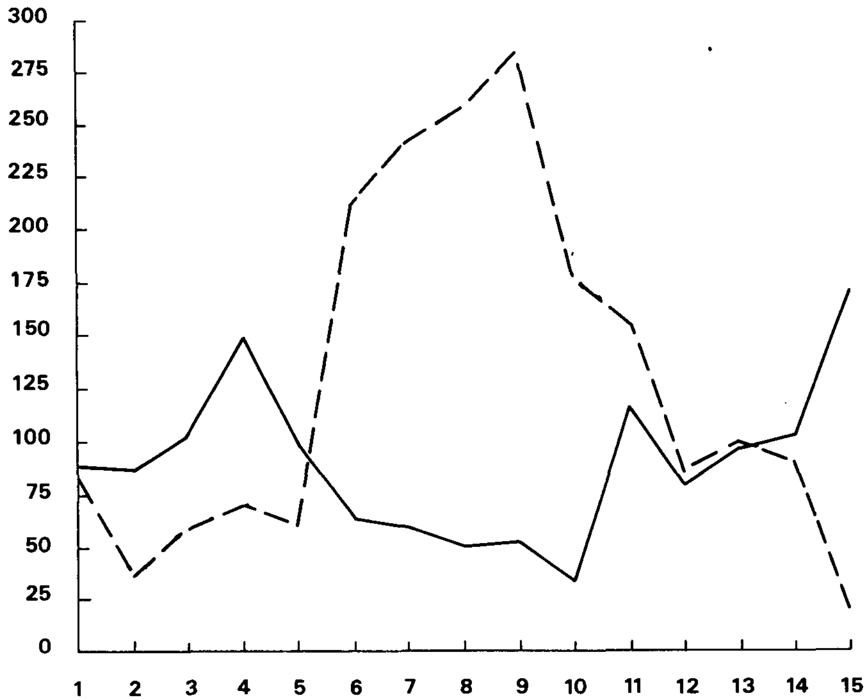

Fig. 1 Primary production in gr/m² (- - - -) and its C.P. in gr/kg.D.M. (——) changes during fifteen months in Yonglei, Sudan. 1 = February, 2 = March, etc. Source: Yath (1984).

The quantity of grass (herbs) only, or of grass and green biomass of woody species, if for any practical purpose for a given area to be calculated by (Van Gils et al., 1983):

$$y = a + bx \qquad (1)$$

y = yearly DM* production in kg/ha/year of grass (herbs) alone or grass and leaves of woody species together depending on vegetation form type.
a = constant (−400 till 100, depending on area).
b = constant (1 till 10 depending on soil, altitude, rainfall seasonality etc.; lowest value in Sahel, highest value in mediterranean winterrain area and East Afican mid-altitude areas with bi-modal rainfall).
x = annual rainfall in mm per year (a large enough area is assumed to result in a run-off and run-on of zero; if not than x has to be corrected for run-off).

The quality of grass in terms of C.P.% is limited by the N-availability in the rangeland. The Dry Matter should have a minimum C.P. content for livestock maintenance (C.P. 7%) and for meat/milk production (C.P. 10%)**.

For further calculations C.P.% is set at 6.25 x N%.

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* DM = Dry Matter.
** For low productive subsistence pastoralism at current circumstances these limits may be set at 4% respectively 7% C.P.

N-availability on a yearly base (by dry and wet precipitation, legumes, if they nodulate, and mineralization of organic matter) is in most areas 30 kg/ha. If we estimate that half of the N-input is lost mainly due to volatilisation of N from livestock urine, this leaves 15 kg N/ha to be transformed in C.P. which equals (15 x 6.25) approximately 100 kg C.P./ha. From this maximally 1000 kg DM/ha of 10% C.P. may be produced or alternatively 1500 kg DM/ha of 7% C.P.; to achieve this maximum considerable management inputs may be necessary. These calculated figures have several interesting implications for improved rangeland utilisation types.

If the environment (rainfall; slope; soil) allows more than 1000 kg DM/ha forage (grass and browse) production per year, these DM production in excess of this 1000 kg/ha will lead only to further dilution of N in the plant material and therefore to a quality below livestock requirement. A major rangeland improvement in such cases is to plant N-fixating legumes that derive its N from the air.
Desertification may improve forage quality also if DM production is in excess of 1000 kg DM/ha/years as long as increased run-off is not taking place.

2.2.9. *Relationship between vegetation features*

Already a first glance shows that grass lifeform, photo-synthetic pathway (C3/C4) and grass tribe are correlated to some extend. Both tallness and C4 are correlated with subfam. of the *Panicoideae*. Further it seems that the fine-leaved Mimosoid legumes (specially Acacia) are correlated with the sweet veld and the broadleaved *Caesalpinoid* legumes with the sour veld.

3. Conclusions

We found the following unifying vegetation features to characterise the forage availability of rangelands on exploratory scales:
- vegetation form
- sweet/sour in the tropics and winter greenness/dryness in the temperate zone, the mediterranean is sweet throughout
- D.M. production of required quality.

Reference is made to an improved and quantified vegetation form classification system. The concept 'Sweet' was not described scientifically sofar. Some research is necessary here. It is proposed to define sweet grass as a grass with a C.P.% of approximately 4% and higher in the dry season and a sour grass as having C.P. levels in the dry season below 4%. For the moment it is supposed that 'Sweet' includes C3-grasses, annual C4-grasses, short C4-grasses and C -grasses below a certain rainfall limit.
At average N-availability in rangelands of 30 kg/ha/year an excess of D.M. production above 1000 kg DM/ha/year is not useful for livestock production anymore without either addition of N-fertilisation or producing the D.M. in excess of 1000 kg/ha/y as legume forage.
Vegetation form may be inventorised by aerial photography as far as tree/shrub cover is concerned; grass cover needs usually field survey.
Sweet/sour information is to be obtained by reviewing or measuring C.P.% of grasses during the dry season; D.M. production needs to be assessed only if below 1000 kg/ha/y and can be calculated safely in many areas and such

calculated figures need limited testing only.

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