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Estimating grazing index values for plants from arid regions

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Abstract

The Ecological Index Method impacted directly on the estimation of grazing capacities in the Karoo, an arid region in South Africa. Due to inherent deficiencies in the ecological index method, index values formed a disjunct series, 10, 7, 4, and 1 and the fact that different value systems were employed to score plant species, necessitated that index values of species commonly encountered during botanical surveys be subjectively adjusted by means of a species by species comparison, forming a continuous series of index values. These index values were still subjective value judgements of the agronomic value of the Karoo plant species. The author felt that a method should be developed to objectively estimate grazing index values from certain plant variables, i.e. size, animal available dry matter production, and chemical properties of the species. The use of these properties would describe the agronomic value of the plant species, which would lead to agronomically sound current grazing capacities being estimated. The following 2 models were proposed to deal with the karoo subshrubs and the grasses of the karoo separately. Grazing index value for the karoo subshrubs = {(canopy spread cover + available forage + TDN + [K ÷ (Ca + Mg)]) ÷ ether extract} ÷ 100, and grazing index value for the grasses = {(canopy spread cover + available forage + TDN + [K ÷ (Ca + Mg)]) x ether extract} ÷ 100.

Key Words: available dry matter production, canopy spread cover, current grazing capacity, K÷(Ca+Mg) ratio, total digestible nutrients

Resumen

El método de Indice Ecológico impactó directamente en la estimación de la capacidad de apacentamiento del Karoo, una región árida de Sudáfrica. Debido a las deficiencias inherentes del método de Indice Ecológico los valores de los indices formaron un serie disyuntiva, 10, 7, 4 y 1, y el hecho de que se emplearon diferentes sistemas de valores para calificar las plantas, exige que los valores de los indices para las especies comúnmente encontradas durante los reconocimientos botánicos sean subjetivamente ajustados mediante la comparación de especies por especie formando series continuas de valores de los indices. Estos valores de los indices todavía son valores subjetivos del valor agronómicos de las especies de plantas del Karoo. El autor sintió que se debería desarrollar un método para estimar objetivamente los valores del indice de apacentamiento a partir de ciertas variables de la planta, por ejemplo, el tamaño, la disponibilidad de materia seca para el animal y las propiedades químicas de las especies. El uso de estas propiedades describirá el valor agronómico de las especies vegetales, el cual conduciría a la estimación sensata de la capacidad de apacentamiento. Los siguientes 2 modelos fueron propuestos para tratar por separado los arbustos y zacates del Karoo. El valor del indice de apacentamiento para arbustos fue igual a: {(cobertura de la copa extendida + forraje disponible + NTD + [K ÷ (Ca + Mg)]) ÷ extracto etéreo} ÷ 100 y el valor del indice de apacentamiento para zacates fue igual a: {cobertura de la copa extendida + forraje disponible + NTD + [K ÷ (Ca + Mg)]) x extracto etéreo} ÷ 100.

Publication of the Ecological Index Method by Vorster (1982) directly influenced the estimation of grazing capacities in the Karoo. He allocated index values to the karoo plants on the basis:

1) perennial climax grasses, index value 10; in close agreement with Tainton et al. (1980);
2) perennial sub-climax grasses and palatable karoo subshrubs, index value 7;
3) perennial pioneer grasses and the less palatable karoo subshrubs, index value 4; and
4) annual pioneer grasses, unpalatable karoo subshrubs and invader plants, index value 1.

This method has been used throughout the Karoo, with largely acceptable results. The ecological index values are used in the computation of range condition scores (see Tainton 1981), following surveys of sample sites. Grazing capacities for these sample sites are then estimated from the range condition scores. Since Vorster (1982) scored the grasses on ecological attributes and karoo subshrubs on palatability, an agronomic attribute, the range condition score computed for the sample site represents the ecological state of health of the grass sward on one hand, but the agronomic state of health of the karoo subshrubs on the other (see Tainton 1981). Since the score is based partly on ecological principles and partly on palatability, it is inappropriate to estimate grazing capacities, which are agronomic values, from these range condition scores which are assumed to indicate the agronomic potential of the site to support livestock. Several other factors, for instance dry matter production (Botha et al. 1993) need to be considered when a realistic grazing capacity is to be estimated.

The ecological index method is largely dependent upon classical succession theory, similar to many methods currently employed elsewhere in South Africa (Foran et al. 1978, Tainton et al. 1980, Mentis et al. 1980, Hardy and Hurt 1989, Hurt and Bosch 1991). Another of the deficiencies was that some of the late developmental stage grasses, previously referred to as climax grasses, received too high an index value to be used in the computations when estimating the current grazing capacity (Tainton

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et al. 1980, Edwards 1981, Vorster 1982). Research revealed that not all the late developmental stage grasses should have an index value of 10 (Du Toit and Botha 1993). Because of the above mentioned deficiencies, a committee investigated the apparent shortcomings in order to correct them in an effort to move away from the classical succession theory. The index values of all the species commonly encountered during botanical surveys, were adjusted subjectively by means of a species by species comparison. Each species being assessed on the basis of the following 6 variables:

1) The ability to produce forage, i.e. the amount of grazable dry matter produced per year: Low producers score 1, high producers score 10.
2) The nutritional value during the growing season: Species with a low nutritional value score 1, species with a high nutritional value score 10.
3) The nutritional value during the dormant season, as in No. 2.
4) Relative ease with which the species can be grazed i.e. presence or absence of spines: spiny species score 1, species without spines score 10. The presence of resins and aromatic oils downgraded the score due to anti-herbivory.
5) Perenniality: Annual species score 1, strong perennial sodforming grasses score 10.
6) Ability of the plant to protect the soil against surface soil erosion: Upright karoo subshrubs have a low score, decumbent bushes score fairly high, annual tufted grasses score 1, tufted perennial grasses, depending on productivity and habit, have an intermediate score due to the erosive channeling effect they may have on runoff water, sod forming grasses, where infiltration of rainwater is heightened, score 10.

These 6 agronomic properties of the species were chosen to ensure that individual species scores were comparable and the estimate free from bias. Each variable scored a maximum of 10. Individual variable scores were summed and the final species score calculated to occupy a position between 0 and 10. The average of the scores submitted by the members, and standard deviation was calculated for each species score. Values falling outside the range $x \pm SD$ were discarded. A new mean was calculated for the remaining values. The resultant score called the subjective grazing index value was vetted taking into account scores of related species, as well as unrelated species of known similar grazing value. The phases of the operational research study (Wilkes 1989) were followed.

These index values, however, still represent subjective value judgements of the actual agronomic value of the Karoo plant species. The author felt that a method should be developed to estimate grazing index values more objectively from certain agronomic plant variables; size, dry matter production, and chemical properties of the species. These properties were studied for a period of 3 years, to largely exclude extreme variations in productivity which is so characteristic of vegetation from semi-arid range types (Sneva and Hyder 1962). Species from distinct agro-ecological regions were studied. It was attempted to study related species in the different regions, to ascertain differences in grazing value between different species in an area and between related species of different areas. These objective grazing index values will replace the ecological index values. To avoid future confusion as to which index values have been used, and that an agronomic method of grazing capacity estimation was used, the ecological index method is replaced by the Grazing Index Method (Du Toit 1995).

Grazing index values estimated by the model, should reflect agronomic values of plant species more objectively and when used in conjunction with the Grazing Index Method, estimate more acceptable current grazing capacities. These grazing index values should furthermore verify the relative position of the species in the series, when compared to the subjective grazing index values developed earlier (Du Toit et al. 1995).

Methodology

Canopy spread cover

The canopy spread cover of a number of grasses and bushes was measured at random at each locality from 1990 to 1993. Fifty plants per species were selected from small to large plants, including the range of sizes normally found within the species. A frame 1 m x 1 m, subdivided into blocks of 50 mm x 50 mm for the large species and 25 mm x 25 mm for the smaller species, was used for this purpose. The canopy spread cover was estimated by counting the blocks of which half or more of each block was engaged by the perpendicular projection of the crown (Goebel et al. 1958). The number of blocks counted were then expressed as square centimeters of canopy spread cover. The canopy spread cover of 50 plants per species obtained this way included a representative sample of sizes, from small plants to large plants. The 50 measurements gave a reliable average value (Roux 1963). The plants were harvested *in toto* at a height of approximately 20 mm to 50 mm above the soil surface. The plants were selected at random over an area of 1 hectare (Vlok 1963), to minimize variations in plant ecotypic differences. The harvested material was separated into potentially grazable and ungrazable material on the basis of the 2 mm rule of thumb (Botha 1981, Du Toit 1996a). The 2 mm rule of thumb states that stems thicker than 2 mm are not grazed. While stems thicker than 2 mm were regarded as ungrazable, thinner stems contributed to the available grazable forage (Botha 1981, Du Toit 1993). Grass tufts were harvested by clipping to a stubble height of 20–50 mm and the whole fraction was regarded as being grazable. Plant material was dried in a forced draft oven between 60°C to 80°C, for 24 hours.

Relation between canopy spread cover and mass

The canopy spread cover : total mass relation of specific species were determined by regression to determine the relation between plant cover and the available forage (Payne 1974).

Chemical analyses

The grazable material was chemically analyzed for N according to the Kjeldahl method (AOAC 1964), Ca, P, Na, Mg, K were analyzed by atomic adsorption spectrophotometer, (Homer and Parker 1961) and acid detergent fibre was analyzed according to a modified Weende method (Van Soest 1963).

Model development

The proposed model attempts to objectively allocate a grazing index value to each of the studied species, based on the agronomic variables; size of the species i.e. canopy spread cover, the cornerstone of the range condition assessment technique, animal available dry matter, and certain chemical properties. Stepwise regressions (Statistical Graphics Corporation 1991) of the subjective grazing index values on the values obtained for the different parameters of the studied species indicated the most important elements to be included in the model.

Taxonomy

Nomenclature follows Arnold and De Wet (1993). Species names used in this paper and in the tables with their authorities are given in Table 1.

Results and discussion

Available forage and canopy spread cover

The relation between available forage and canopy spread cover, for all values, has a coefficient of determination, r^2 = 0.62. The slope of the regression line is less than 45°. This means that as the plants increase in size, there is not the expected corresponding increase in available forage. With the available forage being over-estimated by about 25% (Du Toit 1993, 1996a), the regression relation should have a slope of much less than 45°. The available mass recovered from a plant with a certain canopy spread cover varies considerably. Therefore, cover on its own does not provide a reliable estimate of available forage, in contrast to the finding of Mueller Dombois and Ellenberg (1974). Uresk (1990) proposed that frequency and canopy spread cover be multiplied to render an index of forage mass, which would probably be a reliable indication of available forage. In this case the relation between plant cover, available forage and forage value was to be used to calculate a grazing index value for each species. Floristic composition measured by the grazing index method, together with the grazing index values of the species would then describe the grazing capacity.

Nutrient requirements of grazing animals

According to Du Toit et al. (1940), growing sheep needs approximately 0.16% calcium and 0.14% phosphorus in their diet, while Louw (1969) recommends that the diet must contain between 0.2% to 0.5% calcium and 0.2% to 0.46% phosphorus, which agrees with values quoted by Woods (1959). The calcium : phosphorus ratio must be in the region of 1.0 for normal growth and development.

Potassium, calcium, and magnesium are included as the K ÷ (Ca + Mg) ratio. These elements have a direct influence on the grazing value since unfavourable ratios lead to tetany (Kemp and T'Hart 1957, Kidambi et al. 1989). Values of these macronutrients are included in the formulae for the objective estimation of the grazing index values. Low or high values and unfavourable ratios have detrimental

Table 1. Species names and their authorities used in this paper and in Tables 1 to 3.

Chrysocoma ciliata L.
Eberlanzia ferox (L. Bol.) L. Bol.
Eriocephalus aspalathoides DC.
Eriocephalus ericoides (L.f.) Druce
Eriocephalus spinescens Burch.
Felicia fascicularis DC.
Felicia filifolia (Vent.) Burtt Davy
Felicia macrorrhiza (Thunb.) DC.
Felicia muricata (Thunb.) Nees
Galenia procumbens L.f.
Galenia secunda (L.f.) Sond.
Helichrysum dregeanum Sond. & Harv.
Helichrysum lucilioides Less.
Hermannia desertorum Eckl. & Zeyh.
Hertia pallens (DC.) Kuntze
Lycium cinerium Thunb. (Sens. Lat.)
Monechma incanum (Nees) C.B.Cl.
Nenax microphylla (Sond.) Salter
Osteospermum microphyllum DC.
Osteospermum spinescens Thunb.
Pentzia globosa Less.
Pentzia incana (Thunb.) Kuntze
Pentzia spinescens Less.
Phymaspermum parvifolium (DC.) Benth. & Hook. ex Jackson
Plinthus cryptocarpus Fenzl
Plinthus karooicus Verdoorn
Protasparagus suaveolens (Burch.) Oberm.
Pteronia adenocarpa Harv.
Pteronia glauca Thunb.
Pteronia glomerata L.f.
Pteronia sordida N.E.Br.
*Pteronia staehelinoide*s DC.
Pterothrix spinescens DC.
Rhigozum obovatum Burch.
Rosenia humilis (Less.) Bremer
Rosenia oppositifolia (DC.) Bremer
Salsola calluna Fenzl ex C.H.Wr.
Salsola rabieana Verdoorn
Salsola tuberculata (Moq.) Fenzl
Walafrida geniculata (L.f.) Rolfe
Walafrida saxatilis (E.Mey.) Rolfe
Zygophyllum gilfillanii N.E.Br.
Zygophyllum lichtensteinianum Cham. & Schlechtd.
Zygophyllum microphyllum L.f.
Grasses
Aristida adscensionis L.
Aristida congesta Roem. & Schult. subsp. *congesta*
Aristida diffusa Trin. subsp. *diffusa*
Cymbopogon plurinodis (Stapf) Stapf ex Burtt Davy
Cynodon dactylon (L.) Pers.
Digitaria eriantha Steud.
Enneapogon desvauxii Beauv.
Eragrostis bergiana (Kunth) Trin.
Eragrostis chloromelas Steud.
Eragrostis curvula (Schrad.) Nees var. *conferta*
Eragrostis lehmanniana Nees var. *lehmanniana*
Eragrostis obtusa Munro ex Fical. & Hiern
Fingerhuthia africana Lehm.
Heteropogon contortus (L.) Roem. & Schult.
Hyparrhenia hirta (L.) Stapf
Merxmuellera disticha (Nees) Conert
*Sporobolus fimbriatus (*Trin.) Nees
Stipagrostis ciliata (Desf.) De Winter var. *capensis*
Stipagrostis obtusa (Del.) Nees
Themeda triandra Forssk.

Table 2. Objective grazing index values (OGIV) calculated for species from the False Upper Karoo (Acocks 1988), compared to their corresponding subjective grazing index values (SGIV), illustrating the annual and seasonal variation.

	OGIV					SGIV
1990/91	May	Aug.	Nov.	Jan.	Mean	
Chrysocoma ciliata	1.22	0.31	1.29	0.51	0.83	1.50
Eriocephalus ericoides	2.44	1.67	3.44	4.16	2.93	5.00
Pentzia incana	1.64	1.33	2.01	1.94	1.73	5.70
Aristida congesta	3.36	1.92	0.94	1.07	1.82	1.30
Digitaria eriantha	19.59	7.72	13.51	6.46	11.82	8.90
Themeda triandra	15.04	10.19	8.31	6.69	10.06	9.30
1991/92	May	Aug	Nov	Jan	Mean	
Eriocephalus spinescens	3.09	2.75	0.29	2.73	2.22	4.50
Pentzia incana	1.67	1.17	1.42	1.93	1.55	5.70
Rosenia humilis	3.28	2.90	3.99	3.03	3.30	3.50
Heteropogon contortus	4.17	5.36	4.37	3.77	4.42	7.20
Stipagrostis ciliata	3.78	4.48	2.38	3.61	3.56	7.20
Stipagrostis obtusa	3.49	4.46	1.01	2.34	2.83	6.60
1992/93	May	Aug	Nov	Jan	Mean	
Eriocephalus ericoides	1.48	1.78	2.85	2.63	2.18	5.00
Pentzia incana	1.19	0.97	1.16	1.57	1.22	5.70
Rosenia humilis	3.16	4.56	4.60	3.65	3.99	3.50
Aristida congesta	1.82	1.58	0.78	0.85	1.26	1.30
Heteropogon contortus	3.77	5.06	4.15	3.98	4.24	7.20
Themeda triandra	6.64	6.26	5.65	4.70	5.81	9.30

effects on animal production (Van Hoven and Ebedes 1988). Low values lead to serious deficiencies in animal feeding (Woods 1959). Unfavourable values negatively affect index values.

In addition to the chemical properties mentioned above, the % ash and ether extract of the species were obtained from the literature for analyses previously carried out on plantspecies occurring in the same areas (Louw et al. 1968a, 1968b, 1968c, Steenkamp and Hayward 1979, Botha and Nash 1990, Botha et al. 1990a, 1990b, 1990c).

Total digestible nutrients (TDN)

Because of the prominence that total digestible nutrients receives in animal feeding ration formulations (Maynard and Loosli 1962), in the comparison of different feedstuffs (Swift 1957) and in this study, the comparison of different natural forages, it is included in these equations as a primary variable. The 2 variables incorporated in the determination of TDN (Glover et al. 1960, Bartholomew 1985, Bredon and Meaker undated), i.e. the percentages of nitrogen and acid detergent fibre, can be excluded from the model, since their influence on the index value is already taken into account.

The formula for the estimation of TDN using acid detergent fibre, is composed of the formulae developed by:

1) Glover et al. (1960) and Bredon and Meaker (undated) where : TDN = 75.1 + [(6.25 x log % crude protein)– 0.75 x % crude fibre)] and;
2) Du Toit (1996b) where : Crude fibre = – 4.32 + 0.92 x % acid detergent fibre.
   TDN = 75.1 + {(6.25 x log % N) – (0.75 x [– 4.32 + (0.92 x % acid detergent fibre)])} (Du Toit 1996b).

Proposed model, used to estimate grazing index values

The model takes into account the size of the plant i.e. canopy spread cover, which is the cornerstone of the method of botanical survey for estimating grazing capacity, through the Grazing Index Method. Two approaches were followed with the formulation of the model. In the case of the karoo subshrubs the ether extract value negatively affects the grazing value, on account of it's contribution to the smell and taste of the karoo subshrubs. The higher the ether extract value of the karoo subshrub, the higher the resin and aromatic oil content. Experience teaches that plants with high resin and aromatic oil contents are the more unpalatable karoo subshrubs. Compare the unpalatable karoo subshrub *Chrysocoma ciliata* with ether extract values of 8.9 in summer and 9.2 in winter to the more palatable karoo subshrub *Pentzia incana* with ether extract values of 2.3 and 3.9 in summer and winter respectively (Botha et al. 1990c) (Table 2). High ether extract contents act as deterrents to herbivores, while the higher the ether extract values of certain shrubs, the higher the loss of energy rich esters, ethers and aldehydes through the urine of sheep (Cook et al. 1952). The usable energy of these forages is not as high as their calculated TDN values indicate. Consequently the sum of the calculated values of the different variables is divided by the ether extract value, a lower index value for karoo subshrubs with high ether extract values are estimated, in accordance with their relatively low nutritional value.

Model a, grazing index value for karoo subshrubs

Grazing index value for the karoo subshrubs = {(canopy spread cover + available forage + TDN + [K ÷ (Ca + Mg)]) ÷ ether extract} ÷ 100 (Du Toit 1996b) (Table 3).

In the case of grasses, ether extract values positively contributes to the grazing value, through the carotene content (Van Der Merwe 1985). Grasses with high ether extract values are late developmental stage species, they are more productive and assumed to be more nutritious, than early developmental stage grasses with normally low ether extract percentages and low carotene contents. High ether extract values indicate high carotene contents of the grasses and a more favourable vitamin A, B, E, and probably D content (McDonald et al. 1973). Late developmental stage grasses *Digitaria eriantha* and *Themeda triandra* have the highest ether extract values, 2.02

Table 3. Mean objective grazing index values (OGIV) calculated according to the model, compared to the subjective grazing index values (SGIV)

Karoobushes	OGIV				SGIV
	Min	Max	Mean	Std dev	
Chrysocoma ciliata	0.31	1.29	0.83	0.43	1.50
Eberlanzia ferox	1.07	3.68	1.96	0.67	2.70
Eriocephalus ericoides	0.57	7.67	2.54	1.67	5.00
Eriocephalus spinescens	0.29	5.77	3.65	1.20	4.50
Felicia fascicularis	0.22	0.95	0.48	0.23	6.20
Felicia filifolia	1.94	4.23	2.63	0.93	5.90
Felicia macrorrhiza	1.70	2.37	2.05	0.24	5.70
Galenia secunda	2.53	6.21	4.92	1.46	4.70
Helichrysum dregeanum	0.43	0.53	0.47	0.04	6.30
Helichrysum lucilioides	0.94	3.09	1.75	0.57	5.20
Hermannia desertorum	1.09	1.35	1.21	0.09	5.90
Monechma incanum	6.01	18.69	9.76	5.20	5.40
Nenax microphylla	0.50	4.07	1.16	0.83	7.00
Osteospermum microphyllum	1.51	1.79	1.66	0.10	7.00
Osteospermum spinescens	2.92	6.03	4.63	1.34	6.00
Pentzia globosa	0.71	1.73	1.26	0.30	4.80
Pentzia incana	0.97	2.01	1.50	0.33	5.70
Pentzia spinescens	0.44	6.16	2.43	1.12	4.80
Phymaspermum parvifolium	0.39	3.71	1.60	1.12	6.20
Plinthus cryptocarpus	0.54	4.70	1.95	1.35	6.70
Plinthus karooicus	0.81	3.06	2.06	0.72	6.40
Pteronia adenocarpa	1.19	3.19	1.82	0.59	3.90
Pteronia glauca	1.89	3.81	2.77	0.80	3.20
Pteronia glomerata	1.15	2.63	2.06	0.55	3.90
Pteronia staehelinoides	0.14	0.22	0.18	0.03	4.00
Pterothrix spinescens	0.11	3.03	1.91	1.91	2.00
Rosenia humilis	2.44	6.06	4.00	0.89	3.50
Rosenia oppositifolia	0.50	1.24	0.82	0.30	3.10
Salsola calluna	4.24	5.71	5.11	0.62	7.20
Salsola rabieana	2.79	4.09	3.39	0.42	6.70
Salsola tuberculata	1.64	6.88	4.21	2.04	6.90
Walafrida geniculata	2.01	4.29	3.33	0.75	7.00
Walafrida saxatilis	0.54	0.86	0.69	0.12	2.00
Zygophyllum lichtensteinianum	1.20	1.62	1.43	0.17	4.00
Zygophyllum microphyllum	2.91	4.52	3.79	0.57	4.00
Grasses					
Aristida congesta	0.78	3.36	1.54	0.80	1.30
Aristida diffusa	2.56	11.00	5.75	2.36	5.10
Digitaria eriantha	4.82	19.59	8.58	4.47	8.90
Eragrostis curvula conferta	0.95	4.98	2.76	1.40	6.90
Eragrostis lehmanniana	1.87	5.64	2.70	0.89	5.40
Fingerhuthia africana	2.07	5.19	3.41	1.11	6.60
Heteropogon contortus	3.77	5.36	4.33	0.55	7.20
Hyparrhenia hirta	7.74	10.78	8.71	1.21	6.30
Merxmuellera disticha	4.91	12.24	7.46	2.82	5.00
Sporobolus fimbriatus	5.22	10.02	7.08	1.80	9.50
Stipagrostis ciliata	1.87	12.93	5.82	3.12	7.20
Stipagrostis obtusa	0.62	5.65	2.41	1.28	6.60
Themeda triandra	2.32	15.04	6.10	3.09	9.30

(summer) and 1.92 (winter) as opposed to the early developmental stage grasses *Aristida congesta* and *A. adscensionis* with a content of 1.34 in both summer and winter (Botha et al. 1990c) (Table 2) (Acocks 1988). Therefore the sum of the calculated values of the different variables is multiplied by the ether extract value. This action favours grasses with high ether extract values.

Model b, grazing index value for grasses

Grazing index value for the grasses = {(canopy spread cover + available forage + TDN + [K ÷ (Ca + Mg)]) x ether extract} ÷ 100 (Du Toit 1996b) (Table 3).

The estimated grazing index values

Although not all the plant species presented in the botanical surveys (Table 4) have objectively estimated grazing index values, the range condition scores and the resultant current grazing capacities resulting from the use of the objectively estimated grazing index values are closer to the accepted grazing capacity norms than where the subjectively estimated grazing index values have been used. Assuming that the grazing capacity norms set for the various areas are correct, the conclusion can be reached that it is more appropriate to use the objectively estimated grazing index values in the estimate of the grazing capacity, than either the ecological index values or the subjectively estimated grazing index values. It follows that the use of the objectively estimated grazing index values will result in more realistic estimates of the current grazing capacities of rangeland. Furthermore, the objectively estimated grazing index values verify the relative position of the subjectively estimated grazing index values of the different plant species on the grazing index value scale.

With this model, the grazing index value of any species can be estimated with a certain degree of confidence. Quality parameters can be gleaned from the literature, or be determined empirically. It may be possible to refine this model, by incorporating some of the parameters excluded at the moment. However, different grazing index values are estimated for species for the different seasons (Table 2) which in turn sheds more light on the concept of palatable and unpalatable species, as well as the seasonal palatability of a species.

The index value scale

It is questionable whether the top of the grazing index value scale should be 10. The use of a scale with values from 1 to 10 has become customary and is often proposed in biological work (cf. Curtis and McIntosh 1951, Brown and Curtis 1952, Vorster 1982, Hurt and Bosch 1991). It is clear that unbeknown to the estimators of the subjectively estimated grazing index values, the old ecological index method scale (Vorster 1982) and the climax adaptation values (Curtis and McIntosh 1951, Brown and Curtis 1952) played an important role in positioning the subjective estimates of the grazing index values. From the foregoing it then becomes clear that all the subjectively estimated grazing index values will have to be adjusted, mainly downwards, so as to fall into line with the objectively estimated grazing index values. Once this action is accomplished, current grazing capacities can be estimated much more reliably and realistically and different homogeneous areas can be directly compared to each other on a realistic and agriculturally sound scientific basis.

Table 4. Botanical composition, percentage canopy spread cover (CS), range condition scores (VCS) and the respective estimated current grazing capacities (CGC) presented for 7 sample sites from 4 reasonably homogeneous areas in the Karoo, i.e. the Bushmanland, the Eastern Mixed Karoo, the Great Karoo and the Central Upper Karoo. Sites follow a gradient from the arid northwest through the south and central Karoo to the relatively moist north eastern Karoo. The ecological, subjective grazing index and objective grazing index values of the different species are compared, as well as the results of their respective products with the percentage strikes on the species. Where no OGIV was available for a plant species, the SGIV was included as the OGIV score, this is indicated by an asterisk next to the species name. CGC is given in ha.LSU^{-1}. EIV = ecological index value, SGIV = subjective grazing index value and OGIV = objective grazing index value.

Grappies Farm (29° 25'S, 19° 57'E), Pofadder district; June 1992, median rainfall 82 mm.a^{-1}, grazing capacity norm 39 ha.LSU^{-1}, Bushmanland.

	%	EIV	Score	SGIV	Score	OGIV	Score
Aristida congesta	1	1	1	1.3	1.3	1.5	1.5
Eriocephalus spinescens	2	4	8	4.5	9.0	3.7	7.4
Stipagrostis ciliata	39	10	390	7.2	280.8	5.8	226.2
Stipagrostis obtusa	25	10	250	6.6	165.0	2.4	60.0
CS	67	VCS	649	VCS	456	VCS	295.1
CGC			7.2		10.2		15.7

Knolepark Farm (30° 38'S, 26° 20'E), Burgersdorp district; February 1992, median rainfall 450 mm.a^{-1}, grazing capacity norm 10 ha.LSU^{-1}, Eastern Mixed Karoo.

	%	EIV	Score	SGIV	Score	OGIV	Score
*Cymbopogon plurinodis**	*78*	*10*	*780*	*7.6*	*592.8*	*7.6*	*592.8*
Digitaria eriantha	2	10	20	8.9	17.8	8.3	16.6
Pentzia globosa	1	4	4	4.8	4.8	1.3	1.3
Themeda triandra	9	10	90	9.3	83.7	6.1	54.9
CS	90	VCS	894	VCS	699	VCS	665.6
CGC			5.2		6.6		7.0

Diephoek Farm (30°07'S, 24° 15'E), Petrusville district; July 1992, median rainfall 312 mm.a^{-1}, grazing capacity norm 20 ha.LSU^{-1}, Eastern Mixed Karoo.

	%	EIV	Score	SGIV	Score	OGIV	Score
Eragrostis lehmanniana	30	7	210	5.4	162.0	2.7	81.0
Pentzia globosa	15	4	60	4.8	72.0	1.3	19.5
Aristida congesta	4	1	4	1.3	5.2	1.5	6.0
Plinthus karooicus	8	7	56	6.4	51.2	2.1	16.8
*Enneapogon desvauxii**	1	1	1	1.0	1.0	1.0	1.0
*Hertia pallens**	2	1	2	1.2	2.4	1.2	2.4
*Lycium cinereum**	1	1	1	3.0	3.0	3.0	3.0
*Protasparagus suaveolens**	4	1	4	1.0	4.0	1.0	4.0
*Eriocephalus aspalathoides**	1	4	4	4.0	4.0	4.0	4.0
*Galenia procumbens**	5	4	20	4.3	21.5	4.3	21.5
*Eragrostis bergiana**	3	4	12	2.8	8.4	2.8	8.4
CS	74	VCS	374	VCS	3.35	VCS	167.7
CGC			12.4		13.9		27.7

Hillstone Farm (31° 20'S, 25° 31'E), Middelburg district; July 1992, median rainfall 346 mm.a^{-1}, grazing capacity norm 16 ha.LSU^{-1}, Eastern Mixed Karoo.

	%	EIV	Score	SGIV	Score	OGIV	Score
Sporobolus fimbriatus	14	10	140	9.5	133.0	7.1	99.4
*Eragrostis obtusa**	9	7	63	4.0	36.0	4.0	36.0
Eragrostis lehmanniana	1	7	7	5.4	5.4	2.7	2.7
Eriocephalus ericoides	15	4	60	5.0	75.0	2.5	37.5
Pentzia globosa	6	4	24	4.8	28.8	1.3	7.8
Aristida congesta	20	1	20	1.3	26.0	1.5	30.0
*Cynodon dactylon**	4	4	16	4.5	18.0	4.5	18.0
*Lycium cinereum**	8	1	8	3.0	24.0	3.0	24.0
*Eragrostis chloromelas**	1	7	7	5.5	5.5	5.5	5.5
Eriocephalus spinescens	1	4	4	4.5	4.5	3.7	3.7
Chrysocoma cilata	1	1	1	1.5	1.5	0.8	0.8
CS	80	VCS	350	VCS	358	VCS	265.4
CGC			13.3		13.0		17.5

(Continued on Page 535)

(Table 4. Continued)
Swartgrond Farm (33° 04'S, 22° 56'E), Beaufort West district; August 1992, median rainfall 199 mm. a^{-1}, grazing capacity norm 32 ha. LSU^{-1}, Great Karoo.

	%	EIV	Score	SGIV	Score	OGIV	Score
Aristida congesta	2	1	2	1.3	2.6	1.5	3.0
*Protasparagus suaveolens**	1	1	1	1.0	1.0	1.0	1.0
Pentzia incana	14	4	56	5.7	79.8	1.5	21.0
*Rhigozum obovatum**	2	7	14	6.6	13.2	6.6	13.2
Eberlanzia ferox	1	1	1	2.7	2.7	2.0	2.0
Hermannia desertorum	5	7	35	5.9	29.5	1.2	6.0
Stipagrostis obtusa	2	10	20	6.6	13.2	2.4	4.8
Eriocephalus ericoides	1	4	4	5.0	5.0	2.5	2.5
*Felicia muricata**	3	7	21	6.5	19.5	6.5	19.5
*Lycium cinereum**	1	1	1	3.0	3.0	3.0	3.0
*Pteronia sordida**	1	4	4	4.5	4.5	4.5	4.5
Eriocephalus spinescens	1	4	4	4.5	4.5	3.7	3.7
*Enneapogon desvauxii**	1	1	1	1.0	1.0	1.0	1.0
Stipagrostis ciliata	2	10	20	7.2	14.4	5.8	11.6
Felicia filifolia	1	7	7	5.9	5.9	2.6	2.6
Zygophyllum microphyllum	1	4	4	4.0	4.0	3.8	3.8
CS	39	VCS	195	VCS	204	VCS	103.2
CGC			23.8		22.8		45.0

Abrahamskraal Farm (31° 46'S, 22° 40'E), Victoria West district; February 1992, median rainfall 227 mm.a^{-1} grazing capacity norm 26 ha.LSU^{-1},Central Upper Karoo.

Grass/karoo bush range	%	EIV	Score	SGIV	Score	OGIV	Score
Eberlanzia ferox	1	1	1	2.9	2.9	2.0	2.0
Eriocephalus spinescens	1	4	4	4.5	4.5	3.7	3.7
Felicia filifolia	2	7	14	5.9	11.8	2.6	5.2
Pentzia incana	34	4	136	5.7	193.8	1.5	51.0
Pteronia glauca	1	4	4	3.2	3.2	2.8	2.8
*Pteronia sordida**	4	4	16	4.5	18.0	4.5	18.0
Rosenia humilis	1	1	1	3.5	3.5	4.0	4.0
Salsola tuberculata	1	7	7	6.9	6.9	4.2	4.2
Stipagrostis obtusa	20	10	200	6.6	132.0	2.4	4.8
Walafrida geniculata	1	7	7	7.0	7.0	3.3	3.3
*Zygophyllum gilfillanii**	2	7	14	5.9	11.8	5.9	11.8
CS	68	VCS	404	VCS	395	VCS	154
CGC			11.5		11.7		30.0
Mean current grazing capacity of Abrahamskraal farm							
			17.2		14.1		29.3

Conclusions

The objectively estimated grazing index values verifies the relative position of the species in the series and they can be compared to the subjective grazing index values developed earlier at the Grootfontein Agricultural Development Institute (Du Toit et al. 1995).

It is possible to objectively estimate grazing index values for plant species of the arid areas by means of a suitable model. In the estimates used in the model, certain plant variables such as the canopy spread cover, the available forage on the plant and the chemical content of the available forage at that instant, play prominent roles.

The objective grazing index values have been successfully used in the computation of range condition scores and in the calculation of current grazing capacities from these range condition scores (Table 4). These current grazing capacities have been estimated for widely differing areas. It is clear that they closely approximate the long-term grazing capacity norms prescribed for these areas by the South African Department of Agriculture.

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