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Wildlife substitution equivalents based on metabolisable energy for calculating stocking densities on Southern African wildlife ranches

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Abstract

This study aims to bridge the gap between the large stock unit method and the grazer and browser unit methods for estimating the stocking densities of wild herbivore ungulates on wildlife ranches and reserves using both extensive and intensive production methods. Animal substitution equivalents based on metabolisable energy are calculated to estimate stocking densities; however an annual up-to-date vegetation evaluation is required to estimate the carrying capacity of the habitat to support wild herbivore ungulates without it being degraded over time. This study provides an applied approach to how refined large stock, wild herbivore, grazer, and browser unit equivalents can be used effectively. The two production methods described differ in their intensity of animal management. In the extensive wild herbivore ungulate production method, the mean animal mass is used to calculate the large stock, wild herbivore, grazer, and browser substitution equivalent units, while in the intensive wild herbivore ungulate production method, the mean mass per physiological state, with varying percentages of suckling offspring, is used to do so. These methods are extrapolated from mean linear transformations of the different physiological states and sexes of the different types of herbivores. The extensive wild herbivore ungulate production method is preferred when evaluating wildlife ranches focused on hunting and tourism, as wildlife census data do not incorporate the numbers of males, females, and offspring, whereas the intensive wild herbivore ungulate production method is preferred for intensive breeding systems in which the numbers of males, females, and offspring are known.

Keywords: extensive wild herbivore ungulate production, intensive wild herbivore ungulate production, breeding system, metabolisable energy, metabolic mass, stocking rate, substitution equivalent units

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Introduction

One of the fundamental questions relating to wildlife ranch or game ranch management is how many animals a given habitat can support at a particular point in time without degrading it over time (Meissner, 1982; Danckwerts & Teague, 1989; Grossman *et al.*, 1999; Bothma *et al.*, 2004). However,

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the number of animals that the habitat on a wildlife ranch/reserve can support sustainably will depend on factors such as rainfall, fire, herbivory, condition of the vegetation, and the ranch's objectives. Therefore, a clear statement of objectives is a prerequisite to formulating a veld management strategy. For example, objectives may include maximising meat production, breeding rare species or subspecies for resale, providing biltong and trophy quality animals for hunting, providing viewing and ecotourism experiences, or a combination of some or all of these objectives (Grossman *et al.*, 1999).

Stocking densities (SD) for wild animals on wildlife ranches and reserves in southern Africa are often determined using carrying capacity (CC) norms set by agriculturalists based on grazing livestock, and are expressed as ha/large stock unit (LSU) (Meissner, 1982; Grossman *et al.*, 1999; Bothma *et al.*, 2004). This has led to wildlife ecologists refining SD estimates for wild herbivore ungulates by developing a method where both the grazing and browsing capacity of the habitat are incorporated into SD calculations; the resultant grazer unit (GU) and browser unit (BU) values are better able to protect the habitat from overutilisation (Peel *et al.*, 1994, 1999; Dekker, 1997; Bothma *et al.*, 2004). This study aims to provide an easy-to-use practical guide for agriculturalists, wildlife ecologists, wildlife ranchers, and vegetation ecologists.

The SD is the concentration of wild or domesticated herbivores on the veld and/or pasture at any moment in time and is expressed as the hectares per LSU (ha/LSU) (Trollope *et al.*, 1990). The stocking rate (SR) is the number of animals allocated to a specific piece of land for a specified period of time and is expressed as the hectares per LSU per time period (ha/LSU/time period) (Trollope *et al.*, 1990; Tainton *et al.*, 1999). Although the CC is often criticised as a nebulous concept (Dhondt, 1988; Grossman *et al*., 1999; Del Monte-Luna *et al*., 2004; Sayre, 2008), it is commonly applied to extensive systems, where it is defined as the potential of an area to support livestock/wildlife through forage and/or fodder production over an extended number of years without degrading the habitat (Trollope *et al.*, 1990). Furthermore, it is a function of the veld or pasture management applied, the trampling effects of the animals, the water point distribution, the availability and amount of edible and nutritious plants, and the existence of competitive animal behaviours. These factors all relate to food intake to varying degrees, where the food intake by the animal is determined by its energy requirements and the animal's ability to fulfil these needs by the food that it selects (Meissner, 1982). A vegetation study is, therefore, a prerequisite to assess how much edible forage (cellulolytic energy source) is available to sustain a population of herbivores. This has led to the development of models through which the CC, SD, and SR can be estimated on wildlife ranches and reserves.

The animal units used in these models are the LSU, also known as the livestock unit (LU), the animal unit, also known as the large animal unit (LAU), the GU, and the BU. An LSU is equivalent to a steer with a body mass of 450 kg, whose body mass increases by 500 g per day, on grassland with a mean digestible energy concentration of 55%. This equates to a requirement of 75 MJ of metabolisable energy (ME) per day to maintain this growth (Meissner, 1982). The LAU, originally described by Meissner (1982), is also equivalent to a 450 kg steer with a mass increase of 500 g per day, but does not account for the animals' daily energy requirement (Van Rooyen & Bothma, 2016). The GU is equivalent to a mature 180 kg blue wildebeest (*Connochaetes taurinus*), and the BU is equivalent to a mature 180 kg greater kudu (*Tragelaphus strepsiceros*) (Van Rooyen & Bothma, 2016).

The main difference between the animal units (specific animal equivalents) used in these methods is that the LAU, GU, and BU equivalents, which are estimated for different wild herbivore ungulates, are calculated by dividing the metabolic mass of a particular herbivore by the metabolic mass of a 450 kg steer (an LSU) or a 180 kg wild herbivore, to calculate the BU and GU (Owen-Smith, 1999; Bothma *et al*., 2004; Van Rooyen & Bothma 2016). In contrast, the LSU method, as proposed by Mentis & Duke (1976), Mentis (1977), Meissner (1982), and Shepstone *et al*. (2022), uses the ME requirement instead of the metabolic mass as its baseline, to compare the energy requirements of a poorly studied wild herbivore ungulate to that of a well-studied 450 kg steer (*Bos indicus/taurus*).

The calculated ME (ME^C), calculated LSU (LSU^C), calculated GU (GU^C), calculated BU (BU^C), and calculated GU/BU (GU^C/BU^C) equivalents described by Shepstone *et al*. (2022) have been replaced by the refined ME, LSU, wild herbivore unit (WHU), GU, and BU equivalents to estimate SD and SR on wildlife ranches and reserves (Shepstone *et al.*, in press; Shepstone, in press). The ME was compared to other published research when considering the accuracy of the refined animal unit equivalents. The mean field metabolic rate of animals of low and medium activity levels compares well with the maintenance energy requirements of animals of similar mass in other published literature (Meissner, 1982; NRC, 2007; Shepstone *et al.*, 2022) and with the values calculated using feed formulation

software (Zootrition© 2.7 Software, St. Louis, USA). The field metabolic rate estimates the animal's total energy expenditure, including all primary energy costs (Costa & Maresh, 2018), and is determined by multiplying the basal metabolic rate (Heusner, 1982; Hayssen & Lacy, 1985) by an approximated value of 1.35 for low activity and 1.85 for medium activity animals (Karasov, 1992).

The two approaches used to estimate the SD and calculate the SR on wildlife ranches and reserves are illustrated in Figure 1. The vegetation survey, veld condition assessment, and grazing and browsing capacity calculations used in rangeland assessments are discussed in detail by several authors (Grossman *et al.*, 1999; Bothma *et al.*, 2004; Van Rooyen & Bothma, 2016).

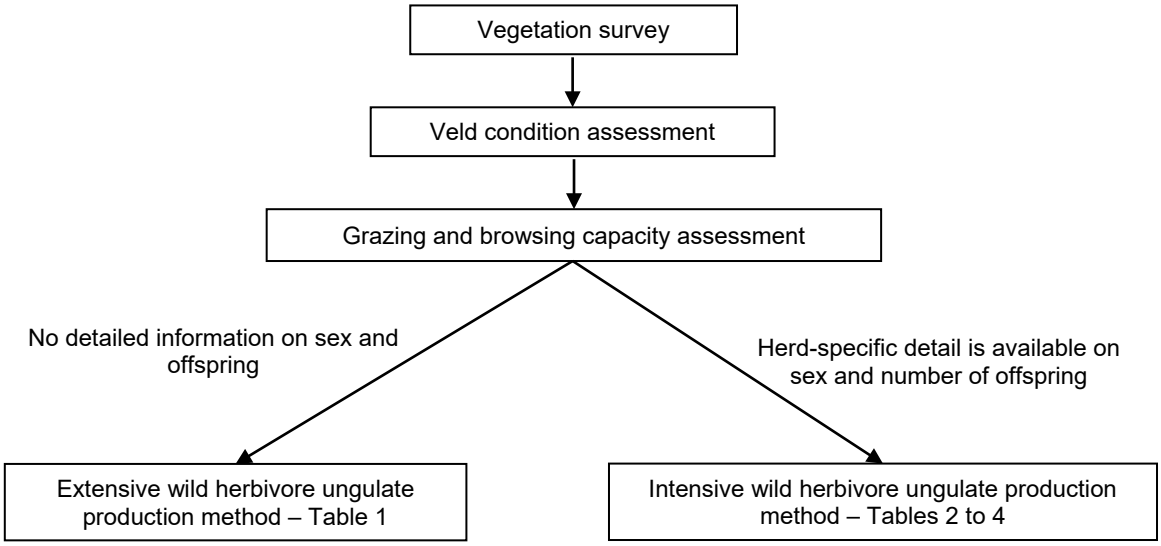

Figure 1 Steps to estimate stocking densities and calculate stocking rates on wildlife ranches and reserves.

The animal substitution equivalents that can be used to (a) estimate the current or future optimal SD for extensive wild herbivore production systems and (b) calculate a suitable SR for intensive wild herbivore production/breeding systems without degrading the habitat quality over time will be discussed next. Four examples in which a fixed number of animals are in the same baseline environment are used to compare the extensive and intensive wild herbivore ungulate production methods (also referred to as the extensive and intensive production methods), with and without offspring (and thus, lactating females). The intensive breeding of wildlife requires additional veterinary care and nutrition, and focuses on production parameters such as improving animal condition, calving percentage, weaning mass, horn growth, immune status, and general health (Shepstone, in press).

Materials and methods

The methods for calculating the wild herbivore SD and SR are divided into those suitable for extensive wildlife ranching, which focuses on hunting and tourism, and those suitable for intensive wildlife ranching, which focuses on breeding some or all of the wild herbivore ungulates on the ranch, either in camps or on the entire property. The data used to estimate the SD and SR, namely the mean animal mass (population mean), the mean mass as per physiological state, and the percentage of grass and browse in the population's diets, are extracted from Bothma *et al.* (2004), Orban (2014), and Van Rooyen & Bothma (2016).

The extensive wild herbivore ungulate production method (Table 1) is used for extensive wildlife ranches and reserves focusing on hunting and tourism (Shepstone *et al*., in press). The mean animal mass, the LSU and WHU ME requirements in MJ ME, and the percentages of grass and browse in the diets are used to estimate the percentage of dry matter intake (DMI), refined ME, LSU, WHU, GU, and BU substitution equivalents. The animal unit substitution equivalents are extrapolated from the mean linear transformations irrespective of physiological states (Shepstone *et al*., 2022). Appendix 1 lists the animal substitution equivalents used to estimate the SD and SR on wildlife ranches and reserves.

The intensive wild herbivore ungulate production method (Tables 2, 3, and 4) is used for semi-intensive or intensive wildlife ranching systems. This method incorporates the mean mass of each of the three different physiological states (male, female, and female with offspring) within the LSU and WHUs ME requirements in MJ ME for each type of herbivore. The proportion of grass and browse that a specific type of wild herbivore selects is used to estimate the refined ME, LSU, WHU, GU, and BU substitution equivalents. The animal unit substitution equivalents are extrapolated from the mean linear transformations for the different physiological states, incorporating sex (Shepstone *et al*., 2022) but excluding the calf/lamb component. Appendix 2 lists the animal substitution equivalents used to estimate the SD and SR on a wildlife breeding ranch.

The calculations used to show the differences between the old and newly established methods to estimate the extensive and intensive wild herbivore production method's different animal unit equivalents are as follows:

The metabolic mass method's LAU and WHU substitution equivalents for a 460 kg Cape eland (*Taurotragus oryx*) are 1.02 LAU and 2.02 WHU:

$$\frac{460^{0.75}}{450^{0.75}} = 1.02\ LAU$$

$$\frac{460^{0.75}}{180^{0.75}} = 2.02\ WHU$$

The extensive wild herbivore ungulate production method's calculations used to calculate a wild herbivore's daily ME requirement, and refined LSU, WHU, GU, and BU equivalents are as follows:

The ME requirement in MJ ME of an average Cape eland with a mean mass of approximately 460 kg is:

$$LOG\ ME = (0.827 \times \log 460) - 0.320 = 1.882$$

$$ME\ required\ per\ day = 10^{1.882}$$

$$MJ\ ME\ per\ day = 76.23$$

This is converted into refined LSU and WHU equivalents as follows:

With the LSU's daily energy requirement of 75 MJ ME (Meissner, 1982) and the WHU's daily energy requirement of 29.71 MJ ME (Shepstone *et al*., 2022), the Cape eland will have a refined LSU equivalent of 1.02 and a WHU equivalent of 2.57 (Table 1 and Appendix 1).

$$Refined\ LSU = 76.23 \div 75\ MJ\ ME\ per\ day$$

$$LSU = 1.02$$

and

$$WHU = 76.23 \div 29.71\ MJ\ ME\ per\ day$$

$$WHU = 2.57$$

When converting this to a GU or BU, diet selection is incorporated, and the Cape eland is thus equivalent to 1.28 GU and 1.28 BU (Appendix 1).

$$GU = WHU \times percentage\ grass\ in\ the\ diet$$

$$GU = 2.57 \times 50\%$$

$$GU = 1.28$$

and

$$BU = WHU \times percentage\ browse\ in\ the\ diet$$

$$BU = 2.57 \times 50\%$$

$$BU = 1.28$$

The calculations used to calculate the daily ME requirement, and refined LSU, WHU, GU, and BU equivalents for the intensive production method are as follows:

The ME requirement in MJ ME of a Cape eland bull with a mass of approximately 632.5 kg is:

$$LOG\ ME = (0.823 \times \log 632.5) - 0.358 = 1.947$$

$$ME\ required\ per\ day = 10^{1.947}$$

$$MJ\ ME\ per\ day = 88.57$$

This is converted to refined LSU and/or WHU values as follows:

With the LSU's daily energy requirement of 75 MJ ME (Meissner, 1982) and the WHU's daily energy requirement of 29.71 MJ ME (Shepstone *et al.*, 2022), a Cape eland bull will have a refined LSU equivalent of 1.18 and a WHU equivalent of 2.98 (Table 2).

The ME requirement in MJ ME of a dry Cape eland cow with a mass of approximately 460 kg is:

$$LOG\ ME = (0.824 \times \log 460) - 0.345 = 1.849$$

$$ME\ required\ per\ day = 10^{1.849}$$

$$MJ\ ME\ per\ day = 70.65$$

This is converted to refined LSU and/or WHU values as follows:

With the LSU's daily energy requirement of 75 MJ ME (Meissner, 1982) and the WHU's daily energy requirement of 29.71 MJ ME (Shepstone *et al.*, 2022), the dry Cape eland cow will have a refined LSU equivalent of 0.94 and a WHU equivalent of 2.38 (Table 2 and Appendix 2).

The daily ME requirement in MJ ME of a Cape eland cow with a calf with a mass of approximately 460 kg is:

$$LOG\ ME = (0.819 \times \log 460) - 0.228 = 1.953$$

$$ME\ required\ per\ day = 10^{1.953}$$

$$MJ\ ME\ per\ day = 89.70$$

This is converted to refined LSU and/or WHU values as follows:

With the LSU's daily energy requirement of 75 MJ ME (Meissner, 1982) and the WHU's daily energy requirement of 29.71 MJ ME (Shepstone *et al.*, 2022), the Cape eland cow with a calf will have a refined LSU equivalent of 1.2 and a WHU equivalent of 3.02 (Table 2 and Appendix 2).

When calculating the WHU, GU, and BU equivalents for the intensive production method, the values for percentage graze and browse in the diet for the different physiological states listed in Appendix 2 are used.

Results

In all the examples discussed below, the following criteria are kept constant: The calculations are made for a 2000 ha wildlife ranch/reserve with a grazing capacity of 200 LSU, with 328 adult animals (Tables 1 and 2), of which 30% are bulls; however, in Tables 3 and 4, the animal numbers are greater because the offspring are added. The ranch/reserve has a grazing capacity of 10 ha/LSU and 5 ha/GU, and has a browsing capacity of 10 ha/BU. The numbers of male and female animals are also kept constant in all examples. It is also assumed in all examples that a qualified vegetation ecologist has recently conducted a vegetation study or veld evaluation to confirm the habitat's grazing and browsing capacities.

Example 1 (Table 1) describes a typical bushveld wildlife ranch/reserve where appropriate wild herbivore ungulates are present. Using the animal-specific mean mass, the mean LSU, the WHU equivalents from Appendix 1, and the percentages of grass and browse in the diet, the SD can be calculated/estimated using the extensive wild herbivore ungulate production method. In this example, the ranch/reserve would, therefore, be able to stock 200 LSU conservatively or 400 GU and 200 BU. The numbers of animal units listed in Tables 1 to 4 are the numbers that the habitat can potentially support based on the vegetation survey, and are the products of direct calculations of the size of the ranch divided by the sum of the respective LSU, WHU, and GU and BU equivalents, estimating the grazing or browsing capacity of the habitat. The numbers of LSU, WHU, GU, and BU in Tables 1 to 4 are the actual population sizes of the different wild herbivore ungulates, expressed as LSU, GU, and BU. The calculated animal unit equivalents in LSU, GU, and BU (Table 1) are as follows: the 200 LSU are equal to the vegetation study's estimated LSU, the 318 GU are less than the estimated 400 GU, and the 187 BU are less than the estimated 200 BU.

Example 2 (Table 2) describes a wildlife ranch where 20% of the 328 animals from Example 1 (Table 1) are offspring, over a fixed time period (a year). The intensive production method is used for the calculations instead of the extensive production method, because the calculations incorporate the offsprings' dams, and thus include 20% lactating females. The habitat of the ranch/reserve would be able to conservatively support 200 LSU, 400 GU, and 200 BU without being degraded. When using the grazing and browsing capacities of the intensive production method and its estimated SD (vegetation study) results (Table 2), the 178 LSU is less than the estimated SD of 200 LSU, the 288 GU is less than the estimated 400 GU, and the 182 BU is less than the estimated 200 BU.

Example 3 (Table 3) describes a wildlife ranch/reserve where 20% of the females conceive and raise their offspring over a defined period (a year). The expected 46 offspring, with a male-to-female ratio of 50:50, are added to the 328 adult animals. The 213 LSU are more than the vegetation study's estimated SD of 200 LSU. However, the 344 GU is less than the estimated SD of 400 GU, and the 193 BU is less than the estimated 200 BU.

Example 4 (Table 4) describes an intensive breeding system where at least 80% of the female animals conceive and raise their offspring. The 183 offspring with a male-to-female ratio of 50:50 are added to the 328 adult animals. In this intensively managed environment, the ranch can, conservatively, be stocked with 200 LSU, 400 GU, and 200 BU. When using the grazing and browsing capacities of the intensive wild herbivore production method and its estimated SD, the 234 LSU is greater than the estimated SR of 200 LSU based on the vegetation study, the 379 GU is less than the estimated SR of 400 GU, and the 213 BU is more than the estimated 200 BU.

Table 1 The refined large stock unit (LSU), wild herbivore unit (WHU), grazer unit (GU), and browser unit (BU) equivalents for a specified number of wild southern African herbivores, based on the percentage of grass and browse selected, necessary to estimate the stocking density of a 2000 ha wildlife ranch/reserve in the southern African bushveld when using the extensive wild herbivore ungulate production method

Wild herbivore	Feeding type	Mean mass (kg)*	Mean physiological state calculated ME (MJ/day)	Refined LSU equivalent	WHU equivalent	GU equivalent per animal based on % grass in diet	BU equivalent per animal based on % browse in diet	Number of animals	Number of LSU	Number of GU	Number of BU
Blue wildebeest (*Connochaetes taurinus*)											
	SG	180.0	35.08	0.47	1.18	1.03	0.15	60	28.07	61.64	9.21
Cape eland (*Taurotragus oryx*)											
	IM	460.0	76.23	1.02	2.57	1.28	1.28	40	40.65	51.31	51.31
Impala (*Aepyceros melampus melampus*)											
	IM	41.0	10.32	0.14	0.35	0.16	0.19	67	9.22	10.48	12.80
African buffalo (*Syncerus caffer*)											
	BG	520.0	84.36	1.12	2.84	2.21	0.62	65	73.11	143.96	40.60
Plains zebra (*Equus quagga burchellii*)											
	BG	260.0	47.55	0.63	1.60	1.49	0.11	26	16.49	38.70	2.91
Greater kudu (*Tragelaphus strepsiceros*)											
	B	180.0	35.08	0.47	1.18	0.18	1.00	70	32.75	12.40	70.26
Totals								**328**	**200.28**	**318.49**	**187.11**

Notes:

- Feeding types: selective grazer (SG), intermediate feeder (IM), bulk grazer (BG), browser (B).
- *Animal masses are taken from Orban (2014) and Bothma & Du Toit (2016).
- The mean mass represents all the ages and sexes in the population.
- The refined mean metabolisable energy (ME) requirement equation used to calculate the refined LSU and WHU is: LOG ME = (0.827 × log X) − 0.320, where X is animal mass.
- The WHU is a 180 kg blue wildebeest or greater kudu requiring 29.71 MJ ME per day.
- WHU = GU + BU.
- GU and BU equivalents = WHU × percentage grass or browse selected.

Ranch/reserve specifics and the respective grazing and browsing capacities:		
Size of ranch (ha)	2000	ha
Carrying capacity (LSU)	10	ha/LSU
Grazing capacity (GU)	5	ha/GU
Browsing capacity (BU)	10	ha/BU
Number of animal units the ranch/reserve can potentially keep (vegetation study):		
Number of LSU	200	LSU
Number of GU	400	GU
Number of BU	200	BU
The number of LSU, WHU, GU, and BU on the ranch/reserve:		
Total LSU	200.28	LSU
Total GU	318.49	GU
Total BU	187.11	BU
Total WHU (GU+BU)	505.6	WHU

Table 2 The refined large stock unit (LSU), wild herbivore unit (WHU), grazer unit (GU), and browser unit (BU) equivalents for the different physiological states of a specified number of wild southern African herbivores, based on the percentage of grass and browse selected and where 20% of the population are offspring, necessary to estimate the stocking density of a 2000 ha wildlife ranch/reserve in the southern African bushveld using the intensive wild herbivore ungulate production method

Wild herbivore	Feeding type	Sex	Mean mass (kg)*	Mean physiological state refined ME (MJ/day)	Refined LSU	Refined WHU equivalent	GU equivalent per animal based on % grass in diet	BU equivalent per animal based on % browse in diet	Number of animals per physiological state	Total	Number of refined LSU	Number of GU	Number of BU
Blue wildebeest (*Connochaetes taurinus)*													
		M	235.0	39.21	0.52	1.32	1.15	0.17	18		9.41	20.67	3.09
	SG	F	185.0	33.35	0.44	1.12	0.98	0.15	18	60	8.00	17.58	2.63
		F+O	185.0	42.54	0.57	1.43	1.25	0.19	12 (+12**)		6.81	14.95	2.23
Cape eland (*Taurotragus oryx*)													
		M	632.5	88.57	1.18	2.98	1.49	1.49	12		14.17	17.89	17.89
	IM	F	460.0	70.65	0.94	2.38	1.19	1.19	12	40	11.30	14.27	14.27
		F+O	460.0	89.70	1.20	3.02	1.51	1.51	8 (+8**)		9.57	12.08	12.08
Impala (*Aepyceros melampus melampus*)													
		M	63.0	13.27	0.18	0.45	0.20	0.25	20		3.54	4.02	4.91
	IM	F	43.5	10.12	0.13	0.34	0.15	0.19	20	66	2.70	3.07	3.75
		F+O	43.5	13.00	0.17	0.44	0.20	0.24	13 (+13**)		2.25	2.56	3.13

Notes:

- Feeding types: selective grazer (SG), intermediate feeder (IM), bulk grazer (BG), browser (B).
- *Animal masses are taken from Orban (2014) and Bothma & Du Toit (2016).
- The mean mass represents the mass of the respective sexes in the population, where female + offspring (F+O) only has the females' mass (F).
- The refined metabolisable energy (ME) requirement equation used to determine the LSU and WHU for the male is: LOG ME = (0.823 × log X) − 0.358, for the female is: LOG ME = (0.824 × Log X) − 0.345, and for the female with offspring is: LOG ME = (0.819 × Log X) − 0.228, where X is the animal mass.
- The WHU is a 180 kg blue wildebeest or greater kudu requiring 29.71 MJ ME per day.
- WHU = GU + BU.
- GU and BU equivalents = WHU × percentage grass or browse selected.
- **Number represents the number of offspring when calculating the total number of animals.

Ranch/reserve specifics and the respective grazing and browsing capacities:		
Size of ranch (ha)	2000	ha
Carrying capacity (LSU)	10	ha/LSU
Grazing capacity (GU)	5	ha/GU
Browsing capacity (BU)	10	ha/BU
Number of animal units the ranch/reserve can potentially keep (vegetation study):		
Number of LSU	200	LSU
Number of GU	400	GU
Number of BU	200	BU
The number of LSU, WHU, GU, and BU on the ranch/reserve:		
Total LSU	178.32	LS
Total GU	288.11	GU
Total BU	162.04	BU
Total WHU (GU+BU)	450.15	WHU

Table 2 (continued)

Wild herbivore	Feeding type	Sex	Mean mass (kg)*	Mean physiological state refined ME (MJ/day)	Refined LSU	Refined WHU equivalent	GU equivalent per animal based on % grass in diet	BU equivalent per animal based on % browse in diet	Number of animals per physiological state	Total	Number of refined LSU	Number of GU	Number of BU
African buffalo (*Syncerus caffer*)													
		M	750.0	101.90	1.36	3.43	2.68	0.75	20		27.17	53.51	15.09
	BG	F	578.0	85.28	1.14	2.87	2.24	0.63	20	66	22.74	44.78	12.63
		F+O	578.0	108.15	1.44	3.64	2.84	0.80	13 (+13**)		18.75	36.91	10.41
Plains zebra (*Equus quagga burchellii*)													
		M	315.0	49.90	0.67	1.68	1.56	0.12	8		5.32	12.50	0.94
	BG	F	315.0	51.71	0.69	1.74	1.62	0.12	8	26	5.52	12.95	0.97
		F+O	315.0	65.78	0.88	2.21	2.06	0.15	5 (+5**)		4.39	10.30	0.77
Greater kudu (*Tragelaphus strepsiceros*)													
		M	244.5	40.51	0.54	1.36	0.20	1.16	21		11.34	4.29	24.34
	B	F	160.0	29.59	0.39	1.00	0.15	0.85	21	70	8.29	3.14	17.78
		F+O	160.0	37.77	0.50	1.27	0.19	1.08	14 (+14**)		7.05	2.67	15.13
Totals										**328**	**178.32**	**288.11**	**162.04**

Notes:

- Feeding types: selective grazer (SG), intermediate feeder (IM), bulk grazer (BG), browser (B).
- *Animal masses are taken from Orban (2014) and Bothma & Du Toit (2016).
- The mean mass represents the mass of the respective sexes in the population, where female + offspring (F+O) only has the females' mass (F).
- The refined metabolisable energy (ME) requirement equation used to determine the LSU and WHU for the male is: LOG ME = (0.823 × log X) − 0.358, for the female is: LOG ME = (0.824 × Log X) − 0.345, and for the female with offspring is: LOG ME = (0.819 × Log X) − 0.228, where X is the animal mass.
- The WHU is a 180 kg blue wildebeest or greater kudu requiring 29.71 MJ ME per day.
- WHU = GU + BU.
- GU and BU equivalents = WHU × percentage grass or browse selected.
- **This number represents the number of offspring when calculating the total number of animals.

Ranch/reserve specifics and the respective grazing and browsing capacities:

Size of ranch (ha)	2000	ha
Carrying capacity (LSU)	10	ha/LSU
Grazing capacity (GU)	5	ha/GU
Browsing capacity (BU)	10	ha/BU

Number of animal units the ranch/reserve can potentially keep (vegetation study):

Number of LSU	200	LSU
Number of GU	400	GU
Number of BU	200	BU

The number of LSU, WHU, GU, and BU on the ranch/reserve:

Total LSU	178.32	LS
Total GU	288.11	GU
Total BU	162.04	BU
Total WHU (GU+BU)	450.15	WHU

Table 3 The refined large stock unit (LSU), wild herbivore unit (WHU), grazer unit (GU), and browser unit (BU) equivalents for the different physiological states of several wild southern African herbivores, based on the percentage grass and browse selected and where 20% of the females have suckling offspring, necessary to estimate the stocking densities of a 2000 ha wildlife ranch/reserve in the southern African bushveld, using the intensive wild herbivore ungulate production method

Wild herbivore	Feeding type	Sex	Mean mass (kg)*	Mean physiological state refined ME (MJ/day)	Refined LSU equivalent	WHU equivalent	GU equivalent per animal based on % grass in the diet	BU equivalent per animal based on % browse in diet	Number of animals per physiological state	Total	Number of LSU	Number of GU	Number of BU
Blue wildebeest (*Connochaetes taurinus*)													
		M	235.0	39.21	0.52	1.32	1.15	0.17	18		9.41	20.67	3.09
	SG	F	185.0	33.35	0.44	1.12	0.98	0.15	34	68	15.12	33.21	4.96
		F+O	185.0	42.54	0.57	1.43	1.25	0.19	8 (+8**)		4.54	9.97	1.49
Cape eland (*Taurotragus oryx*)													
		M	632.5	88.57	1.18	2.98	1.49	1.49	12		14.17	17.89	17.89
	IM	F	460.0	70.65	0.94	2.38	1.19	1.19	22	46	20.72	26.16	26.16
		F+O	460.0	89.70	1.20	3.02	1.51	1.51	6 (+6**)		7.18	9.06	9.06
Impala (*Aepyceros melampus melampus*)													
		M	63.0	13.27	0.18	0.45	0.20	0.25	20		3.54	4.02	4.91
	IM	F	43.5	10.12	0.13	0.34	0.15	0.19	38	76	5.13	5.82	7.12
		F+O	43.5	13.00	0.17	0.44	0.20	0.24	9 (+9**)		1.56	1.77	2.17

Notes:

- Feeding types: selective grazer (SG), intermediate feeder (IM), bulk grazer (BG), browser (B).
- *Animal masses are taken from Orban (2014) and Bothma & Du Toit (2016).
- The mean mass represents the mass of the respective sexes in the population, where female + offspring (F+O) only has the females' mass (F).
- The refined metabolisable energy (ME) requirement equation used to determine the LSU and WHU for the male is: LOG ME = (0.823 × log X) − 0.358, for the female is: LOG ME = (0.824 × log X) − 0.345, and for the female with offspring is: LOG ME = (0.819 × log X) − 0.228, where X is the animal mass.
- The WHU is a 180 kg blue wildebeest or greater kudu requiring 29.71 MJ ME per day.
- WHU = GU + BU.
- GU and BU equivalents = WHU × percentage grass or browse selected.
- **This number represents the number of offspring when calculating the total number of animals.

Ranch/reserve specifics and the respective grazing and browsing capacities:		
Size of ranch (ha)	2000	ha
Carrying capacity (LSU)	10	ha/LSU
Grazing capacity (GU)	5	ha/GU
Browsing capacity (BU)	10	ha/BU
Number of animal units the ranch/reserve can potentially keep (vegetation study):		
Number of LSU	200	LSU
Number of GU	400	GU
Number of BU	200	BU
The number of LSU, WHU, GU, and BU on the ranch/reserve:		
Total LSU	212.70	LSU
Total GU	343.64	GU
Total BU	193.30	BU
Total WHU (GU+BU)	536.94	WHU

Table 3 (continued)

Wild herbivore	Feeding type	Sex	Mean mass (kg)*	Mean physiological state refined ME (MJ/day)	Refined LSU equivalent	WHU equivalent	GU equivalent per animal based on % grass in the diet	BU equivalent per animal based on % browse in diet	Number of animals per physiological state	Total	Number of LSU	Number of GU	Number of BU
African buffalo (*Syncerus caffer*)													
		M	750.0	101.90	1.36	3.43	2.68	0.75	20		27.17	53.51	15.09
	BG	F	578.0	85.28	1.14	2.87	2.24	0.63	36	74	40.93	80.60	22.73
		F+O	578.0	108.15	1.44	3.64	2.84	0.80	9 (+9**)		12.98	25.55	7.21
Plains zebra (*Equus quagga burchellii*)													
		M	315.0	49.90	0.67	1.68	1.56	0.12	8		5.32	12.50	0.94
	BG	F	315.0	51.71	0.69	1.74	1.62	0.12	14	30	9.65	22.66	1.71
		F+O	315.0	65.78	0.88	2.21	2.06	0.15	4 (+4**)		3.51	8.24	0.62
Greater kudu (*Tragelaphus strepsiceros*)													
		M	244.5	40.51	0.54	1.36	0.20	1.16	21		11.34	4.29	24.34
	B	F	160.0	29.59	0.39	1.00	0.15	0.85	39	80	15.39	5.83	33.02
		F+O	160.0	37.77	0.50	1.27	0.19	1.08	10 (+10**)		5.04	1.91	10.81
Totals										**374**	**212.70**	**343.64**	**193.30**

Notes:

- Feeding types: selective grazer (SG), intermediate feeder (IM), bulk grazer (BG), browser (B).
- *Animal masses are taken from Orban (2014) and Bothma & Du Toit (2016).
- The mean mass represents the mass of the respective sexes in the population, where female + offspring (F+O) only has the females' mass (F).
- The refined metabolisable energy (ME) requirement equation used to determine the LSU and WHU for the male is: LOG ME = (0.823 × log X) − 0.358, for the female is: LOG ME = (0.824 × log X) − 0.345, and for the female with offspring is: LOG ME = (0.819 × log X) − 0.228, where X is the animal mass.
- The WHU is a 180 kg blue wildebeest or greater kudu requiring 29.71 MJ ME per day.
- WHU = GU + BU.
- GU and BU equivalents = WHU × percentage grass or browse selected.
- **This number represents the number of offspring when calculating the total number of animals.

Ranch/reserve specifics and the respective grazing and browsing capacities:		
Size of ranch (ha)	2000	ha
Carrying capacity (LSU)	10	ha/LSU
Grazing capacity (GU)	5	ha/GU
Browsing capacity (BU)	10	ha/BU
Number of animal units the ranch/reserve can potentially keep (vegetation study):		
Number of LSU	200	LSU
Number of GU	400	GU
Number of BU	200	BU
The number of LSU, WHU, GU and BU on the ranch/reserve:		
Total LSU	212.70	LSU
Total GU	343.64	GU
Total BU	193.30	BU
Total WHU (GU+BU)	536.94	WHU

Table 4 The refined large stock unit (LSU), wild herbivore unit (WHU), grazer unit (GU), and browser unit (BU) equivalents for the different physiological states of several wild southern African herbivores, based on the percentage grass and browse selected and where 80% of the females have suckling offspring, necessary to estimate the stocking densities of a 2000 ha wildlife ranch/reserve in the southern African bushveld, using the intensive wild herbivore ungulate production method

Wild herbivore	Feeding type	Sex	Mean mass (kg)*	Mean physiological state refined ME (MJ/day)	Refined LSU equivalent	WHU equivalent	GU equivalent per animal based on % grass in diet	BU equivalent per animal based on % browse in diet	Number of animals per physiological state	Total	Number of LSU	Number of GU	Number of BU
Blue wildebeest (*Connochaetes taurinus)*													
		M	235.0	39.21	0.52	1.32	1.15	0.17	18		9.41	20.67	3.09
	SG	F	185.0	33.35	0.44	1.12	0.98	0.15	8	94	3.56	7.81	1.17
		F+O	185.0	42.54	0.57	1.43	1.25	0.19	34 (+34**)		19.29	42.36	6.33
Cape eland (*Taurotragus oryx*)													
		M	632.5	88.57	1.18	2.98	1.49	1.49	12		14.17	17.89	17.89
	IM	F	460.0	70.65	0.94	2.38	1.19	1.19	6	62	5.65	7.13	7.13
		F+O	460.0	89.70	1.20	3.02	1.51	1.51	22 (+22**)		26.31	33.21	33.21
Impala (*Aepyceros melampus melampus*)													
		M	63.0	13.27	0.18	0.45	0.20	0.25	20		3.54	4.02	4.91
	IM	F	43.5	10.12	0.13	0.34	0.15	0.19	9	105	1.21	1.38	1.69
		F+O	43.5	13.00	0.17	0.44	0.20	0.24	38 (+38**)		6.59	7.48	9.14

Notes:

- Feeding types: selective grazer (SG), intermediate feeder (IM), bulk grazer (BG), browser (B).
- *Animal masses are taken from Orban (2014) and Bothma & Du Toit (2016).
- The mean mass represents the mass of the respective sexes in the population, where female + offspring (F+O) only has the females' mass (F).
- The refined metabolisable energy (ME) requirement equation used to determine LSU and WHU for the male is: LOG ME = (0.823 × log X) − 0.358, for the female is: LOG ME = (0.824 × log X) − 0.345, and the female with offspring is: LOG ME = (0.819 × log X) − 0.228, where X is the animal mass.
- The WHU is a 180 kg blue wildebeest or greater kudu requiring 29.71 MJ ME per day.
- WHU = GU + BU.
- GU and BU equivalents = WHU × percentage grass or browse selected.
- **This number represents the number of offspring when calculating the total number of animals.

Ranch/reserve specifics and the respective grazing and browsing capacities:		
Size of ranch (ha)	2000	ha
Carrying capacity (LSU)	10	ha/LSU
Grazing capacity (GU)	5	ha/GU
Browsing capacity (BU)	10	ha/BU
Number of animal units the ranch/reserve can potentially keep (vegetation study):		
Number of LSU	200	LSU
Number of GU	400	GU
Number of BU	200	BU
The number of LSU, WHU, GU, and BU on the ranch/reserve:		
Total LSU	234.34	LSU
Total GU	378.85	GU
Total BU	212.71	BU
Total WHU (GU+BU)	591.56	WHU

Table 4 (continued)

Wild herbivore	Feeding type	Sex	Mean mass (kg)*	Mean physiological state refined ME (MJ/day)	Refined LSU equivalent	WHU equivalent	GU equivalent per animal based on % grass in diet	BU equivalent per animal based on % browse in diet	Number of animals per physiological state	Total	Number of LSU	Number of GU	Number of BU
African buffalo (*Syncerus caffer*)													
		M	750.0	101.90	1.36	3.43	2.68	0.75	20		27.17	53.51	15.09
	BG	F	578.0	85.28	1.14	2.87	2.24	0.63	9	101	10.23	20.15	5.68
		F+O	578.0	108.15	1.44	3.64	2.84	0.80	36 (+36**)		51.91	102.21	28.83
Plains zebra (*Equus quagga burchellii*)													
		M	315.0	49.90	0.67	1.68	1.56	0.12	8		5.32	12.50	0.94
	BG	F	315.0	51.71	0.69	1.74	1.62	0.12	4	40	2.76	6.48	0.49
		F+O	315.0	65.78	0.88	2.21	2.06	0.15	14 (+14**)		12.28	28.83	2.17
Greater kudu (*Tragelaphus strepsiceros*)													
		M	244.5	40.51	0.54	1.36	0.20	1.16	21		11.34	4.29	24.34
	B	F	160.0	29.59	0.39	1.00	0.15	0.85	10	109	3.95	1.49	8.47
		F+O	160.0	37.77	0.50	1.27	0.19	1.08	39 (+39**)		19.64	7.44	42.15
Totals										**511**	**234.34**	**378.85**	**212.71**

Notes:

- Feeding types: selective grazer (SG), intermediate feeder (IM), bulk grazer (BG), browser (B).
- *Animal masses are taken from Orban (2014) and Bothma & Du Toit (2016).
- The mean mass represents the mass of the respective sexes in the population, where female + offspring (F+O) only has the females' mass (F).
- The refined metabolisable energy (ME) requirement equation used to determine LSU and WHU for the male is: LOG ME = (0.823 × log X) − 0.358, for the female is: LOG ME = (0.824 × log X) − 0.345, and the female with offspring is: LOG ME = (0.819 × log X) − 0.228, where X is the animal mass.
- The WHU is a 180 kg blue wildebeest or greater kudu requiring 29.71 MJ ME per day.
- WHU = GU + BU.
- GU and BU equivalents = WHU × percentage grass or browse selected.
- **This number represents the number of offspring when calculating the total number of animals.

Ranch/reserve specifics and the respective grazing and browsing capacities:

Size of ranch (ha)	2000	ha
Carrying capacity (LSU)	10	ha/LSU
Grazing capacity (GU)	5	ha/GU
Browsing capacity (BU)	10	ha/BU

Number of animal units the ranch/reserve can potentially keep (vegetation study):

Number of LSU	200	LSU
Number of GU	400	GU
Number of BU	200	BU

The number of LSU, WHU, GU, and BU on the ranch/reserve:

Total LSU	234.34	LSU
Total GU	378.85	GU
Total BU	212.71	BU
Total WHU (GU+BU)	591.56	WHU

Discussion

When considering the animal units used in SD, SR, and CC estimates for a ranch/reserve, it is essential to appreciate that different fields of study use different methods when calculating these parameters. Agriculturalists using the livestock approach include mass and the relevant physiological production states of the herbivores, and thus their energy requirements, while wildlife ecologists only use the mean animal mass (Shepstone *et al.*, 2022). Furthermore, agriculturists focus on grazing livestock (Meissner, 1982; Grossman *et al*., 1999), while wildlife ecologists incorporate the available edible browse for browsing wild herbivores into their assessments (Peel *et al*., 1994, 1999; Dekker, 1997). It is important to note that the feed/forage selected and eaten by a wild herbivore ungulate is directly related to the animal's energy and other nutrient requirements (Meissner, 1982).

The main reason why it was necessary for wildlife ecologists to modify the LSU model for wild herbivores was that the LSU methodology ignored the edible portion of trees and shrubs. Most wild herbivores will select both grasses and browse as food sources (Van Rooyen & Bothma, 2016); however, some species cannot digest dry lignified plant material, making the available dry grass worthless during the dry season. These wild herbivore species will, therefore, only select grass while it is green and moist. Such species are classified as concentrate selectors (browsers), as they select the more digestible dry browse as a food source in the dry season (Hofmann, 1973; Clauss *et al.*, 2003; Cheeke & Dierenfeld, 2010). Consequently, if a vegetation study does not incorporate the edible browse portion, the interpretation should only consider wild herbivores that can eat and digest grass in the dry season.

Over the last three decades, many livestock and wildlife ranches have converted or incorporated intensive wildlife breeding systems. This practice has led to wild herbivores being intensively ranched like livestock (Oberem & Oberem, 2016). Critical management interventions are therefore necessary to ensure that these changes are effective, particularly when calculating the SD, SR, and CC from the available forage, and stocking the ranch or reserve accordingly. The strategic feeding of balanced rations and provision of internal and external parasite control may also be necessary. The incorporation of the animals' energy requirements, through the use of the refined LSU and WHU methods, would, therefore, be preferable.

The relative animal units and methods for estimating the LAU, GU, BU, and WHU equivalents are mathematically similar, with animal mass as the common denominator. In contrast, when considering the LSU method, the animal's mass and ME requirements at a particular physiological production state are used to estimate the LSU equivalent, while the methodologies applied to replace the LSU method rely only on metabolic mass, and thus make it an unequal comparison. The derived log-log transformation equations described by Shepstone *et al*. (2022) provide a more accurate method for determining the relative refined ME, LSU, GU, BU, and WHU equivalents for the different wild herbivore species at different physiological production states. For a more thorough discussion of why the refined LSU, WHU, GU, and BU methods – based on metabolic energy – should replace the LAU and GU/BU methods – based on metabolic mass – see Shepstone *et al*. (2022).

This study illustrates an applied approach to comparing the extensive and intensive wild herbivore production methods, where the refined LSU, GU, BU, and WHU values for both methods can be used to estimate suitable SD and SRs.

It should be noted that for this calculation to work, the camps used for intensive wildlife breeding must be large enough and have enough suitable forage to sustain the wild herbivores throughout the year. The only form of supplemental feed supplied to the animals should be low-intake nutrient supplements designed to compensate for the nutrient shortfalls of the green and dry forage. This enables the animal to attain an optimal physical body condition and reach its production goals. For example, a green season mineral lick contains salt, calcium, phosphorus, and trace minerals, and a dry season supplement contains protein, energy, macro minerals, trace minerals, and vitamins.

When evaluating the veld condition of a wildlife ranch/reserve that focuses on hunting and/or tourism, the extensive wild herbivore ungulate production method and/or the intensive wild herbivore ungulate production method can be used. When comparing the extensive method described in example 1 with the intensive method described in example 2 (Table 5), the population in example 1 is only considered to be adult animals, whereas the population in example 2 consists of 40% males and 60% females, of which 20% are offspring. Therefore, the examples compare a baseline population to a more specified one (Table 5 and Figure 2). The extensive wild herbivore ungulate method was selected to reach 200 LSU, with the population illustrated in example 1 (Table 5 and Figure 2). If the intensive

production method, where 20% of the population are offspring with an LSU equivalent of 178, is used, the wildlife rancher can increase the population by 22 LSU, or keep to the 200 LSU as estimated using the extensive production method.

Based on the WHU values from examples 1 and 2, the ranch's estimated grazing and browsing capacity in the vegetation study is 400 GU and 200 BU, respectively (Table 5). The populations in examples 1 and 2 indicate that the WHU population on the ranch (505 and 450 WHU, respectively) comprises 318 GU and 187 BU according to the extensive production method, and 288 GU and 162 BU according to the intensive method. These are both lower than the estimated WHU CC extrapolated from the vegetation study's 400 GU and 200 BU. Therefore, the ranch can increase its stocking density accordingly, although the size of the increase will differ (Figure 2).

Nonetheless, animal unit equivalents are, in practice, only guidelines, as most wildlife counts are done by aeroplane or helicopter and some of the animals on the reserve may hide during these counts; consequently, the actual number of animals may be more than counted. Therefore, the extensive production method is generally considered a safer option than the intensive production method. However, when the exact numbers of males, females, and offspring on the wildlife ranch/reserve are known, the intensive production method is more suitable for determining the appropriate animal numbers, based on the CC calculated from the vegetation study (examples 2–4; Table 5).

Examples 1 to 4 (Table 5) illustrate which method is suitable for estimating the CC and SD on a wildlife ranch/reserve, and demonstrate how females with suckling offspring affect the CC and SD estimates. When examples 1 to 3 are compared in terms of their LSU, the extensive production method (example 1) results in a total of 200 LSU, whereas the intensive production method used in examples 3 and 4 results in totals of 213 and 234 LSU, respectively (Table 5). The intensive production method will be more suitable in these cases because it incorporates the extra energy requirements of females with suckling offspring. However, since the LSU equivalent values exceed the CC of the ranch, these examples indicate that the ranch should destock by 13 (example 3) or 34 (example 4) LSU to prevent overstocking (Table 5).

The WHU values calculated demonstrate the same general tendency as for the calculated LSU values. The equivalent values are 344 GU and 193 BU, and 379 GU and 213 BU, in examples 3 and 4, respectively, which are generally lower than the 400 GU and 200 BU recommended based on the vegetation survey, apart from the higher BU value of 213 in example 4 (Table 5). On a wildlife ranch/reserve, the SD can be changed to reach the equivalent WHU values recommended by the vegetation survey. When interpreting the results, in terms of the LSU and WHU values, the intensive production method produces higher animal equivalent values than the extensive production method. This is because the energy requirements of females with suckling offspring are higher than those of the average animal used in the extensive production method, as lactating females require higher quality forage to satisfy their daily energy requirements to stay in a good physical body condition and produce milk.

The suckling phase and time from birth to weaning for different herbivore species must also be considered for accurate CC and SD estimates. The examples were calculated using both 20% lactating females (example 3) and 80% lactating females (example 4) so that the means could be used as the final CC and SD estimates in the evaluation. A 20% suckling offspring value, rather than a zero value, was used to ensure that younger, weaned animals were still included.

In summary, when estimating the CC or SD, it is important to decide in advance which production method will be used and whether to use the LSU or WHU values derived from the vegetation survey. The derived log-log transformation equations used for the two production methods attempt to address the management circumstances for each system, as they are more accurate for determining the ME requirements of wild herbivores in different production systems. Therefore, if the objective is to determine the SD of a wildlife ranch/reserve using the latest vegetation survey, then use the extensive production method to indicate whether the reserve/ranch is understocked, overstocked, or stocked correctly. The intensive production method will be more accurate when the vegetation survey is used as a tool to determine how many of a desired type of herbivore, such as African buffalo or sable antelope (*Hippotragus niger*), can be kept free-ranging or in a camp system for semi-intensive or intensive breeding purposes.

Table 5 Summary of the four examples in which the extensive wild herbivore ungulate production method (example 1) is compared to the intensive wild herbivore ungulate production method, where 20% of the population are offspring (example 2), 20% of the females have suckling offspring (example 3), or 80% of the females have suckling offspring (example 4)

Examples	1 Extensive wild herbivore ungulate production method	2 Intensive wild herbivore ungulate production method (20% of the population are offspring)	3 Intensive wild herbivore ungulate production method (20% of females have suckling offspring)	4 Intensive wild herbivore ungulate production method (80% of females have suckling offspring)	Type of unit
Ranch/reserve specifics and the respective grazing and browsing capacities:					
Size of ranch (ha)	2000	2000	2000	2000	Hectares
Carrying capacity (LSU)	10	10	10	10	ha/LSU
Grazing capacity (GU)	5	5	5	5	ha/GU
Browsing capacity (BU)	10	10	10	10	ha/BU
Number of animal units the ranch/reserve can potentially support, based on the vegetation study:					
Number of LSU	200	200	200	200	LSU
Number of GU	400	400	400	400	GU
Number of BU	200	200	200	200	BU
Estimated number of refined LSU, GU, and BU on the ranch/reserve:					
Total LSU	200	178	213	234	LSU
Total GU	318	288	344	379	GU
Total BU	187	162	193	213	BU
Total WHU	505	450	537	592	WHU
Animal specifics and population demographics:					
Number of adult males	-	98	98	98	
Number of adult females	-	164	230	230	
Number of young males	-	33	23	92	
Number of young females	-	33	23	92	
Total number of animals	328	328	374	512*	
% of population that are male	-	40%	32%	37%	
% of population that are female	-	60%	68%	63%	
% of population that are offspring	-	20%	12%	36%	

Offspring are included when calculating the percentage of males and females in the population, and are assumed to be 50% male and 50% female.
Wild herbivore unit (WHU) = grazer unit (GU) + browser unit (BU). *512 is precisely 80%, but the decimals in Table 4 round off to 511.

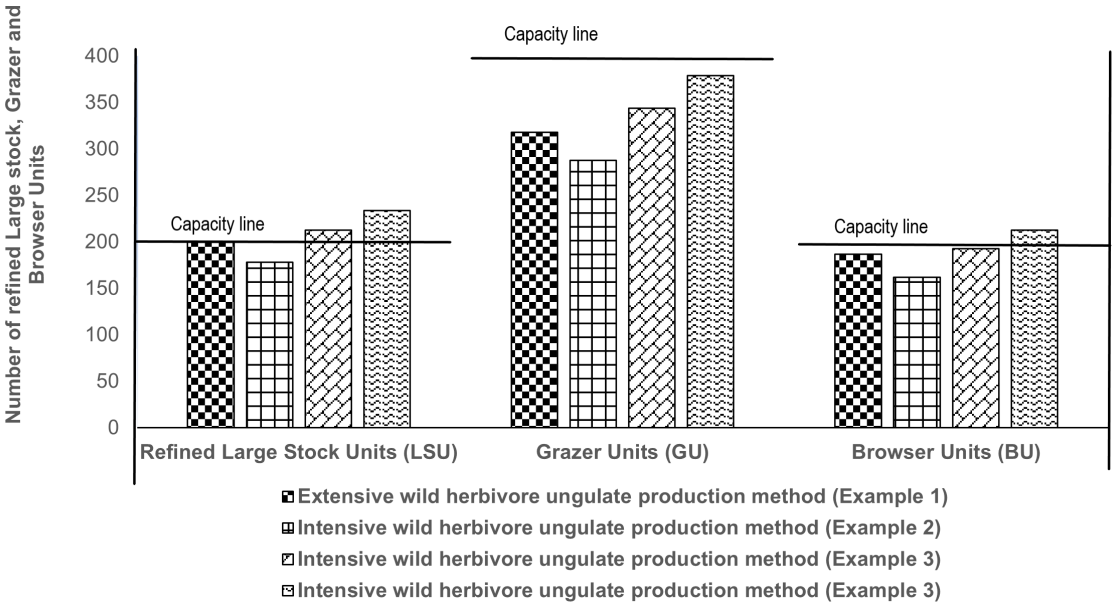

Figure 2 The refined large stock, grazer, and browser units based on the grazing and/or browsing capacity of the habitat when using the two wild herbivore production methods. The values above the capacity line indicate overstocking.

Conclusions

This study of the methods that can be used to calculate/estimate the CC and SD of herbivores on a wildlife ranch/reserve or in a breeding system has indicated that the extensive wild herbivore ungulate production method is suitable for all extensively managed animals on ranches/reserves. The intensive wild herbivore ungulate production method is ideal for estimating the CC and SD of animals on ranches that focus on breeding animals for live sale or trophy hunting. Using the incorrect method increases the chances of making costly mistakes. The refined ME, LSU, WHU, GU, and BU animal unit equivalents derived in this study will enable wildlife reserves, ranches, and breeding systems to accurately calculate/estimate CC and SD values. The appropriate long-term application of these methods will contribute to optimising animal and veld production and improving ecosystems and animal health.

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Authors' contributions

C.A.S. wrote the paper with input from N.V.R., M.W.V.R., J. du P.B., and R.B.

Conflict of interest declaration

The authors declare that there is no conflict of interest regarding the publication of this manuscript.

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Appendix 1 The refined large stock unit (LSU), wild herbivore unit (WHU), grazer unit (GU), and browser unit (BU) equivalents for different wild southern African herbivore ungulates based on the extensive wild herbivore ungulate production method. The essential factors necessary to estimate stocking densities on wildlife ranches and reserves and calculate stocking rates, where the necessary vegetation study or veld evaluation is done periodically, are mean metabolic mass, refined metabolisable energy per day, percentage of grass and browse in the diet, apparent digestibility of the forage in the dry season, and the animals' dry matter intake. Wild herbivores are listed alphabetically according to common names within each feeding type.

Wild herbivore	Mean mass (kg)	Mean animal ME (MJ/day)	LSU equivalent	WHU equivalent	% grass in diet	% browse in diet	Apparent digestibility in the dry season	GU equivalent per animal based on % grass in the diet	BU equivalent per animal based on % browse in diet	Dry matter intake % (DMI %)
Selective grazers										
Black wildebeest/Gnu (*Connochaetes gnou*)	160.0	31.83	0.42	1.07	81%	19%	51%	0.87	0.20	2.62
Blesbok (*Damaliscus pygargus phillipsi*)	65.0	15.11	0.20	0.51	90%	10%	51%	0.46	0.05	3.08
Blue wildebeest (*Connochaetes taurinus*)	180.0	35.08	0.47	1.18	87%	13%	51%	1.03	0.15	2.58
Bontebok (*Damaliscus pygargus pygargus*)	60.0	14.14	0.19	0.48	90%	10%	51%	0.43	0.05	3.13
Bushpig (*Potamochoerus larvatus*)	55.0	13.16	0.18	0.44	80%	20%	51%	0.35	0.09	3.14
Gemsbok (*Oryx gazella*)	210.0	39.85	0.53	1.34	75%	25%	51%	1.01	0.34	2.48
Mountain reedbuck (*Redunca fulvorufula*)	23.0	6.40	0.09	0.22	95%	5%	50%	0.20	0.01	3.71
Oribi (*Ourebia ourebi*)	14.0	4.24	0.06	0.14	90%	10%	51%	0.13	0.01	4.02
Ostrich (*Struthio camelus*)	69.0	15.88	0.21	0.53	80%	20%	51%	0.43	0.11	3.02
Red hartebeest (*Alcelaphus buselaphus*)	120.0	25.09	0.33	0.84	75%	25%	51%	0.63	0.21	2.73
Reedbuck (*Redunca arundinum*)	55.0	13.16	0.18	0.44	95%	5%	50%	0.42	0.02	3.19
Roan antelope (*Hippotragus equinus*)	240.0	44.51	0.59	1.50	85%	15%	51%	1.27	0.22	2.45
Sable antelope (*Hippotragus niger*)	220.0	41.42	0.55	1.39	85%	15%	51%	1.18	0.21	2.49
Tsessebe (*Damaliscus lunatus lunatus*)	126.0	26.12	0.35	0.88	95%	5%	50%	0.84	0.04	2.76
Warthog (*Phacochoerus africanus*)	30.0	7.97	0.11	0.27	70%	30%	52%	0.19	0.08	3.46
Waterbuck (*Kobus ellipsiprymnus*)	205.0	39.07	0.52	1.31	84%	16%	51%	1.10	0.21	2.51

*Animal masses are based on Orban (2014) & Bothma & Du Toit (2016).

A WHU is a 180 kg blue wildebeest or greater kudu requiring 29.71 MJ ME per day; GU and BU equivalents = WHU × % grass or browse selected.

The percentage of grass and browse in diets is based on Gagnon & Chew (2000); Grubb (2005); Skinner & Chimimba (2005); Bothma & Du Toit (2016).

Digestibility is calculated by multiplying the selected grass and browse percentage, where grass digestibility is calculated at 50% and browse at 55% (excluding fruit and twigs).

The mean mass represents the mass of the respective sexes in the population, where female + offspring (F+O) only has the females' mass (F).

The refined mean metabolisable energy requirement equation used to calculate the refined LSU and WHU is: LOG ME = (0.827 x log X) − 0.320, where X is the animal mass.

Appendix 1 (continued)

Wild herbivore	Mean mass (kg)	Mean animal ME (MJ/day)	LSU equivalent	WHU equivalent	% grass in diet	% browse in diet	Apparent digestibility in the dry season	GU equivalent per animal based on % grass in the diet	BU equivalent per animal based on % browse in diet	Dry matter intake % (DMI %)
Intermediate feeders										
Cape eland (*Taurotragus oryx*)	460.0	76.23	1.02	2.57	50%	50%	53%	1.28	1.28	2.11
Cape grysbok (*Raphicerus melanotis*)	10.0	3.21	0.04	0.11	30%	70%	54%	0.03	0.08	4.02
Elephant (*Loxodonta africana*)	3750.0	432.24	5.76	14.55	28%	72%	54%	4.07	10.47	1.44
Impala (*Aepyceros melampus melampus*)	41.0	10.32	0.14	0.35	45%	55%	53%	0.16	0.19	3.20
Sharpe's grysbok (*Raphicerus sharpei*)	8.0	2.67	0.04	0.09	30%	70%	54%	0.03	0.06	4.18
Springbok (*Antidorcas marsupialis*)	37.0	9.48	0.13	0.32	32%	68%	53%	0.10	0.22	3.22
Steenbok (*Raphicerus campestris*)	10.0	3.21	0.04	0.11	34%	66%	53%	0.04	0.07	4.04
Bulk grazers										
African buffalo (*Syncerus caffer)*	520.0	84.36	1.12	2.84	78%	22%	51%	2.21	0.62	2.13
Cape mountain zebra (*Equus zebra*)	240.0	44.51	0.59	1.50	95%	5%	50%	1.42	0.07	2.47
Plains zebra (*Equus quagga burchellii*)	260.0	47.55	0.63	1.60	93%	7%	50%	1.49	0.11	2.43
Hippopotamus (*Hippopotamus amphibius*)	1321.0	182.38	2.43	6.14	99%	1%	50%	6.08	0.06	1.85
White rhinoceros (*Ceratotherium simum*)	1727.0	227.64	3.04	7.66	100%	0%	50%	7.66	0.00	1.77

*Animal masses are based on Orban (2014) & Bothma & Du Toit (2016).

A WHU is a 180 kg blue wildebeest or greater kudu requiring 29.71 MJ ME per day; GU and BU equivalents = WHU × % grass or browse selected.

The percentage of grass and browse in diets is based on Gagnon & Chew (2000); Grubb (2005); Skinner & Chimimba (2005); Bothma & Du Toit (2016).

Digestibility is calculated by multiplying the selected grass and browse percentage, where grass digestibility is calculated at 50% and browse at 55% (excluding fruit and twigs).

The mean mass represents the mass of the respective sexes in the population, where female + offspring (F+O) only has the females' mass (F).

The refined mean metabolisable energy requirement equation used to calculate the refined LSU and WHU is: LOG ME = (0.827 x log X) - 0.320, where X is the animal mass.

Appendix 1 (continued)

Wild herbivore	Mean mass (kg)	Mean animal ME (MJ/day)	LSU equivalent	WHU equivalent	% grass in diet	% browse in diet	Apparent digestibility in the dry season	GU equivalent per animal based on % grass in the diet	BU equivalent per animal based on % browse in diet	Dry matter intake (DMI %)
Browsers										
Black rhinoceros (*Diceros bicornis*)	818.0	122.70	1.64	4.13	4%	96%	55%	0.17	3.96	1.83
Blue duiker (*Philantomba monticola*)	4.5	1.66	0.02	0.06	1%	99%	55%	0.00	0.06	4.50
Bushbuck (*Tragelaphus scriptus*)	30.0	7.97	0.11	0.27	10%	90%	55%	0.03	0.24	3.27
Damara dik-dik (*Madoqua kirkii*)	5.0	1.81	0.02	0.06	17%	83%	54%	0.01	0.05	4.48
Giraffe (*Giraffa camelopardalis*)	830.0	124.19	1.66	4.18	1%	99%	55%	0.04	4.14	1.82
Greater Kudu (*Tragelaphus strepsiceros*)	180.0	35.08	0.47	1.18	15%	85%	54%	0.18	1.00	2.41
Grey bush duiker (*Sylvicapra grimmia*)	19.0	5.46	0.07	0.18	12%	88%	54%	0.02	0.16	3.54
Grey rhebok (*Pelea capreolus*)	20.0	5.70	0.08	0.19	7%	93%	55%	0.01	0.18	3.49
Klipspringer (*Oreotragus oreotragus*)	13.0	3.99	0.05	0.13	20%	80%	54%	0.03	0.11	3.81
Nyala (*Tragelaphus angasii*)	73.0	16.63	0.22	0.56	20%	80%	54%	0.11	0.45	2.83
Red duiker (*Cephalophus natalensis*)	12.0	3.74	0.05	0.13	1%	99%	55%	0.00	0.12	3.80
Suni (*Neotragus moschatus*)	5.0	1.81	0.02	0.06	6%	94%	55%	0.00	0.06	4.44

*Animal masses are based on Orban (2014) & Bothma & Du Toit (2016).

A WHU is a 180 kg blue wildebeest or greater kudu requiring 29.71 MJ ME per day; GU and BU equivalents = WHU × % grass or browse selected.

The percentage of grass and browse in diets is based on Gagnon & Chew (2000); Grubb (2005); Skinner & Chimimba (2005); Bothma & Du Toit (2016).

Digestibility is calculated by multiplying the selected grass and browse percentage, where grass digestibility is calculated at 50% and browse at 55% (excluding fruit and twigs).

The mean mass represents the mass of the respective sexes in the population, where female + offspring (F+O) only has the females' mass (F).

The refined mean metabolisable energy requirement equation used to calculate the refined LSU and WHU is: LOG ME = (0.827 x Log X) - 0.320, where X is the animal mass.

Appendix 2 The refined large stock unit (LSU), wild herbivore unit (WHU), grazer unit (GU), and browser unit (BU) equivalents for different wild southern African herbivore ungulates based on the intensive wild herbivore ungulate production method. The essential factors necessary to estimate stocking densities on wildlife ranches and reserves and calculate stocking rates, where the necessary vegetation study or veld evaluation is done periodically, are mean metabolic mass, refined metabolisable energy per day, percentage of grass and browse in diet, apparent digestibility of the forage in the dry season, and the animals' dry matter intake. The wild herbivores are listed alphabetically according to common names within each feeding type.

Wild herbivore	Sex	Mean mass in kg*	The mean refined ME (MJ/day)	LSU equivalent	WHU equivalent	% grass in the diet	% browse in the diet	Apparent digestibility in the dry season	GU equivalent per animal based on % grass in the diet	BU equivalent per animal based on % browse in diet	Dry matter intake (DMI %)
Selective grazers											
Black wildebeest / Gnu (*Connochaetes gnou*)	M	170.0	30.04	0.40	1.01	81%	19%	51%	0.82	0.19	2.32
	F	140.0	26.51	0.35	0.89	81%	19%	51%	0.72	0.17	2.49
	F + O	140.0	33.86	0.45	1.14	81%	19%	51%	0.92	0.22	3.18
Blesbok (*Damaliscus pygargus phillipsi*)	M	75.0	15.32	0.20	0.52	90%	10%	51%	0.46	0.05	2.71
	F	65.0	14.09	0.19	0.47	90%	10%	51%	0.43	0.05	2.88
	F + O	65.0	18.06	0.24	0.61	90%	10%	51%	0.55	0.06	3.69
Blue wildebeest (*Connochaetes taurinus)*	M	235.0	39.21	0.52	1.32	87%	13%	51%	1.15	0.17	2.21
	F	185.0	33.35	0.44	1.12	87%	13%	51%	0.98	0.15	2.39
	F + O	185.0	42.54	0.57	1.43	87%	13%	51%	1.25	0.19	3.04
Bontebok (*Damaliscus pygargus pygargus)*	M	61.0	12.92	0.17	0.43	90%	10%	51%	0.39	0.04	2.81
	F	54.5	12.18	0.16	0.41	90%	10%	51%	0.37	0.04	2.97
	F + O	54.5	15.64	0.21	0.53	90%	10%	51%	0.47	0.05	3.81
Gemsbok (*Oryx gazella*)	M	225.0	37.83	0.50	1.27	75%	25%	51%	0.96	0.32	2.20
	F	197.5	35.20	0.47	1.18	75%	25%	51%	0.89	0.30	2.33
	F + O	197.5	44.88	0.60	1.51	75%	25%	51%	1.13	0.38	2.97
Mountain reedbuck (*Redunca fulvorufula*)	M	30.0	7.21	0.10	0.24	95%	5%	50%	0.23	0.01	3.20
	F	26.0	6.62	0.09	0.22	95%	5%	50%	0.21	0.01	3.40
	F + O	26.0	8.53	0.11	0.29	95%	5%	50%	0.27	0.01	4.37

*Animal masses are based on Orban (2014) & Bothma & Du Toit (2016).
A WHU is a 180 kg blue wildebeest or greater kudu requiring 29.71 MJ ME per day; GU and BU equivalents = WHU × % grass or browse selected.
The percentage of grass and browse in diets is based on Gagnon & Chew (2000), Grubb (2005), Skinner & Chimimba (2005), and Bothma & Du Toit (2016).
Digestibility is calculated by multiplying the selected grass and browse percentage, where grass digestibility is estimated at 50% and browse at 55% (excluding fruit and twigs).
The mean mass represents the mass of the respective sexes in the population, where female + offspring (F+O) only has the females' mass (F).
The refined metabolisable energy (ME) requirement equation used to determine the refined LSU and WHU for the male is: LOG ME = (0.823 x log X) − 0.358, for the female is: LOG ME = (0.824 x log X) − 0.345, and for the female with offspring is: LOG ME = (0.819 x log X) − 0.228, where X is the animal mass.

Appendix 2 (continued)

Wild herbivore	Sex	Mean mass in kg*	The mean refined ME (MJ/day)	LSU equivalent	WHU equivalent	% grass in the diet	% browse in the diet	Apparent digestibility in the dry season	GU equivalent per animal based on % grass in the diet	BU equivalent per animal based on % browse in diet	Dry matter intake (DMI %)
Selective grazers (continued)											
Oribi (*Ourebia ourebi*)	M	13.5	3.73	0.05	0.13	90%	10%	51%	0.11	0.01	3.67
	F	12.0	3.50	0.05	0.12	90%	10%	51%	0.11	0.01	3.87
	F + O	12.0	4.53	0.06	0.15	90%	10%	51%	0.14	0.02	5.01
Red hartebeest (*Alcelaphus buselaphus*)	M	150.0	27.10	0.36	0.91	75%	25%	51%	0.68	0.23	2.36
	F	120.0	23.35	0.31	0.79	75%	25%	51%	0.59	0.20	2.54
	F + O	120.0	29.84	0.40	1.00	75%	25%	51%	0.75	0.25	3.25
Reedbuck (*Redunca arundinum*)	M	70.0	14.47	0.19	0.49	95%	5%	50%	0.46	0.02	2.76
	F	50.0	11.35	0.15	0.38	95%	5%	50%	0.36	0.02	3.03
	F + O	50.0	14.57	0.19	0.49	95%	5%	50%	0.47	0.02	3.89
Roan antelope (*Hippotragus equinus*)	M	262.5	42.95	0.57	1.45	85%	15%	51%	1.23	0.22	2.16
	F	235.0	40.62	0.54	1.37	85%	15%	51%	1.16	0.21	2.28
	F + O	235.0	51.75	0.69	1.74	85%	15%	51%	1.48	0.26	2.91
Sable antelope (*Hippotragus niger*)	M	225.0	37.83	0.50	1.27	85%	15%	51%	1.08	0.19	2.22
	F	200.0	35.57	0.47	1.20	85%	15%	51%	1.02	0.18	2.35
	F + O	200.0	45.35	0.60	1.53	85%	15%	51%	1.30	0.23	2.99
Tsessebe (*Damaliscus lunatus lunatus*)	M	142.0	25.90	0.35	0.87	95%	5%	50%	0.83	0.04	2.43
	F	122.5	23.75	0.32	0.80	95%	5%	50%	0.76	0.04	2.59
	F + O	122.5	30.35	0.40	1.02	95%	5%	50%	0.97	0.05	3.30
Waterbuck (*Kobus ellipsiprymnus*)	M	245.0	40.58	0.54	1.37	84%	16%	51%	1.15	0.22	2.18
	F	175.0	31.86	0.42	1.07	84%	16%	51%	0.90	0.17	2.40
	F + O	175.0	40.65	0.54	1.37	84%	16%	51%	1.15	0.22	3.06

*Animal masses are based on Orban (2014) & Bothma & Du Toit (2016).
A WHU is a 180 kg blue wildebeest or greater kudu requiring 29.71 MJ ME per day; GU and BU equivalents = WHU × % grass or browse selected.
The percentage of grass and browse in diets is based on Gagnon & Chew (2000), Grubb (2005), Skinner & Chimimba (2005), and Bothma & Du Toit (2016).
Digestibility is calculated by multiplying the selected grass and browse percentage, where grass digestibility is estimated at 50% and browse at 55% (excluding fruit and twigs).
The mean mass represents the mass of the respective sexes in the population, where female + offspring (F+O) only has the females' mass (F).
The refined metabolisable energy (ME) requirement equation used to determine the refined LSU and WHU for the male is: LOG ME = (0.823 x log X) − 0.358, for the female is: LOG ME = (0.824 x log X) − 0.345, and for the female with offspring is: LOG ME = (0.819 x log X) − 0.228, where X is the animal mass.

Appendix 2 (continued)

Wild herbivore	Sex	Mean mass in kg*	The mean refined ME (MJ/day)	LSU equivalent	WHU equivalent	% grass in the diet	% browse in the diet	Apparent digestibility in the dry season	GU equivalent per animal based on % grass in the diet	BU equivalent per animal based on % browse in diet	Dry matter intake (DMI %)
Intermediate feeders											
Cape grysbok (*Raphicerus melanotis)*	M	10.5	3.04	0.04	0.10	30%	70%	54%	0.03	0.07	3.62
	F	10.5	3.14	0.04	0.11	30%	70%	54%	0.03	0.07	3.74
	F + O	10.5	4.06	0.05	0.14	30%	70%	54%	0.04	0.10	4.84
Cape eland (*Taurotragus oryx*)	M	632.5	88.57	1.18	2.98	50%	50%	53%	1.49	1.49	1.79
	F	460.0	70.65	0.94	2.38	50%	50%	53%	1.19	1.19	1.96
	F + O	460.0	89.70	1.20	3.02	50%	50%	53%	1.51	1.51	2.49
Elephant (*Loxodonta africana*)	M	5500.0	525.19	7.00	17.68	28%	72%	54%	4.95	12.73	1.19
	F	1850.0	222.41	2.97	7.49	28%	72%	54%	2.10	5.39	1.50
	F + O	1850.0	280.42	3.74	9.44	28%	72%	54%	2.64	6.80	1.89
Impala (*Aepyceros melampus melampus*)	M	63.0	13.27	0.18	0.45	45%	55%	53%	0.20	0.25	2.68
	F	43.5	10.12	0.13	0.34	45%	55%	53%	0.15	0.19	2.95
	F + O	43.5	13.00	0.17	0.44	45%	55%	53%	0.20	0.24	3.80
Sharpe's grysbok (*Raphicerus sharpei*)	M	8.5	2.55	0.03	0.09	30%	70%	54%	0.03	0.06	3.76
	F	7.5	2.38	0.03	0.08	30%	70%	54%	0.02	0.06	3.97
	F + O	7.5	3.08	0.04	0.10	30%	70%	54%	0.03	0.07	5.14
Springbok (*Antidorcas marsupialis*)	M	41.0	9.32	0.12	0.31	32%	68%	53%	0.10	0.21	2.85
	F	37.0	8.86	0.12	0.30	32%	68%	53%	0.10	0.20	3.00
	F + O	37.0	11.39	0.15	0.38	32%	68%	53%	0.12	0.26	3.86
Steenbok (*Raphicerus campestris*)	M	10.0	2.92	0.04	0.10	34%	66%	53%	0.03	0.06	3.67
	F	11.5	3.38	0.05	0.11	34%	66%	53%	0.04	0.08	3.70
	F + O	11.5	4.37	0.06	0.15	34%	66%	53%	0.05	0.10	4.78

*Animal masses are based on Orban (2014) & Bothma & Du Toit (2016).
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The percentage of grass and browse in diets is based on Gagnon & Chew (2000), Grubb (2005), Skinner & Chimimba (2005), and Bothma & Du Toit (2016).
Digestibility is calculated by multiplying the selected grass and browse percentage, where grass digestibility is estimated at 50% and browse at 55% (excluding fruit and twigs).
The mean mass represents the mass of the respective sexes in the population, where female + offspring (F+O) only has the females' mass (F).
The refined metabolisable energy (ME) requirement equation used to determine the refined LSU and WHU for the male is: LOG ME = (0.823 x log X) − 0.358, for the female is: LOG ME = (0.824 x log X) − 0.345, and for the female with offspring is: LOG ME = (0.819 x log X) − 0.228, where X is the animal mass.

Appendix 2 (continued)

Wild herbivore	Sex	Mean mass in kg*	The mean refined ME (MJ/day)	LSU equivalent	WHU equivalent	% grass in the diet	% browse in the diet	Apparent digestibility in the dry season	GU equivalent per animal based on % grass in the diet	BU equivalent per animal based on % browse in diet	Dry matter intake (DMI %)
Bulk grazers											
African buffalo (*Syncerus caffer*)	M	750.0	101.90	1.36	3.43	78%	22%	51%	2.68	0.75	1.78
	F	578.0	85.28	1.14	2.87	78%	22%	51%	2.24	0.63	1.93
	F + O	578.0	108.15	1.44	3.64	78%	22%	51%	2.84	0.80	2.45
Cape mountain zebra (*Equus zebra*)	M	255.0	41.94	0.56	1.41	95%	5%	50%	1.34	0.07	2.19
	F	230.5	39.98	0.53	1.35	95%	5%	50%	1.28	0.07	2.31
	F + O	230.5	50.94	0.68	1.71	95%	5%	50%	1.63	0.09	2.95
Plains zebra (*Equus quagga burchellii*)	M	315.0	49.90	0.67	1.68	93%	7%	50%	1.56	0.12	2.11
	F	315.0	51.71	0.69	1.74	93%	7%	50%	1.62	0.12	2.18
	F + O	315.0	65.78	0.88	2.21	93%	7%	50%	2.06	0.15	2.78
Hippopotamus (*Hippopotamus amphibius*)	M	2034.5	231.67	3.09	7.80	99%	1%	50%	7.72	0.08	1.52
	F	1726.0	210.05	2.80	7.07	99%	1%	50%	7.00	0.07	1.63
	F + O	1726.0	264.93	3.53	8.92	99%	1%	50%	8.83	0.09	2.05
White rhinoceros (*Ceratotherium simum*)	M	2400.0	265.41	3.54	8.93	100%	0%	50%	8.93	0.00	1.48
	F	1650.0	202.40	2.70	6.81	100%	0%	50%	6.81	0.00	1.64
	F + O	1650.0	255.34	3.40	8.59	100%	0%	50%	8.59	0.00	2.07
Browsers											
Black rhinoceros (*Diceros bicornis*)	M	860.0	114.05	1.52	3.84	4%	96%	55%	0.15	3.69	1.62
	F	925.0	125.63	1.68	4.23	4%	96%	55%	0.17	4.06	1.66
	F + O	925.0	158.95	2.12	5.35	4%	96%	55%	0.21	5.14	2.10

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The percentage of grass and browse in diets is based on Gagnon & Chew (2000), Grubb (2005), Skinner & Chimimba (2005), and Bothma & Du Toit (2016).
Digestibility is calculated by multiplying the selected grass and browse percentage, where grass digestibility is estimated at 50% and browse at 55% (excluding fruit and twigs).
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Appendix 2 (continued)

Wild herbivore	Sex	Mean mass in kg*	The mean refined ME (MJ/day)	LSU equivalent	WHU equivalent	% grass in the diet	% browse in the diet	Apparent digestibility in the dry season	GU equivalent per animal based on % grass in the diet	BU equivalent per animal based on % browse in diet	Dry matter intake (DMI %)
Browsers (continued)											
Blue duiker (*Philantomba monticola*)	M	4.0	1.37	0.02	0.05	1%	99%	55%	0.00	0.05	4.18
	F	5.0	1.70	0.02	0.06	1%	99%	55%	0.00	0.06	4.15
	F + O	5.0	2.21	0.03	0.07	1%	99%	55%	0.00	0.07	5.39
Bushbuck (*Tragelaphus scriptus*)	M	50.0	10.97	0.15	0.37	10%	90%	55%	0.04	0.33	2.70
	F	36.0	8.66	0.12	0.29	10%	90%	55%	0.03	0.26	2.96
	F + O	36.0	11.13	0.15	0.37	10%	90%	55%	0.04	0.34	3.80
Damara dik-dik (*Madoqua kirkii*)	M	4.25	1.44	0.02	0.05	17%	83%	54%	0.01	0.04	4.20
	F	4.25	1.49	0.02	0.05	17%	83%	54%	0.01	0.04	4.33
	F + O	4.25	1.93	0.03	0.07	17%	83%	54%	0.01	0.05	5.63
Giraffe (*Giraffa camelopardalis*)	M	1185.0	148.48	1.98	5.00	1%	99%	55%	0.05	4.95	1.53
	F	835.0	115.47	1.54	3.89	1%	99%	55%	0.04	3.85	1.69
	F + O	835.0	146.17	1.95	4.92	1%	99%	55%	0.05	4.87	2.13
Greater kudu (*Tragelaphus strepsiceros*)	M	244.5	40.51	0.54	1.36	15%	85%	54%	0.20	1.16	2.05
	F	160.0	29.59	0.39	1.00	15%	85%	54%	0.15	0.85	2.28
	F + O	160.0	37.77	0.50	1.27	15%	85%	54%	0.19	1.08	2.92
Grey bush duiker (*Sylvicapra grimmia*)	M	17.0	4.52	0.06	0.15	12%	88%	54%	0.02	0.13	3.27
	F	21.0	5.55	0.07	0.19	12%	88%	54%	0.02	0.16	3.26
	F + O	21.0	7.16	0.10	0.24	12%	88%	54%	0.03	0.21	4.20
Grey rhebok (*Pelea capreolus*)	M	20.0	5.16	0.07	0.17	7%	93%	55%	0.01	0.16	3.16
	F	20.0	5.33	0.07	0.18	7%	93%	55%	0.01	0.17	3.27
	F + O	20.0	6.88	0.09	0.23	7%	93%	55%	0.02	0.22	4.22

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Appendix 2 (continued)

Wild herbivore	Sex	Mean mass in kg*	The mean refined ME (MJ/day)	LSU equivalent	WHU equivalent	% grass in the diet	% browse in the diet	Apparent digestibility in the dry season	GU equivalent per animal based on % grass in the diet	BU equivalent per animal based on % browse in diet	Dry matter intake (DMI %)
Browsers (continued)											
Klipspringer (*Oreotragus oreotragus*)	M	10.5	3.04	0.04	0.10	20%	80%	54%	0.02	0.08	3.59
	F	15.0	4.21	0.06	0.14	20%	80%	54%	0.03	0.11	3.48
	F + O	15.0	5.44	0.07	0.18	20%	80%	54%	0.04	0.15	4.50
Nyala (*Tragelaphus angasii*)	M	110.0	20.99	0.28	0.71	20%	80%	54%	0.14	0.57	2.37
	F	61.5	13.46	0.18	0.45	20%	80%	54%	0.09	0.36	2.72
	F + O	61.5	17.26	0.23	0.58	20%	80%	54%	0.12	0.46	3.48
Red duiker (*Cephalophus natalensis*)	M	11.5	3.27	0.04	0.11	1%	99%	55%	0.00	0.11	3.47
	F	11.5	3.38	0.05	0.11	1%	99%	55%	0.00	0.11	3.58
	F + O	11.5	4.37	0.06	0.15	1%	99%	55%	0.00	0.15	4.64
Suni (*Neotragus moschatus*)	M	5.5	1.78	0.02	0.06	6%	94%	55%	0.00	0.06	3.97
	F	5.5	1.84	0.02	0.06	6%	94%	55%	0.00	0.06	4.10
	F + O	5.5	2.39	0.03	0.08	6%	94%	55%	0.00	0.08	5.32

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