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The Blue Water Footprint of Extensive Beef Production on Semi-Arid Rangeland over a Full Production Cycle in South Africa

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Abstract

Water plays a critical role in beef cattle production. Current methods used to estimate the blue water footprint of beef cattle are largely based on generic values that do not make provision for different production systems within different regions. Total production cycle measurements should therefore be considered to accurately assess the blue water footprint of beef cattle grazing natural rangeland. The aim of the study was to measure water intake of extensive Bonsmara cattle grazing Marikana Thornveld over a full production cycle at the ARC-Roodeplaat Research Station. Measurements commenced at weaning (June 2017) and continued until the heifers weaned their first calves at approximately 210 days of age (July 2019). Water consumption differed between 21.4 litre per animal per day when the heifers were still growing to 54.3 litres during lactation, relating to between 6.7% and 12.0% of live weight. The blue water footprint over the total production cycle was calculated to be 27,147 litres.

Keywords

Beef Cattle, Marikana Thronveld, Natural Rangeland, Water Intake

1. Introduction

Rangelands comprise 30% - 40% of earth's ice-free terrestrial land surface [1], accounting for 91% of the world's grazing lands [2], which support about 200 million households and 50% of the world's livestock population [3]. The predominant use of rangelands is extensive livestock production by both pastoralists and ranchers [2]. These rangelands are sustained only by rainfall and in some cases, potable drinking water is limited. In addition to rangeland quality and availability, available water resources must also be taken into account to ensure sustainable livestock production.

The media frequently report alarming figures of water use and greenhouse gas emissions by livestock, without discussion of the methods and context of the calculation [4]. Estimates of the amount of water needed to produce 1 kg of beef range from 3700 to 20,000 litres [5]. This variation in estimates reflects differences in the assumptions in water use prediction models, such as the inclusion of natural rain fall, water loss during irrigation, etc.

The water footprint of an extensive beef production system consists of three colour-coded components, viz. the blue, green and grey water components [6]. Blue water relates to the fresh water consumed by the animals, whereas the green water component relates to the water use efficiency (WUE) of the natural rangeland. The WUE is defined as the quantity of dry matter produced by the plants per unit of water consumed [7] [8]. Alternatively, WUE can be defined as the rate of carbon uptake per unit of water lost and it integrates a suite of biotic and abiotic factors, and, importantly, quantifies how much water an ecosystem uses relative to carbon gained [9]. The grey water component relates to the volume of freshwater that is required to assimilate the load of pollutants which is of less importance in an extensive beef production system where only natural rangeland is consumed without supplementation.

Currently, there is an on-going debate regarding the use of blue water and green water in the water footprint of extensive beef cattle [10], and whether both must be accounted for in order to assess the environmental impacts of this production system. Some authors state that environmental impacts are predominantly associated with blue water, and argue that green water could be excluded from the equation [10]. It can be argued that green water consumption does not contribute to regional freshwater scarcity [11] and that freshwater problems are mostly associated with blue water shortages and less associated with competition over green water resources [12].

In an extensive beef production system, where cattle graze natural rangeland, the rain would sustain the vegetation whether the cattle were grazing the land or not. It can be argued that unless the cattle destroy or harm the rangeland, or if the rangeland has the potential to be converted into high producing crop production, the inclusion of the green water footprint does not make sense [11]. If extensive beef cattle are produced under sensible management strategies, the grazing cattle may even be of a net benefit to the water cycle and assist climate stability. Unfortunately, current methods to estimate the water footprint of beef production are largely based on generic values that do not make provision for different production systems.

There are considerable natural variations in the water intake of beef cattle grazing natural rangeland, with limited research supporting current water use estimates. The numerous prediction equations available, had mostly been developed in controlled environments. Some of these equations took temperature and/or humidity and/or season into account by using young growing Angus and Angus type cattle [13], Holstein bulls [14], Nelore bulls [15] and steers [16] [17] [18].

Extrapolating these data to grazing and lactating beef cows under extensive conditions may be problematic [19], emphasizing the need for current local data relating to water intake of extensive beef cattle in South Africa. This led to current study, which assess the voluntary water intake of extensively managed beef cattle in semi-arid rangeland over a full production cycle.

2. Materials and Methods

The study was conducted at the Roodeplaat experimental farm of the ARC-Animal Production (25˚34'11.27"S; 28˚22'05.36"E) in South Africa, comprising of approximately 900 ha of rangeland. The vegetation in the study area is part of the Central Bushveld Bioregion, specifically, the Marikana Thornveld (SVbc 6) veld type [20]. The Roodeplaat experimental farm is situated in a summer rainfall area, which receives an annual precipitation between of 600 and 700 mm, with an average of 654 mm, falling mostly in summer (October-March). The mean monthly maximum and minimum temperatures is 32.8˚C and −1.0˚C for January and July, respectively. The soils are mainly vertic melanic clays with dystrophic or mesotrophic plinthic catenas and some freely well-drained, deep soils. Elevation at the farm ranges from 1050 to 1450 m above sea level [20]. The vegetation at the farm is a typical semi-arid savanna, comprising a variety of herbaceous and woody plant species. The dominant plant communities at the experimental farm include: *Vachellia tortilis* subsp. *heterocantha* – *Brachiaria nigropedata* low open woodland; *Vachellia tortilis* subsp. *heterocantha* – *Digitaria argyrograpta* short thicket and *Vachellia tortilis* subsp. *heterocantha* – *Bothriochloa bladhii* low open woodland [21]. Generally, the rangeland condition score at the Roodeplaat farm ranges between 55% (moderate) and 65% (good) during winter and summer, respectively. The meteorological classification of seasonality according to temperature were used with the conventional break of 3 months for each season e.g. December/January/February (summer), March/April/May (autumn), June/July/August (winter), September/October/November (spring) [22] [23]. This is the most widely used classification in South Africa [24] [25] and widely used in agroclimatological studies [26].

The 26 Bonsmara weaner heifers allocated to the project were divided into two uniform groups of 13 heifers each according to date of birth and weaning weight. These two groups of heifers were allocated to specific camps. These camps had the same vegetation composition, biomass availability and carrying capacity to ensure uniform grazing conditions. All camps were free of any natural water resources. Each camp contained one 500 liter water trough equipped with a ball float valve. Volumetric rotary piston water meters were installed at each water trough. Daily group water intake was measured. Measurements started in June 2017 with Bonsmara heifer weanlings and continued until the heifers weaned their first calves (July 2019), in order to evaluate a total production cycle. Animals were subjected to standard management procedures e.g. lick supplementation (mineral lick in summer and protein lick in winter), weighing, dipping (commercially available pour-on acaricide), and vaccination (Anthrax, Botulism, Black-quarter, Lumpy skin and Rift valley fever); that are performed on a regular basis on farms making use of natural grazing in South Africa. Animals were mated over a 3 month mating season (January 2018-March 2018). Calves were weaned at approximately 210 days of age (July 2019). Animal weight is expressed as the standardized South African large stock unit (LSU), commonly defined as the equivalent of an ox with a weight of 450 kg, gaining weight at the rate of 500 g per day relating to an energy requirement of approximately 75 MJ metabolizable energy per day grazing natural rangeland [27] [28]. This equated to a dry matter intake of approximately 9 kg per LSU with an average vegetation digestibility of 55%.

All procedures and the handling of the animals were in accordance with SANS 10386 guidelines (South African Bureau of Standards, 2008) for the care and use of animals for scientific purposes, and no invasive procedures were performed.

The total blue water footprint from a full production cycle of extensive beef cattle (weaned heifers producing and weaning their first calves) was calculated at the end of the production cycle (June 2017-July 2019).

3. Results and Discussion

Water intake results from the current study of Bonsmara heifers differed between 6.69% and 12.0% of live weight (**Figure 1**). These results are in line with data reported by Glen Selk, Oklahoma State University (2011) where daily water requirements for non-lactating beef cattle on pasture varied between 6% and 12% of body weight. However, they found water consumption of lactating cows to be approximately 18% of body weight [29], whereas water consumption of lactating cows in the current project varied between 7.6% - 12.1% of body weight. In the current project, the lactation period coincided with the rainy season and it was observed that animals did consume water from pooled rain water in the rangeland after heavy rains partly explaining the lower than expected average water intake during lactation.

Figure 2 indicates the average animal body weight and the amount of water consumed by the animals on a monthly basis over the 25-month project period. Average water consumption differed between 21.4 liter per animal per day when the heifers were still growing to 54.3 liter per animal per day when animals were lactating.

The lowest water intake of 21.4 liters per heifer per day for non-pregnant growing heifers weighing 272 kg was in late winter (June 2017). This was in line with the water intake recommendations of 22.0 liters per 273 kg growing heifer per day at 10˚C published by the National Research council (NRC) [30] as indicated in **Table 1**.

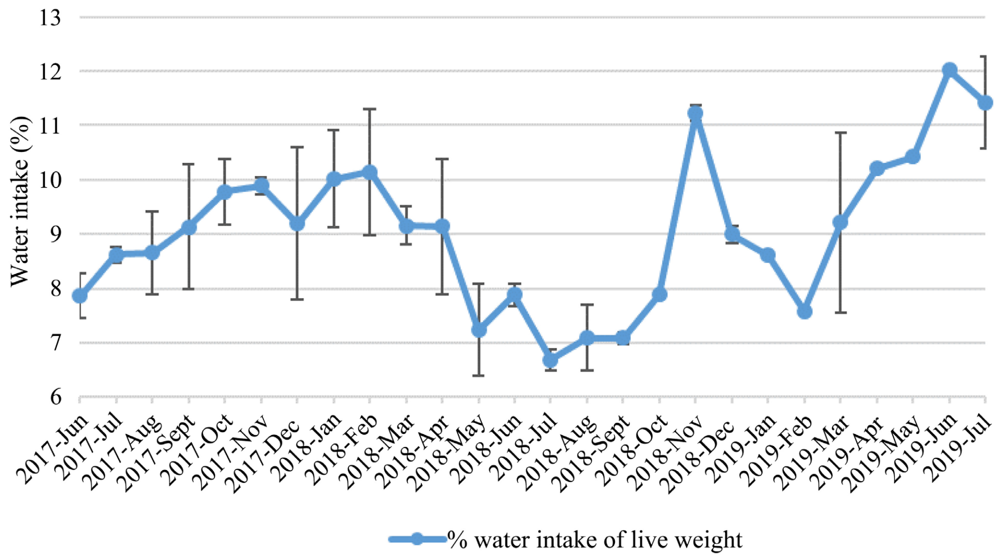

Figure 1. Water intake of Bonsmara heifers over a full production cycle as a percentage of live weight.

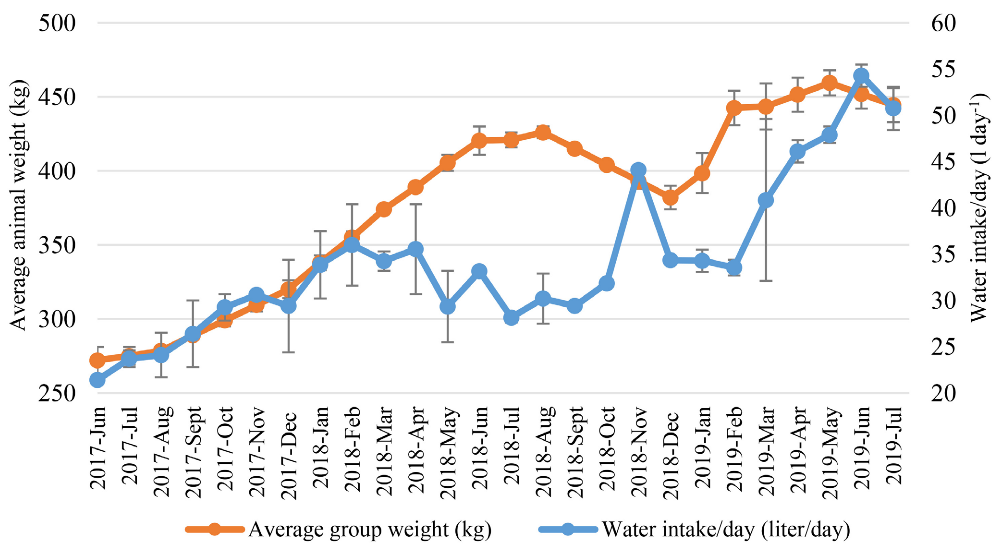

Figure 2. Water intake in relation to body weight for Bonsmara heifers over a full production cycle.

Table 1. Approximate total daily water intake of beef cattle [30].

Heifer weight	Temperature (˚C)					
	4.4˚C	10˚C	14.4˚C	21.1˚C	26.6˚C	32.2˚C
	Daily water intake (l)					
182	15.1	16.3	18.9	22.0	25.4	36.0
273	20.1	22.0	25.0	29.5	33.7	48.1
364	23.0	25.7	29.9	34.8	40.1	56.8
409 (pregnant)	25.4	27.3	31.4	36.7	-	-
409 (lactating)*	43.1	47.7	54.9	64.0	67.8	61.3

*Cows larger than 409 kg (900) lbs are included in this recommendation.

The highest water intake for growing non-pregnant heifers was 36.0 liters for heifers weighing 355 kg in summer. This water intake was very close to the recommended 34.8 liters per animal weighing 364 kg at 21.1˚C. The average weight for pregnant heifers in autumn was 406 kg with an average water intake of 29.35 liters. This water intake was also in line with the NRC expected intake of between 31.4 liters (14.4˚C) for pregnant cows weighing approximately 409 kg [30]. The NRC expected water intake recommendations for lactating animals over 409 kg differ between 43.1 liter (4.4˚C) and 61.3 liter (32.2˚C). In the current project, an average daily water intake of 45.6 liter was found for lactating heifers with an average weight of 449 kg, which is much lower when compared to the NRC recommendations of 64.0 liters per day at 21˚C [30]. In contrast, a higher water intake would have been expected from lactating heifers as average ambient temperatures were much higher in this study, especially during the summer months. Although water intake results were not analysed by taking weather data into account for the current study, from the results there is an indication that temperature had an influence on the water intake.

Table 2 gives a comparison of average monthly water intake and expected water intake on the basis of dry matter consumed. According to Meissner [31], water intake are related to dry matter intake related to four liter water per kg dry matter consumed with an average dry matter intake of nine kg per LSU. Thus it is expected for one LSU to consume 45 liters per day [31] although the author indicated that water intake could increase by 50% during hot weather, relating to 67 liters per LSU.

When results from the current project were compared with Meissner's [31] expected water intake, it was clear that the average water intake over the whole production cycle (34.9 l) compared well with expected water intake of 35.2 liter related to 45 liters per LSU per day (**Table 2**). However, when results are compared over different physiological stages (**Figure 3**), water intake was higher than

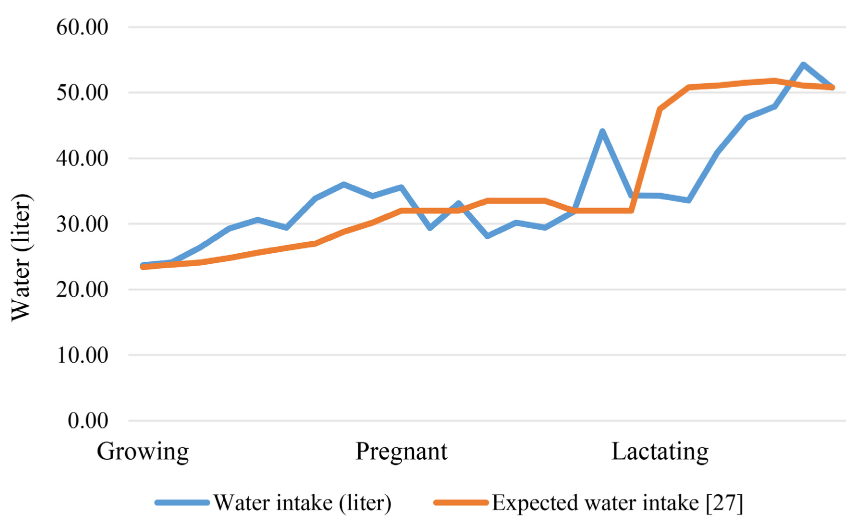

Figure 3. Water intake and expected water intake [31] in relation to physiological status for Bonsmara heifers over a full production cycle.

Table 2. Water intake and dry matter intake per large stock unit over different months.

	$^{\Delta}$LSU	*Dry matter intake	Water intake (l)	**Expected water intake (l)
Jul-17	0.65	5.9	23.70	23.4
Aug-17	0.66	5.9	24.10	23.8
Sep-17	0.67	6.0	26.40	24.1
Oct-17	0.69	6.2	29.25	24.8
Nov-17	0.71	6.4	30.60	25.6
Dec-17	0.73	6.6	29.40	26.3
Jan-18	0.75	6.8	33.85	27.0
Feb-18	0.80	7.2	36.00	28.8
Mar-18	0.84	7.6	34.25	30.2
Apr-18	0.89	8.0	35.55	32.0
May-18	0.89	8.0	29.35	32.0
Jun-18	0.89	8.0	33.15	32.0
Jul-18	0.93	8.4	28.15	33.5
Aug-18	0.93	8.4	30.20	33.5
Sep-18	0.93	8.4	29.40	33.5
Oct-18	0.89	8.0	31.85	32.0
Nov-18	0.89	8.0	44.10	32.0
Dec-18	0.89	8.0	34.35	32.0
Jan-19	1.32	11.9	34.30	47.5
Feb-19	1.41	12.7	33.55	50.8
Mar-19	1.42	12.8	40.85	51.1
Apr-19	1.43	12.9	46.10	51.5
May-19	1.44	13.0	47.90	51.8
Jun-19	1.42	12.8	54.30	51.1
Jul-19	1.41	12.7	50.75	50.8
Av. 25 mnths	0.98	8.8	34.9	35.2

$^{\Delta}$Large stock unit (LSU) [27] *Dry matter intake was estimated at 9 kg/LSU [27]; **Calculated at 4 liter/1kg dry matter intake [31].

expected when the animals were still growing and lower than expected during lactation.

It must be taken into consideration that dry matter intake for this project was estimated from live weight and not physically measured. In addition, the animals were grazing natural rangeland with a high moisture content during spring and summer with moisture content decreasing in late summer and throughout winter. Although moisture content was not measured in the project, grass moisture content can differ between 85% in summer to 5.5% in winter [32]. Furthermore, the rainy season coincided with the warmest time of the year and the observation was made during the project that animals drank water pooled in the veld after heavy rains and this may partly explain why intake from the water troughs did not show much increase in the hot summer months.

4. Conclusions

Water consumption differed between 21.4 liter per animal per day when the heifers were still growing to 54.3 liter per animal per day when animals were lactating relating to between 6.7% and 12.0% of live weight. Average daily water intake from growing and pregnant heifers compared well with data from the NRC, although average daily water intake from the lactating heifers was less than water intake recommendations [30]. The current study's average water intake compared well with data assuming water intake at 45 liters per LSU.

The blue water footprint for an extensively managed medium framed heifer from weaning until her first calf is weaned (25 month period) was calculated at 27,147 liter.

Africa is highly dependent on livestock production from natural rangeland. With good management practices, a balance can be found between the cattle grazing the land and the natural resource base.

A follow-up study is currently in progress where the water use efficiency of the vegetation will be taken into account to calculate the water footprint of the whole system. Extensive livestock production systems rely completely on rainfall to function optimally. The availability of water in the soil to plants dictates the productivity of the veld and thus the quantity and quality of livestock that can be maintained on the natural veld. However, the water use efficiency of rangelands and the management thereof are often excluded from these extensive management practices due to the complicated interactions of rainfall (quantity and variability), soil moisture, soil microbial composition, plant species composition, plant soil cover, water use by plants and losses from plants, as well as the livestock requirements. This follow-up study will shed light on the interaction between the cattle and the plants being grazed to obtain a water footprint of the whole system.

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Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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