Review Article

Geographical distribution of the selenium status of herbivores in South Africa

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Abstract

Available information on the selenium (Se) status of grazing herbivores in South Africa is reviewed and collated in the form of a geographical distribution map. Marginal to acute Se deficiencies have been reported to occur in the Midlands region and in mountainous areas of the KwaZulu-Natal province and in the southern coastal region of the Western Cape province. These areas receive a high annual rainfall and the soils are predominantly acid. The Se status of livestock in the highland sourveld areas of the Gauteng, northern Free State and Mpumalanga provinces is varied. Selenium intake appears to be adequate in most areas although localised cases of deficiencies occur. Substantial air and water pollution occurs in some of these areas, and the presence of Se antagonists could increase the incidence of Se deficiency in future. Limited data indicates that vegetation in the arid regions of South Africa provides Se sufficient to meet the requirements of grazing herbivores. Subterranean water from a number of locations contains Se at concentrations higher than the norm for safe drinking water, the impact of which has not yet been established. There are large areas of South Africa for which little or no information on the Se status of grazing animals exist, and further investigations are required.

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Introduction

The decision to provide selenium (Se) as a supplement to natural pastures for grazing livestock should be based on the anticipated response to supplementation at that specific locality. This requires knowledge of the Se status of the animal or, at least, knowledge that conditions in the region are conducive to Se deficiency. A survey of veterinarians practising in the beef industry in South Africa and Namibia revealed that Se was cited, along with phosphorus, as the most frequently prescribed mineral supplement for beef cattle (Mapham & MacGillivray, 2000). In the majority of these cases, the decision to supplement would probably not have been based on verification of the Se status of the cattle. The quantity of Se consumed by animals can vary widely within and between regions. Maps showing the geographical distribution of the Se status of animals and/or vegetation have been compiled for many countries (Oldfield, 1999). Although a substantial amount of information is available on the Se status of herbivores in South Africa, this information has not been collated in the form of a regional distribution map.

Overt clinical symptoms of white muscle disease are usually only displayed by small proportion of Se-deficient animals. Symptoms of mineral disorders are usually non-specific, and conditions are therefore classified as sub-clinically or marginally deficient (Paynter, 1996). Many factors can affect the Se status of animals. These include seasonal variations in the Se concentration of vegetation consumed and differences between Se requirements for different physiological states, breeds and species (Harthoorn & Turkstra, 1976; Van Niekerk *et al.*, 1990a, b, c).

Different approaches for assessing the Se status of animals have been followed in different regions of the world (Oldfield, 1999). Although a clinical or production response to supplementation is the most reliable indication of a mineral deficiency (Underwood & Suttle, 1999), controlled supplementation-response trials are expensive and time consuming. Reid & Horvath (1980) state that the most important factors determining the Se content of soils are the Se content of the parent rock and the intensity of weathering and leaching. Analysis of the Se content of soil that is available to plants has been used to compile maps showing Se deficient areas (Oldfield, 1999). However, most authorities consider soil analyses and classifications to be of limited value for predicting the mineral status of animals (Suttle, 1988; Paynter, 1996; McDowell, 1997: Judson & McFarlane, 1998). According to Judson & McFarlane (1998), conditions conducive to low absorption rates by plants, and thus low pasture Se concentrations, are low soil pH, waterlogging, rainfall above 500 mm per annum and clover-domination of pastures. The Se concentration in vegetation has been used to identify areas where grazing animals are at risk of Se deficiency (Judson & McFarlane, 1998; Oldfield, 1999). This approach ignores the effects of dietary antagonists of Se (Judson & McFarlane, 1998) and selective feed intake by animals. Recommendations differ between countries, but dietary concentrations of 0.05-0.1 mg Se/kg dry matter (DM) are generally considered to be the minimum required for farm animals.

In the case of estimates derived from biochemical analyses of body tissues and fluids, an assumption is made that the trace element concentration or enzyme activity in the sample reflects the status of the element at the functional site most sensitive to depletion (Van Ryssen, 1997). An advantage of tissue analysis is that factors influencing bioavailability are accounted for. Concentrations of Se in whole blood, plasma, serum and liver, and blood glutathione peroxidase activity show a reasonably high positive correlation with the Se intake of the animal. However, the criteria used to define adequacy and deficiency vary substantially between countries (Cloete *et al*., 1999; Van Ryssen *et al*., 1999a). These criteria are affected by many factors including the intake of vitamin E, other antioxidants and especially the level of oxidative stress in the body (Suttle, 1986; Van Ryssen *et al*., 1999a).

The objective of this review is to collate current information on the Se status of grazing livestock and game in South Africa in order to compile a regional distribution map. This will assist nutritional advisors to identify regions where a response to Se supplementation would be likely to occur and regions for which little or no information is available. Criteria of adequacy for domestic livestock were used in the case of game species, as no comparable information is available for these species.

Criteria used for classification of Se status

A Se concentration of < 0.1 mg/kg DM in plant material was classified as marginally deficient and a concentration of < 0.05 mg/kg DM was classified as deficient. Concentrations of > 0.05 mg Se/l in drinking water are considered potentially hazardous for animals (Casey *et al*., 1998). Suttle (1986) stated that it is unlikely that simple threshold values for Se status can be used universally. As biochemical criteria for assessing the Se status of livestock under South African conditions are lacking (Cloete *et al*., 1999; Van Ryssen *et al*., 1999a), the Se concentrations recommended by Puls (1994) for plasma and blood in cattle and sheep were used (Table 1). Although some of the data was derived from animals grazing green pastures where vitamin E intake would presumably have been adequate, it is important to note that no information was available on vitamin E intake. Published threshold values for estimation of Se status from liver concentrations vary by more than ten-fold (Grace & Clark, 1991; Puls, 1994; McDowell, 1997; Underwood & Suttle, 1999). Since liver is often the only tissue available for analysis, e.g. from culled game, it was decided to use the values suggested by Caple & McDonald (1983) for sheep.

Table 1 Threshold values used for classification of Se status

	Liver*		Plasma / Serum**		Whole blood**	
	mg/kg DM	ng/g DM	mg/l	ng/ml	mg/l	ng/ml
Deficient	< 0.20	< 200	< 0.03	< 30	< 0.05	< 50
Marginal	0.20-0.5	200-500	0.03-0.06	30-60	0.05-0.08	50-80
Adequate	0.5-3.0	500-3000	0.06-0.40	60-400	0.08-1.2	80-1200
High	> 6.0	> 6000	> 2.5	> 2500	> 3.0	> 3000

* Caple & McDonald (1983) ;** Puls (1994)

The criteria used for plasma and blood (Table 1), compare favourably with McDowell’s (1997) critical level of 0.03 mg/l for serum, but are substantially higher than criteria used in New Zealand (Grace & Clark, 1991) and those quoted by Underwood & Suttle (1999). In lactating dairy cows much higher Se concentrations in blood than those presented in Table 1 are considered the norm (Jukola *et al*., 1996). It has become standard practice in most parts of South Africa to include Se in dairy cow diets. Therefore, data from dairy cows were not used, except where the measurements were taken before Se supplementation became common practice, e.g. O’Hagan (1994). The distribution map presented in Figure 1 was compiled according to the criteria given in Table 1, although no distinction was made between areas where a deficiency or an apparent marginal deficiency was reported.

Results and discussion

Only a few reports mention clinical symptoms of Se deficiency (white muscle disease) among young animals in South Africa. Most of these cases occurred under non-grazing conditions. Tustin (1959), Bryson & Zumpt (1979) and Hasell (1994) reported incidences of white muscle disease in lambs, in all cases apparently related to low dietary Se intakes due to a high lucerne content in the diet of their dams. A number of young antelope at the National Zoological Gardens of Pretoria showed symptoms of white muscle disease (Ebedes, 1987). This was attributed to low Se concentrations in the staple diet (lucerne) of their dams. White muscle disease was also diagnosed in young roan antelopes kept in confinement near Thabazimbi in the North West Province (A.H. Alberts, 1998, unpublished results). Their dams were fed locally-produced lucerne. It is well documented that plant species differ in their ability to absorb Se from the soil (Van Ryssen *et al*., 1999b), and legumes often possess a lower Se absorption ability than grasses (Judson & McFarlane, 1998). Lucerne hay from the Vaalhartz irrigation scheme in the Northern Cape Province contained 0.033±0.003 mg Se/kg DM (J.B.J. van Ryssen, unpublished results). Many cases of distinct Se deficiency in South Africa seem to be associated with conditions where a large proportion of the diet consists of lucerne.

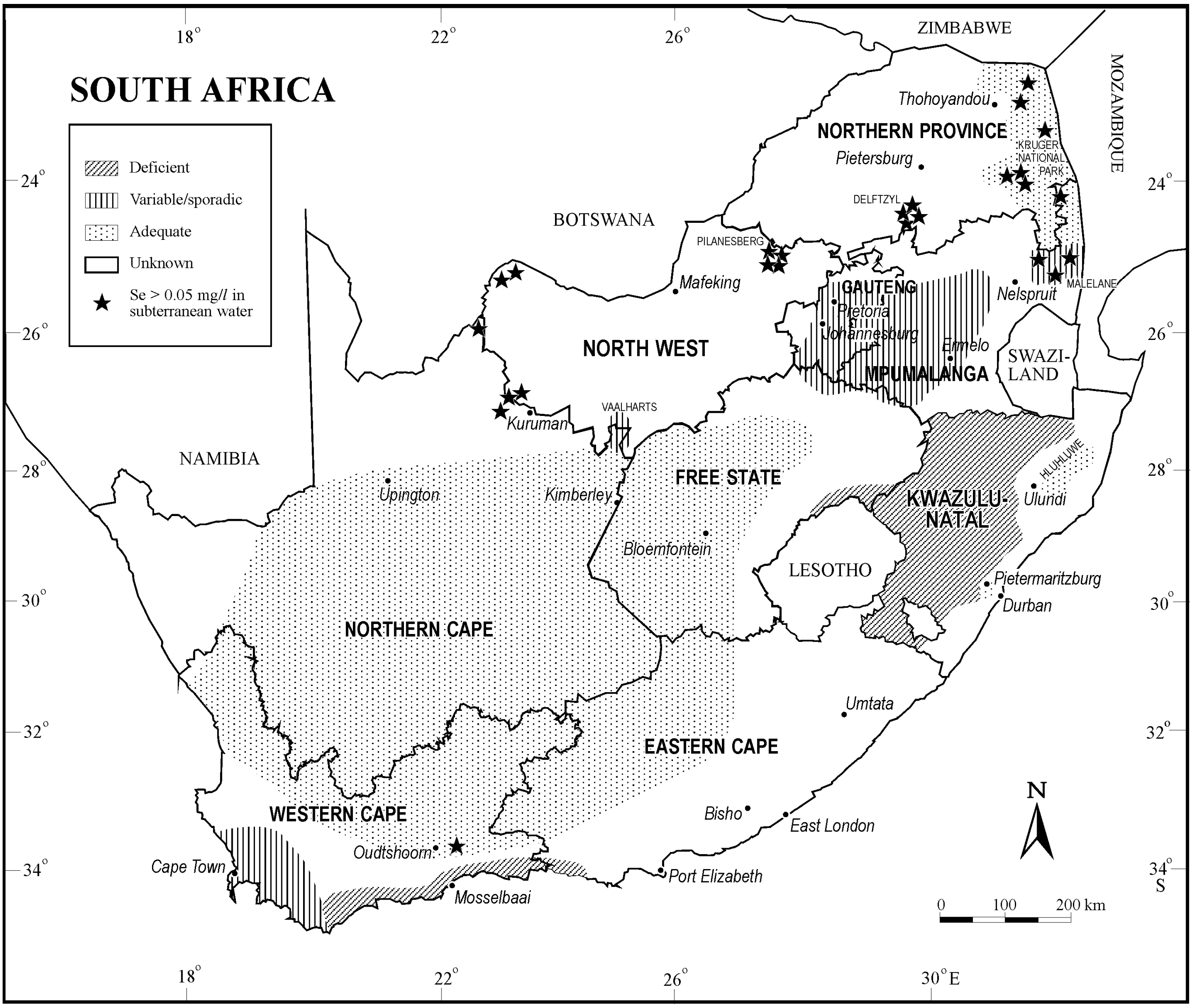

Figure 1 Geographical distribution of the selenium status of herbivores in South Africa

In the Midlands of the KwaZulu-Natal Province, Se supplementation resulted in a reduced incidence of mastitis and improved fertility in dairy cows (Q.K. Turner, 1991, personal communication; MacFarlane, 1992; O'Hagan, 1994), and in improved reproduction and growth in sheep (Bradfield, 1991; Van Ryssen & Bradfield, 1992; Van Ryssen *et al*., 1992; Van Ryssen *et al*., 1999b). The average Se concentration in whole blood of dairy cows from six farms in the Midlands was 0.034 mg/l and varied between 0.016 and 0.075 mg/l (O'Hagan, 1994). Blood Se concentrations as low as 0.09 mg/l were measured in lambs grazing kikuyu pastures at the Cedara Agricultural Research Station in this region (Van Ryssen *et al*., 1999b). A variety of soil types occur in the Midlands of KwaZulu-Natal, all of which have a low pH (Miles *et al*., 1995). Higgins & Fey (1993) measured Se concentrations in samples of ryegrass and veld grass (*Themeda triandra*) collected from different regions in KwaZulu-Natal. Samples collected in the highland sourveld regions contained very low Se concentrations, generally < 0.05 mg Se/kg DM. Of the veld grass samples only one, from the Hluhluwe Game Reserve in north-eastern KwaZulu-Natal bushveld, contained a very high concentration of Se *viz*. 1.01 mg Se/kg DM (Higgins & Fey, 1993). This confirms an earlier report by Harthoorn & Turkstra (1976) who found that liver Se concentrations of game in the Umfolozi Game Reserve close to Hluhluwe suggested an adequate Se intake. In northern KwaZulu-Natal high sulphur (S) concentrations in ground water and on vegetation have apparently manifested as copper and Se deficiencies in livestock (W.D. O'Donovan, 1998, personal communication). It would seem that the S originated mainly from coal mining activities in the region. The Se status of experimental sheep on the research farm of the University of Natal, situated at the drier south-eastern border of Pietermaritzburg, was found to be adequate, although blood collected from experimental cattle and sheep which originated from northern KwaZulu-Natal near Ladysmith/Besters and Dundee indicated a Se deficiency (J.B.J. van Ryssen, unpublished results). All the above information indicates that grazing herbivores in the sourveld regions of KwaZulu-Natal probably suffer from mild to serious Se deficiency. Areas for which there is no data are the sandy soil areas of the northern coastal region towards St Lucia and the Makatini flats.

The southern coastal region of the Western Cape Province has fine sandy loam topsoils that are acid and low in trace minerals. Research conducted on the Outeniqua Agricultural Development Centre near George, south of the Outeniqua mountain range, confirmed that a marginal Se deficiency exists in sheep, but responses to Se supplementation could not be linked directly to Se deficiency (Kritzinger, 1985; Cloete *et al*., 1994, 1999; Van Niekerk *et al*., 1995). Growth responses were obtained in lambs supplemented with Se in the Bredasdorp/Napier area (Anonymous, unpublished results), and Se deficiency is believed to exist in the Tsitsikamma area (A. MacGillivray, 2000, personal communication). Casey *et al*. (1998) measured high concentrations of Se in borehole water used by ostriches north of the Outeniqua mountain range in the Klein Karoo near Oudsthoorn, but the Se status of animals in this region has not yet been determined. Whole blood Se concentrations of sheep and Angora goats in the Riviersonderend district (Van Niekerk *et al.,* 1990a) and of different sheep breeds kept on cultivated pastures at Stellenbosch (Van Niekerk *et al.,* 1990c) suggest that Se intakes are sufficient, although Kritzinger (1985) reported a marginal deficiency in sheep during spring at Elsenburg near Stellenbosch. The blood Se concentrations of sheep, goats and cattle at the Nortier experimental farm, situated in the "strandveld" of the arid western coastal region of the Western Cape were within the adequate range (Van Niekerk *et al.,* 1990b). No information could be obtained for the northeastern region of the Eastern Cape Province, e.g. the Transkei and Ciskei. The high rainfall and acid soils in these areas suggest that a Se deficiency in livestock would be quite possible.

Liver Se concentrations of springbok harvested from different locations in the semi-desert Northern Cape Province were as follows (mg/kg DM): Mier: 4.53, Carnavon: 3.66, Somerset-East (Eastern Cape): 1.38, Gariep: 8.49 (J.H. Hoon, 1999, unpublished data). These concentrations are indicative of high Se intakes, especially in the Gariep area. Whole blood Se concentrations of Dorper sheep at a farm situated between Pofadder and Kenhardt varied between 0.24 and 0.58 mg/l, indicating an adequate to high Se intake (W.A. van Niekerk, 2000, unpublished data). In the 1960's Brown and co-workers conducted a comprehensive and extensive survey of Se concentrations of plants in the central Karoo, and recorded high to toxic Se concentrations in many plant species (Brown & De Wet, 1967; Brown, 1968). Unfortunately the analytical technique used by Brown was apparently inaccurate and overestimated Se concentrations (Bath, 1979). According to Bath (1979) subsequent studies revealed non-toxic Se concentrations in these plant species. Casey *et al*. (1998) measured high Se concentrations in borehole water collected in the vicinity of Kuruman in the Northern Cape and in the North West Provinces. In general, available information suggests that the Se status of herbivores in the Karoo and other regions of the Northern Cape Province is within the normal to high range. However, more comprehensive studies are needed to confirm this.

The Se status of grazing livestock in the highland sourveld of Mpumalanga, Gauteng and the eastern Free State seems to vary from marginally deficient to adequate. Analysing sheep livers collected at abattoirs in the Mpumalanga highveld, Hasell (1994) measured a Se concentration that would be classified as deficient for only one farm near Bethal/Hendrina. Year-old sheep bought by our laboratory from farms in the Bethal and Ermelo districts contained whole blood concentrations of > 0.2 mg Se/l, but the blood of newly-weaned lambs contained between 0.057 and 0.086 mg Se/l. It could not be established whether the older sheep had received Se supplementation. Whole blood samples from cattle (n = 30) from a farm near Vereeniging in Gauteng (an area subject to substantial air and water pollution) contained 0.049 ± 0.012 mg Se/l, indicating a marginal deficiency. The blood Se concentrations of sheep at the experimental farm at Pretoria University vary between adequate and marginally deficient, and hay and fodder trees leaves often contain concentrations of < 0.1 mg Se/kg DM. Ehret *et al.* (1989) found that cattle grazing cultivated pastures irrigated with purified water from sewage and wastewater at the Johannesburg municipality farm were Se deficient, although Se supplementation did not improve the fertility of cows. A median Se concentration of 0.065 mg/l blood in sheep at farms near Bethlehem/Fouriesburg in the eastern Free State was measured by Erasmus & Faanhof (1983). Values varied from 0.01 to 0.253 mg/l. Large areas of the Mpumalanga highveld and the Gauteng Province are polluted by sulphur emissions from industries and power plants, and it has been suggested that this could decrease the bioavailability of Se in soil and fodder (Hasell, 1994; Van Niekerk, 1996). The Se status of animals in these highveld regions tends to vary, with fairly localised occurrences of deficiencies.

Erasmus & Faanhof (1983) measured a median concentration of 0.165 mg Se/l in whole blood of sheep (Erasmus, 1983) in the drier central regions of the Free State Province near Kroonstad, and Erasmus (1984) recorded a value of 0.360 mg/l at Bultfontein in the arid southern Free State. No information on the Se status of animals in the North West Province could be found, although Smith (A. Smit, 1999, personal communication) stated that a deficiency is suspected on sandy soils in the western part of the province.

The liver Se concentrations of 666 African buffaloes culled in the Kruger National Park were 1.18±0.039 mg/kg DM in the northern region, 0.63±0.037 mg/kg DM in the central region and 0.41±0.034 mg/kg DM in the southern region (Erasmus *et al*., 2000). Based on criteria of adequacy for domestic animals, it was concluded that the Se intake of buffaloes is adequate in most parts of the Park, except for a possible marginal deficiency in the southern region. The Se concentrations in subterranean water from a number of watering points throughout the Park were > 0.05 mg/l (Casey *et al*., 1998), even in areas where buffalo were apparently marginally deficient. On game farms west of the Park, in the vicinity of Phalaborwa, the Se concentrations in the livers of impalas indicated that Se intake was sufficient. However, the average Se concentration in the whole blood of sable antelope was 0.062 mg/l, suggesting a possible marginal deficiency. The lowest liver Se concentration recorded by Harthoorn & Turkstra (1976) among pregnant and lactating impala at the Sabi Sand Nature Reserve west of the Kruger National Park was 0.5 mg/kg (presumably on a wet basis). At the Delftzyl experimental farm on the Springbok flats in the Northern Province and in the Pilanesberg National Park, Casey *et al*. (1998) measured Se concentrations of > 0.05 mg/l in the subterranean water from some boreholes. Preliminary results from a survey in progress in the Venda region of the Northern Province north of the Soutpansberg indicate that the Se intake of cattle is adequate (A.E. Nesamvuni & J.B.J. van Ryssen, 2000, unpublished results). However, cattle at one dipping tank showed a marginal deficiency with blood Se concentrations of between 0.06 and 0.09 mg/l. Climatic conditions in the provinces in the northern part of South Africa vary widely, from arid to high rainfall regions. It is likely that the Se status of animals will vary appreciably, especially since the water supply often contains high concentrations of Se.

Conclusions

Clear responses to Se supplementation have been documented for the eastern high-rainfall regions of South Africa, although no information could be obtained for the previously independent territories in the eastern part of the country *viz.* Ciskei, Transkei, northeastern KwaZulu-Natal, parts of Venda and other homelands bordering the Kruger National Park. However, animals in these regions often suffer from malnutrition due to overgrazing, which may complicate the interpretation of results. In general, vegetation in the arid regions of the country seems to supply sufficient Se for grazing animals. Locations for which the Se status varies between sufficient and deficient are the highveld regions of Mpumalanga, the northern Free State and parts of Gauteng Province. Many of these areas are subject to air pollution and acid rain, which may precipitate Se-related problems in future. The survey conducted by Mapham & MacGillivray (2000) indicates that Se is supplemented fairly extensively to grazing livestock, most probably with very little or no prior knowledge of the Se status of the animals. This is not only wasteful, but will complicate future surveys aimed at establishing the Se status of grazing animals in these regions. An alternative would be to investigate the Se status of free-ranging game in such areas, as suggested by Ullrey (1987).

Although the Se status of some of the areas shown in Figure 1 is based on extrapolation, it will hopefully prompt further investigations in those areas for which little or no information is available and encourage laboratories and nutritional advisors to publish available information. It is also important to establish the impact of high Se concentrations in drinking water on Se status, since high concentrations of antagonists to Se metabolism are often present in drinking water (Casey *et al*., 1998). An important problem limiting the reliability of information on the Se status of animals in South Africa is the lack of clearly defined criteria of adequacy for predicting Se status from biochemical parameters.

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