MINERAL STATUS OF GRAZING CATTLE IN SOUTH SULAWESI, INDONESIA: 1. MACROMINERALS[1,2]

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Summary

A study was conducted to determine the macromineral status of grazing cattle in three climatic regions of the province of South Sulawesi, Indonesia. Soil, forage, blood and rib bone samples were collected within the Western, Central and Eastern regions, respectively, in February-March and August-September of 1987. Calcium and magnesium were not deficient in soil samples. For forages, calcium and phosphorus were deficient for all regions and forage sodium was deficient except for the western region in the dry season. Crude protein was deficient during the dry season. The overall percentage of deficient plasma phosphorus samples was 17 or 23% for the wet and dry seasons, respectively. Based on these analyses, macrominerals most likely deficient in both seasons were phosphorus and calcium in all regions, in addition to sodium in the Central and Eastern regions.
(**Key Words:** Mineral Status, Indonesia, Deficiency, Cattle)

Introduction

For grazing ruminants, forages are the major sources of essential nutrients. Only rarely, however, can tropical forages completely satisfy all nutrient requirements, especially minerals (McDowell, 1985). In tropical countries, nutritional mineral imbalances are frequently a major limitation to ruminant livestock production. Most naturally occurring mineral deficiencies are associated with specific regions and are directly related to climatic and soil characteristics (McDowell et al., 1980). Although more attention is being paid to mineral nutrition of Indonesian livestock, in South Sulawesi only a few studies on mineral status and supplementation have been conducted. Even fewer have been reported in the available literature. One study from indonesia did show increased gains and reduced soil consumption for lambs receiving minerals (Prabowo et al., 1989).

The purpose of this study was to evaluate the macromineral status of grazing cattle in three climatic regions of South Sulawesi, Indonesia. A companion paper (Prabowo et al., 1990) will evaluate the microelement status for these cattle in this region.

Materials and Methods

Soil, forage, blood and rib bone samples were collected from 10 different districts within three climatic regions in South Sulaweis, Indonesia during the rainy any dry seasons. For each season, collections were made at three, three and four districts within the Western, Central and Eastern regions, respectively. Sampling periods were February-March and August-September of 1987, corresponding to the end of rainy and dry seasons in each region. In all three regions, the majority of soils were red-yellow podsolic, primarily ultisols and oxisols (Muljadi, 1977; cited by Adiningsih et al., 1988), and the predominant forage species were *Cynodon dactylon, Paspalum conjugatum, Axonopus compressus, Drymaria cordata* and *Panicum* sp.

Samples of 30 soils, 60 forages and 100 blood and rib bone samples from slaughtered animals were obtained for each of the sampling periods.

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The animals sampled were male Bali cattle, that were three to four years old and weighed in the range of 250 to 300 kg; they were slaughtered at slaughterhouses in the various districts. Animals which had been sampled were traced back to the original owners in each district where samples of soil and forage were collected from the grazed pastures.

Soils were sampled according to the technique described by Bahia (1978), with samples analyzed according to the procedures used by the IFAS extension soil testing laboratory at the university of Florida, Gainesville (Rhue and Kidder, 1983). Soil samples were analyzed for organic matter, pH, soluble salts, aluminum, calcium, potassium, magnesium, sodium and phosphorus. Minerals were extracted from soils using the Mehlich I extracting solution method (.05 N HCl + .025 N H_2SO_4). Forage samples were processed according to methods described by Fick et al. (1979) and were analyzed for calcium, potassium, magnesium and sodium. Blood plasma samples were analyzed for calcium and phosphorus, whereas serum was analyzed for magnesium. Bones were prepared according to the procedure of Fick et al. (1979) to obtain fat-free bone ash for calcium, magnesium and phosphorus analyses.

Calcium, potassium, magnesium and sodium were determined by atomic absorption spectrophotometry (Perkin-Elmer Corp., 1982). Phosphorus was analyzed using the colorimetric method of Harris and Popat (1954). Additionally, bone specific gravity was measured using a Mettler ME-40290 kit (Mettler Instruments AG, CH-8606 Greifensee, Switzerland), expressed in g/cm^3; forage crude protein concentrations were determined by measuring total nitrogen following the method described by Gallaher et al. (1975) and the Technicon Industrial Systems (1978).

Data obtained in this study were analyzed statistically using a mixed model (Snedecor and Cochran, 1980) with the General Linear Models (GLM) procedures of the SAS System (SAS Institute Inc., 1987).

Results and Discussion

Soil Analyses

Results of soil analyses as related to season and region are presented in table 1 and the percentages of soil samples deficient in macrominerals, compared to the critical values recommended for Florida soils (Breland, 1976; Rhue and Kidder, 1983) are shown in table 2. Seasonal differences were found for soil organic matter ($p < .01$), soluble salts ($p < .01$), calcium ($p < .01$), potassium ($p < .05$) and sodium ($p < .01$) concentrations. The concentrations in the rainy season were higher for soluble salts, calcium, potassium and sodium, but lower for organic matter compared to those in the dry season. The concentrations of organic matter and soluble salts also were affected ($p < .01$) by the season and region interactions.

Regional differences ($p < .01$) were found for soil organic matter concentrations. The central region had higher ($p < .01$) soil organic matter concentrations than the other two regions. Soil pH was similar ($p < .10$) for all regions during both the rainy and dry seasons. Aluminum ion is reported to be the dominant cation associated with soil acidity below pH 5.5 (Sanchez, 1976). Although soil extractable aluminum was found to be relatively high, soil pH was above 5.5 for each of the regions in both seasons. Therefore, it appeared that this high concentration of aluminum did not have much effect on the reduction of available soil phosphorus and the consequent uptake by plants as indicated by Sanchez (1976).

Regional differences ($p < .01$) were found for soil phosphorus concentrations. Furthermore, among the macroelements analyzed, phosphorus was deficient (< 17 ppm) most often, with 100, 44 and 42% of samples deficient during the rainy season for the Western, Central and Eastern regions, respectively. Similar percentages of deficient samples were found for each region during the dry season. Lower ($p < .01$) soil phosphorus concentrations were found in the Western region than in the Eastern region. Tropical soils generally are reported to be deficient in phosphorus (Volkweiss, 1978).

Regional differences ($p < .05$) also were found for soil potassium and sodium. However, the average concentration for potassium in each of the regions during both seasons was above the critical value for deficiency (62 mg/kg) recommended by Rhue and Kidder (1983) for Florida soils. Similar information was reported by Popenoe (1960) for the humid tropical climate in Central and South American countries where clearing and burning of plant material would deposit large

TABLE 1. SOIL ORGANIC MATTER, pH, SOLUBLE SALTS AND MACROMINERAL ANALYSES (DRY BASIS) AS RELATED TO SEASON AND REGION

Variable	Season	Western Mean[a]	Western S.E.[b]	Central Mean	Central S.E.	Eastern Mean	Eastern S.E.	Significance[c]
OM[d], %	Rainy	4.3	.14	5.7	.14	4.2	.12	S**, R^{+}, SR**, C_1^{+}
	Dry	6.3	.14	7.4	.14	4.7	.12	
pH	Rainy	5.6	.28	5.8	.28	6.0	.24	
	Dry	6.3	.28	5.8	.28	6.0	.24	
SS[e], mg/kg	Rainy	427	16	678	16	628	13	S**, SR**
	Dry	357	16	472	16	429	13	
Al, mg/kg	Rainy	1211	27	1197	27	1172	23	
	Dry	1191	27	1241	27	1153	23	
Ca, mg/kg	Rainy	983	21	952	21	1058	18	S**, D(R)**
	Dry	586	21	556	21	656	18	
K, mg/kg	Rainy	306	10	133	10	189	9	S*, R*, D(R)**,
	Dry	291	10	109	10	154	9	C_1, C_2*
Mg, mg/kg	Rainy	235	46	338	46	348	40	D(R)**, SD(R)**,
	Dry	240	46	319	46	410	40	C_2*
Na, mg/kg	Rainy	40.4	4.8	25.7	4.8	45.1	4.1	S**, R*, D(R)*,
	Dry	23.3	4.8	18.2	4.8	28.1	4.1	SD(R)*, C_1*
P, mg/kg	Rainy	9.8	.36	18.8	.36	19.8	.31	R**, C_1^{+}, C_2**
	Dry	9.8	.36	18.2	.36	19.3	.31	

[a]Least squares means of 3 samples/district with 3, 3 and 4 districts within Western, Central and Eastern regions, respectively, for each of the seasons.
[b]Standard error of least squares means.
[c]S = season, R = region, SR = season × region interaction, D(R) = district within region, SD(R) = season × district within region interaction, C_1 = Central vs Western and Eastern, C_2 = Western vs Eastern.
[d]Organic matter.
[e]Soluble salts.
** $p < .01$. * $p < .05$. $^{+}p < .10$.

amounts of exchangeable potassium in the topsoil.

Among other soil macroelements, no deficiencies were detected for the different regions and seasons, although variations due to district ($p < .05$) were observed for calcium, potassium, magnesium and sodium concentrations. Season by district interaction effects ($p < .05$) were found for potassium and sodium concentrations.

Forage Analyses

Forage macromineral and crude protein concentrations for the rainy and dry seasons in the three regions are shown in table 3. The percentages of deficient forage samples, based on the suggested critical values for minerals (McDowell, 1985) and crude protein (Milford and Minson, 1966) are presented in table 4.

Forage calcium concentrations did not differ ($p < .10$) for all regions during both the rainy and dry seasons. Although calcium concentrations were affected by district and interactions of season and district, the average concentration for each of the regions in both seasons was above the value regarded as critical for deficiency (.3%) suggested by McDowell (1985).

Regional differences ($p < .05$) were detected for forage potassium. Forage potassium concen-

TABLE 2. PERCENTAGE OF SOIL SAMPLES DEFICIENT IN MACROMINERALS[a]

Variable	Critical level[b]	Season	Region			Overall
			Western	Central	Eastern	
Ca, mg/kg	< 71	Rainy	0.0	0.0	0.0	0.0
		Dry	0.0	0.0	0.0	0.0
K, mg/kg	< 62	Rainy	0.0	0.0	16.7	6.7
		Dry	0.0	11.1	8.3	6.7
Mg, mg/kg	< 30	Rainy	0.0	0.0	0.0	0.0
		Dry	0.0	0.0	0.0	0.0
P, mg/kg	< 17	Rainy	100.0	44.4	41.7	60.0
		Dry	100.0	44.4	50.0	63.3

[a]Percentages based on 3 samples/district with 3, 3 and 4 districts within Western, Central and Eastern regions, respectively, for each of the seasons.

[b]Concentration below which is deficient, based on recommendations for Florida soils (Breland, 1976; Rhue and Kidder, 1983).

TABLE 3. FORAGE MACROMINERAL AND CRUDE PROTEIN CONCENTRATIONS (DRY BASIS) AS RELATED TO SEASON AND REGION

Variable	Season	Region						Significance[c]
		Western		Central		Eastern		
		Mean[a]	S.E.[b]	Mean	S.E.	Mean	S.E.	
Ca, %	Rainy	.44	.08	.39	.08	.35	.07	D(R)**, SD(R)**
	Dry	.36	.08	.35	.08	.48	.07	
K, %	Rainy	2.40	.21	1.53	.21	1.78	.18	R*, D(R)**, SD(R)**
	Dry	2.12	.21	1.24	.21	1.49	.18	C_1^+, C_2^+
Mg, %	Rainy	.21	.02	.23	.02	.32	.01	SR*, D(R)**, C_2^+
	Dry	.21	.02	.27	.02	.26	.01	
Na, %	Rainy	.13	.02	.07	.02	.08	.02	R^+, D(R)*, SD(R)**
	Dry	.09	.02	.04	.02	.07	.02	C_1*, C_2^+
P, %	Rainy	.18	.03	.27	.03	.26	.02	R^+, D(R)**, SD(R)$^+$
	Dry	.17	.03	.28	.03	.25	.02	C_2^+
CP[d], %	Rainy	8.7	.49	9.2	.49	9.1	.43	S**, D(R)*
	Dry	7.6	.49	7.7	.49	7.7	.43	

[a]Least squares means of 6 samples/district (3 samples/district for CP) with 3, 3 and 4 districts within Western, Central and Eastern regions, respectively, for each of the seasons.

[b]Standard error of least squares means.

[c]S = season, R = region, SR = season × region interaction, D(R) = district within region, SD(R) = season × district within region interaction, C_1 = Central vs Western and Eastern, C_2 = Western vs Eastern.

[d]Crude protein.

** $p < .01$. * $p < .05$. $^+p < .10$.

trations were lower ($p < .10$) in the Central than the other two regions, whereas those for the Eastern region were lower ($p < .10$) than to the Western region. Since potassium in plants is associated with young growing tissue, it is not surprising that potassium is not a problem when plants are still in the active stage of growth (Gomide, 1978). Individual evaluation of samples

TABLE 4. PERCENTAGE OF FORAGE SAMPLES DEFICIENT IN MACROMINERALS AND CRUDE PROTEIN[a]

Variable	Critical level[b]	Season	Region			Overall
			Western	Central	Eastern	
Ca, %	< .3	Rainy	27.8	33.3	16.7	25.0
		Dry	38.9	33.3	25.0	31.7
K, %	< .8	Rainy	0.0	5.6	16.7	8.3
		Dry	0.0	0.0	12.5	5.0
Mg, %	< .2	Rainy	44.4	33.3	16.7	30.0
		Dry	33.3	0.0	25.0	20.0
Na, %	< .06	Rainy	33.3	50.0	41.7	41.7
		Dry	0.0	77.8	45.8	41.7
P, %	< .25	Rainy	88.9	55.6	54.2	65.0
		Dry	88.9	33.3	45.8	55.0
Crude protein, %	< 7	Rainy	11.1	0.0	16.7	10.0
		Dry	33.3	22.2	33.3	30.0

[a]Percentages based on 6 samples/district (3 samples/district for crude protein) with 3, 3 and 4 districts within Western, Central and Eastern regions, respectively, for each of the seasons.

[b]Concentration below which is deficient (Milford and Minson, 1966; McDowell, 1985), based on requirements of beef cattle (NRC, 1984).

based on the critical potassium level of .8% (McDowell, 1985) indicated that only small percentages of them were deficient. The region with highest percentage of samples below the critical concentration in both seasons was the Eastern region.

Season by region interactions ($p < .05$) were found for forage magnesium concentrations. Magnesium in forages from the Western region was lower ($p < .10$) than in those from the Eastern region. The percentage of samples found below the critical concentration of .2% (McDowell, 1985) for the Western region was the highest among regions. Reid and Horvath (1980) indicated the effect of acid, highly leached soils and potassium fertilization on the impaired absorption and reduced availability of magnesium to the plant. Therefore, an explanation for the higher percentage of samples deficient in magnesium in the Western region could be due to soils with relatively high amounts of potassium as also was found in the same region.

Sodium concentrations in forages varied ($p < .10$) among the three regions. The Central region had lower ($p < .05$) concentrations than the other two regions, with the Eastern region ($p < .10$) than the Western. Individual evaluation of samples below the critical level of .06% (McDowell, 1985) also indicated that forage samples from the Central region had the highest percentage of sodium deficiency in both seasons. The overall percentage of forage samples deficient in sodium in both the rainy and dry seasons was 42%.

Regional differences ($p < .10$) were found for forage phosphorus concentrations, with the Western region having lower ($p < .10$) concentrations than the Eastern. Of all samples analyzed, 65% were deficient in phosphorus (< .25%) during the rainy season and 55% were deficient during the dry season. In the Western region, 89% of forage samples analyzed were deficient in phosphorus in both seasons. Forage phosphorus concentrations also varied due to district ($p < .01$) and the interactions of season and district ($p < .10$).

Crude protein was the only variable analyzed in forages, which showed seasonal differences ($p < .05$). The concentrations in the rainy season were higher than those in the dry season. For either season, however, crude protein concentrations were not different ($p > .10$) among regions. The overall percentage of forage samples below the crude protein value of 7%, regarded as critical for protein deficiency (Milford and Minson, 19

66) was higher in the dry season than in the rainy (30 vs 10%). This agreed with Gomide (1978) who found decreased forage nitrogen, phosphorus and potassium with increasing forage maturity. Moore (1980) suggested that mature forages having less than 7 to 8% crude protein are likely to show increased intake due to protein supplementation. Therefore, supplemental protein during the dry season may also be suggested for grazing cattle in South Sulawesi, that may increase voluntary forage intake, energy digestibility and animal performance.

Animal Tissue Analyses

Blood

Blood macromineral concentrations as related to season and region are presented in table 5, with percentages of deficient blood samples shown in table 6. There were no seasonal or regional effects detected ($p > .10$) in plasma calcium concentrations, but variations ($p < .01$) due to the district and the interaction of season by district were found. However, the average calcium concentrations for all regions were greater than the critical level of 8 mg/dl suggested by McDowell (1985). The incidence of calcium deficiency as the percentage of samples below critical levels for the Western, Central and Eastern regions, respectively, during the rainy season was 17, 13 and 5, and the overall incidence was 11%. Similarly, for the dry season, the percentages were

TABLE 5. BLOOD MACROMINERAL CONCENTRATIONS AS RELATED TO SEASON AND REGION

Variable[a]	Season	Region						Significance[d]
		Western		Central		Eastern		
		Mean[b]	S.E.[c]	Mean	S.E.	Mean	S.E.	
Ca, mg/dl	Rainy	8.4	.14	8.5	.14	8.5	.12	D(R)**, SD(R)**
	Dry	8.5	.14	8.7	.14	8.5	.12	
Mg, mg/dl	Rainy	2.2	.10	2.2	.10	2.5	.09	S*, R⁺, SR⁺, D(R)*,
	Dry	2.7	.10	2.4	.10	2.5	.09	SD(R)**, C_1⁺
P, mg/dl	Rainy	6.2	.81	6.1	.81	5.2	.70	D(R)**, SD(R)**,
	Dry	6.4	.81	5.2	.81	5.1	.70	C_2⁺

[a]Plasma for Ca and P, and serum for Mg.

[b]Least squares means of 10 samples/district with 3, 3 and 4 districts within Western, Central and Eastern regions, respectively, for each of the seasons.

[c]Standard error of least squares means.

[d]S = season, R = region, SR = season × region interaction, D(R) = district within region, SD(R) = season × district within region interaction, C_1 = Central vs Western and Eastern, C_2 = Western vs Eastern.

** $p < .01$. * $p < .05$. ⁺$p < .10$.

TABLE 6. PERCENTAGE OF BLOOD PLASMA AND SERUM SAMPLES DEFICIENT IN MACROMINERALS[a]

Variable	Critical level[b]	Season	Region			Overall
			Western	Central	Eastern	
Plasma Ca, mg/dl	< 8	Rainy	16.7	13.3	5.0	11.0
		Dry	10.0	6.7	12.5	10.0
Serum Mg, mg/dl	< 2	Rainy	20.0	20.0	2.5	13.3
		Dry	0.0	0.0	5.0	2.0
Plasma P, mg/dl	< 4.5	Rainy	16.7	0.0	30.0	17.0
		Dry	6.7	26.7	32.5	23.0

[a]Percentages based on 10 samples/district with 3, 3 and 4 districts within Western, Central and Eastern regions, respectively, for each of the seasons.

[b]Concentration below which is deficient (McDowell, 1985).

10, 7 and 13% for the Western, Central and Eastern regions, respectively; and the overall incidence of deficiency was 10%.

Seasonal differences ($p < .05$) were found for serum magnesium with concentrations during the dry season higher than those in the rainy season. Season by region interactions ($p < .10$) also were observed for serum magnesium. Serum magnesium concentrations for the Central region were lower ($p < .10$) than the other two regions. In the rainy season, a higher incidence of magnesium deficiency was found in the Western and Central regions than in the Eastern, with 20% of samples for both regions below the critical concentration of 2.0 mg/dl suggested by McDowell (1985). It is important to mention that these two regions also had higher percentages of low forage magnesium concentrations during the rainy season. During the dry season, the overall incidence of low serum magnesium decreased to 2%. McDowell et al. (1984), in a review of the diagnosis of specific mineral deficiencies and toxicities in cattle, reported that blood magnesium levels of 1 to 2 mg/dl are considered deficient, and a level of less than 1 mg/dl indicates danger of tetany.

Plasma phosphorus is not recommended as a practical criterion for assessing phosphorus status of grazing animals by some research groups (NCMN, 1973). There are many factors which could affect plasma phosphorus. Plasma phosphorus concentration is not nearly as constant as calcium level; this is understandable since blood phosphorus is in equilibrium, not only with bone phosphorus, but also with that arising from a large number of organic phosphorus compounds produced as a result of cellular metabolism (Irving, 1973). However, if the methods of collection and sample preparation are controlled, it is considered a good indication of status. Therefore, blood phosphorus values continue to be reported in the literature. No seasonal or regional differences ($p > .10$) were found for plasma phosphorus, although variations ($p < .01$) due to the district and the interactions of season by district were observed. During the rainy season, the Eastern region showed the highest percentage (30%) of samples below the critical concentration of 4.5 mg/dl suggested by McDowell (1985), followed by the Western region (17%) and none was detected for the Central region. The overall

TABLE 7. BONE MACROMINERAL CONCENTRATIONS (DRY, FAT-FREE BASIS) AND SPECIFIC GRAVITY AS RELATED TO SEASON AND REGION

Variable	Season	Region						Significance[c]
		Western		Central		Eastern		
		Mean[a]	S.E.[b]	Mean	S.E.	Mean	S.E.	
Ca, %	Rainy	22.6	.37	22.8	.37	23.1	.32	SD(R)⁺
	Dry	23.2	.37	23.3	.37	23.0	.32	
Mg, %	Rainy	.49	.04	.47	.04	.43	.03	SD(R)**
	Dry	.41	.04	.42	.04	.46	.03	
P, %	Rainy	10.1	.24	10.2	.24	10.1	.21	SD(R)*
	Dry	10.1	.24	10.2	.24	10.2	.21	
Ash, %	Rainy	62.2	1.24	62.1	1.24	63.3	1.07	SD(R)**
	Dry	63.8	1.24	64.3	1.24	63.1	1.07	
SG[d], g/cm³	Rainy	1.71	.06	1.91	.06	1.82	.05	R**, SD(R)**, C_1**
	Dry	1.82	.06	1.85	.06	1.75	.05	

[a]Least squares means of 10 samples/district with 3, 3 and 4 districts within Western, Central and Eastern regions, respectively, for each of the seasons.

[b]Standard error of least squares means.

[c]S = season, R = region, SR = season × region interaction, D(R) = district within region, SD(R) = season × district within region interaction, C_1 = Central vs Western and Eastern, C_2 = Western vs Eastern.

[d]Specific gravity.

** $p < .01$. * $p < .05$. ⁺$p < .10$.

percentage of deficiency was 17. In the dry season, the overall percentage of deficient samples was 23. Compared to the rainy season, a higher incidence of deficiency was found in the Central region, whereas a lower incidence was found in the Western region.

Bone

Bone macromineral concentrations and specific gravity as related to season and region are presented in table 8, with the percentages of deficient bone samples shown in table 9. There were no differences ($p > .10$) detected for seasons and regions in any of the bone variables analyzed, with the exception of specific gravity, which exhibited regional differences ($p < .01$). The values for bone specific gravity in the Central region were higher ($p < .01$) than the other two regions. However, the percentage of deficiencies based on the suggested critical levels (Little, 1972) for all minerals analyzed in each season and region was high. Since bone breakage in live animals is not excessive, it is suggested that the critical levels may overestimate inadequacy of bone minerals. The critical level of specific gravity may more accurately avaluate bone mineral status.

TABLE 8. PERCENTAGE OF BONE SAMPLES DEFICIENT IN MACROMINERALS, ASH AND SPECIFIC GRAVITY[a]

Variable	Critical level[b]	Season	Region			Overall
			Western	Central	Eastern	
Ca, %	< 24.5	Rainy	96.7	90.0	75.0	86.0
		Dry	70.0	73.3	85.0	77.0
P, %	< 11.5	Rainy	96.7	96.7	92.5	95.0
		Dry	96.7	93.3	92.5	94.0
Ash, %	< 66.8	Rainy	100.0	93.3	85.0	92.0
		Dry	80.0	83.3	92.5	86.0
SG[c], g/cm^3	< 1.68	Rainy	30.0	3.3	20.0	18.0
		Dry	10.0	10.0	27.5	17.0

[a]Percentages based on 10 samples/district with 3, 3 and 4 districts within Western, Central and Eastern regions, respectively, for each of the seasons.
[b]Concentration or value below which is deficient (Little, 1972).
[c]Specific gravity.

In both seasons, the average of bone calcium concentrations (dry, fat-free basis) in all regions were below the level suggested as critical (24.5%). Furthermore, individual evaluation of samples indicated that 86 and 77% of all samples analyzed were deficient in calcium for the rainy and dry seasons, respectively. The significant incidence of calcium deficiency indicated by bone calcium is not in agreement with the low incidence of calcium deficiency in blood plasma. This phenomenon, in part, may be attributed to the fact that blood calcium is controlled by hormonal mechanisms (Guyton, 1966) so that only in extreme deficiency would blood calcium below (NCMN, 1973; Boris et al., 1978).

The average bone phosphorus concentrations in all regions were below the critical level of 11.5% for normal cattle (Little, 1972). Overall percentages of deficient bone phosphorus for the rainy and dry seasons, respectively, were 95 and 94%. Cohen (1973) suggested that bone provides a more reliable method for assessing calcium and phosphorus than blood.

The percentage of samples below the critical concentration suggested by McDowell (1985) for bone ash (66.8% dry, fat-free basis) was 92 for all regions for the rainy season. Similar results also were obtained for the dry season, in which an overall 86% of samples were below the critical concentration. Since the majority components in bone ash are calcium and phosphorus (Ammerman et al., 1974; Maynard et al., 1979) the low concentration of bone ash may be attributed to the fact that bone calcium and phosphorus were also found to be low.

Regional differences ($p < .05$) were found for bone specific gravity in the rainy season, but were not found in the dry season. The overall percentage of bone samples below the critical level of 1.68 g/cm^3 (McDowell, 1985) was 18 for the rainy season and 17 for the dry season.

Relationship of soil and forage minerals

Soil-to-plant correlation coefficients were low ($r < .5$). Gross correlations were found for potassium ($r = .457$, $p < .01$) and phosphorus ($r = -.270$, $p < .10$) and sodium ($r = .307$, $p < .10$). A number of studies have shown little relationship between soil and forage minerals (McDowell et al., 1984; McDowell, 1985). Of the total Mineral Concentration in Soils, only a fraction is taken up by plants, soil factors (i.e., pH, drainage etc.) are often more important in determining plant mineral concentrations.

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