Biomass productivity and carrying capacity of the natural grassland on the Accra plains of Ghana

J. E. FLEISCHER, J. A. ALLOTEY & IRENE HEATHCOTE

(J.E.F.: Department of Animal Science, Faculty of Agriculture, University of Ghana, P. O. Box 226, Legon, Accra, Ghana; J.A.A.. and H. I.: Environmental Protection Council, P. O. Box M.326, Accra, Ghana)

SUMMARY

The study assessed the biomass productivity and then estimated the carrying capacity of the natural grassland on the Accra Plains of Ghana between January 1990 and February 1992. Eleven sampling sites with varying grass association, soil type and ease of accessibility were sampled. In each sampling site an area of 5.0 m × 5.0 m was demarcated within which 1.0 m × 1.0 m quadrat was sampled. Sampling was done by clipping the herbage at 5 cm above ground. This was later dried at 70 °C for more than 48 h for dry matter determination. Crop growth rate was then estimated. Overall dry matter yield was 4.80 t ha^{-1} yr^{-1}. It was 4.667 and 5.03 t ha^{-1} yr^{-1} on the clayey and sandy soils respectively. Three periods of crop growth rate were observed. These were i) period of very high productivity (April-July) with values of 2.128 and 2.286 of g m^{-2} day^{-1} for clayey and sandy soils respectively; ii) period of moderately high productivity (October-February) where the growth rate averaged 1.179 and 1.213 g m^{-2} day^{-1} for clayey and sandy soils and iii) periods of at least crop growth rate (March and September) with value of 0.635 and 0.749 g m^{-2} day^{-1} for clayey and sandy soils. The overall average carrying capacity was 3.60 ha AU^{-1} yr^{-1}.

RÉSUMÉ

FLEISCHER, J. E., ALLOTEY, J. A. & HEATHCOTE, IRENE. : *La productivité de la biomass et la capacité de charge d'herbages naturels sur la plaine d'Accra du Ghana.* Cette étude évaluait la productivité de la biomasse puis estimait la capacité de charge d'herbages naturels sur la plaine d'Accra du Ghana entre Janvier 1990 et Février 1992. Onze endroits d' échantillonnage avec association d' herbe, type de sol et facilité d' accessibilité variants, étaient échantillonnés. En chaque endroit d' échantillonnage une superficie de 5.0 m × 5.0 m était délimitée dans laquelle un quadrat de 1.0 m × 1.0 m était échantillonné. L' échantillonnage était fait par l' attachment d'herbage à 5 cm au-dessus du terrain. Celui-ci était sèché plus tard à 70 °C pour plus que 48 h, pour la détermination de la matiére séche. Les taux de croissance de la culture étaient donc estimés. L' ensemble de la matière sèche était 4.80 t ha^{-1} par an. Il était 4.667 et 5.03 t ha^{-1} par an respectivement sur les sols argileux et sablonneux. Trois périods de taux de croissance de la culture étaient observées. Celles-ci étaient; (i) période de la productivité très élevée (Avril - Juillet) avec les valeurs de 2.128 et 2.286 g m^{-2} par jour respectivement pour les sols argileux et sablonneux; (ii) période de la productivité modérément élévée (Octobre - Février) où le taut de croissance avait la moyenne de 1.179 et 1.213 g m^{-2} par jour pour les sols argileux et sablonneux et; (iii) la période de la moindre taux de croissance de la culture (Mars et Septemnbre) avec la valeur de 0.635 et 0.749 g m^{-2} par jour pour les sols argileux et sablonneux. L' ensemble de la capacité de charge moyenne était 3.60 ha AU^{-1} par an.

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Introduction

The Accra Plains of Ghana carry about 6 per cent of the national cattle herd and some 4 per cent of the national small ruminant flock (Min. of Agric. 1991). The ruminant livestock form an important financial security for the farmers in spite of their generally low productivity. However, like the rest of the country, the ruminant livestock production is based largely on the use of the natural grasslands. The characteristics of the natural grassland of the Accra Plains has been described (Baker, 1962; Jenik & Hall, 1976; Rose Innes, 1977). According to Carson (1985), no work has been done to establish the net primary productivity of the Accra Plains. However, Lansbury, Rose Innes & Maybey, (1965) reported dry matter yield of *Vetiveria fulvibarbis - Andropogon canaliculatus - Schizachirium schweinfurthii*

on the sandy and clayey soils to be 3.36 and 2.78 t ha^{-1} yr^{-1} respectively.

Similarly, there has been very limited estimates of the carrying capacity of the natural grasslands of the Accra Plains. Rose Innes (1977) suggested a conservative value of about 3.2 ha per annum per 317 kg beast (i.e. 3.0 ha per annum for livestock unit of 300 kg liveweight) on the western Accra Plains and suggested that a larger area would be required in the drier part of the south central plains. Nevertheless in 1985, Fleischer (unpublished) recognized six classes of range with a carrying capacity varying between 3.2 and 27.38 ha *per annum* per 300 kg beast.

The objective of this work was to study the biomass productivity and estimate the carrying capacity of the natural grasslands of the Accra Plains of Ghana.

Materials and methods

The project area

The work was carried out within the Accra Plains which is triangular in shape and situated in the south-east corner of Ghana between latitudes 06° 14'N and 05° 29'N and longitudes 00° 23'W and 00° 41'E. It covers a total area of 2800 km^2 (Jenik & Hall, 1976). The relief of the Accra plains is generally gentle rolling, rising to about 75 m above sea level except on the Shai Hill where the rocky hills rise abruptly to about 284 m above sea level. Slopes are largely of 2 per cent or less and only on the alluvial areas surrounding the coastal lagoons could it be said to be flat (Brammer, 1962). The major part of the Accra Plains are underlined by ancient igneous rocks. However, in the southern part relatively young unconsolidated sediments may be found. In the flood plains and valleys of the major stream on the plains are recent alluvium.

The actual sampling area which was about 100 km^2 was within the Accra Plains and was bounded on the north-west by the Ayikuma-Doryum road, on the south by the Old-Ningo-Dawa road and on the east by the Dawa-Aveyime road.

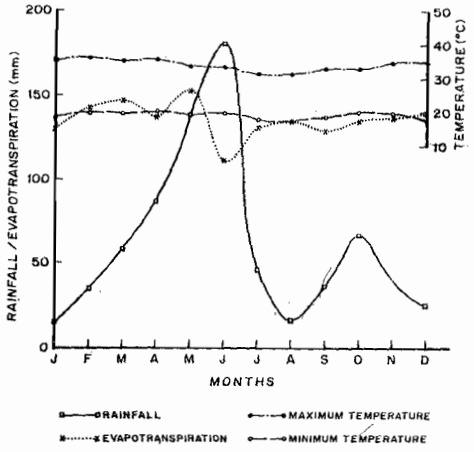

Fig. 1. Climatic characteristics of the Accra Plains

Climate

The climate of the area is typified by that of Accra (5° 33'N, 0° 13'W) as shown in Fig. 1. Temperatures are generally high throughout the year, averaging 26.4 °C. The average maximum temperature is 33.7 °C and the average minimum temperature is 19.0 °C. Rainfall which is the dominant climatic factor averages 732 mm per annum in Accra but very variable. The amount of rainfall increases north-eastwards so that Akuse (6° 06'N, 0° 08'E) in the north has 1170 mm per annum whilst Ada (5°47'N, 0°38'E) in the east has 880 mm per annum. Relative humidity is generally high throughout most of the year.

Vegetation

The vegetation of the Accra Plains has been variously described as "savanna forest", "parkland", "coastal savanna", "coastal forest savanna mosaic", "coastal scrub and grassland" or "coastal thicket and grassland" (Chipps, 1927; Talor, 1960; Jenik & Hall, 1976; Rose Innes, 1977). These various descriptions indicate that the vegetation of the plains is not uniform. It is dominated by grasses of varying heights interspersed with thickets and shrubs on widely scattered termite mounds (Jenik & Hall, 1976).

The large parts of the central and eastern section

is made up of short grasses characterized by such species as *Vetiveria fulvibarbis*, *Brachiaria falcifera*, *Andropogon canaliculatus*, *Monocymbium ceresiiforme*, *Schizachyrium schweinfurthii* etc. Along the Volta flood plains and the riverine areas are the tall grasses such as *Andropogon gayanus* var. *Gayanus*, *Hyperherinia smithiania*, *Panicum maximum*, *Echinochloa pyramidalis* etc. In the western section of the plains may be found short to medium tall grasses such as *Vetiveria fulvibarbis*, *Schizachyrium schweinfurthii*, *Ctenium newtonii*, *Sporobulus pyramidalis*, *Heteropogon contortus* etc. In the lagoon areas may be found such species as *Paspalum vaginatum*, *Pennisetum polystachion*, *Cenchrus biflorus*, *Dactyloctenium aegyptum* etc.

The clumps and thickets which decrease from West to East on the plains, are of such species as *Xanthozylon xyloides*, *Securinega virosa*, *Caparis erthrocarpus*, *Grewia carpinifolia*, *Milletia thorningii*, *Baphia nitida*, *Elaeophorbia drupifera* etc. There is, however, increasing spread of *Azadiracta indica* mainly on the tropical black soils and also *Dichrostachys cinearis* on the sandy soils.

Leguminous species are very few and these may include such species as *Indigofera tetrasperma*, *Aeschynome indica*, *Tephrosia purpureus*, *Desmodium trifolium* etc. A more detailed description of the vegetation of the Accra Plains may be obtained from the literature (Baker, 1962; Jenik & Hall, 1976; Rose Innes, 1977).

Experimental period, sampling site and method

The work was carried out between January 1990 and February 1992, i.e. two calendar years. A total of fourteen sampling sites were selected based on soil type (Brammer, 1962), grass association (Jenik & Hall, 1976), ease of accesibility and the fact that animal grazing is active in the areas. This is shown in Table 1. Sampling locations were carefully chosen to include both shaded and unshaded areas. Because resources were seriously limited,

TABLE 1

Grass Association and Soil Type of Experimental Site on the Accra Plains

Site	*Grass association*	*Soil type*
1	*Vetiveria fulvibarbis-Heteropogon contortus - Panicum maximum*	Clayey
2	*Eragrostis cilliaris-Heteropogon contortus* *Brachiaria falcifera-Monocyabium ceresiiforme*	Sandy
3	*Vetiveria fulvibarbis-Digitaria horizontalis* *Sporobulus pyramidalis*	Clayey
4	*Panicum maximum-Brachiaria falcifera* *Rottboelia exaltata*	Sandy loam
5	*Hyperrhenia rufa-Andropogon gayanus* *Ctenium newtonii*	Sandy
6	*Panicum maximum-Imperata cylindrica* *Digitarion horizontalis*	Sandy
7	*Panicum maximum-Pennisetum polystachion* *Heteropogon contortus* *Sporobulus pyramidalis*	Sandy
8	*Vetiveria fulvibarbis-Andropogon canaliculatus* *Brachiaria falcifera-Heteropogon contortus*	Sandy
9	*Vetiveria fulvibarbis-Brachiaria falcifera* *Andropogon canaliculatus-Sporobulus pyramidalis*	Sandy
10	*Andropogon canaliculatus* - *Sporobulus pyramidalis-Heteropogon contortus*	Clayey
11	*Rottboelia exaltata* - *Sporobulus pyramidalis-Heteropogon contortus*	Clayey

there were only two replications on the individual sampling sites. Soil samples were, however, taken at quarterly intervals for analysis at the Soil Research Institute, Kumasi.

In each sampling site, an area of 5.0 m × 5.0 m was demarcated within which 1.0 m × 1.0 m quadrat was sampled. Harvesting was done at 28-31 day intervals throughout the year by clipping the herbage at 5 cm above ground level. At harvest, the samples were weighed and sub-samples taken and later dried in an oven at 70 °C for more than 48 h and weighed for dry matter determination. There were thus two sets of readings made up of 12 readings per sampling site per year. Crop growth rates were estimated according to the method by Hunt (1990) i.e. by dividing the dry matter yield of each site by the number of days of the growth period for that site.

Estimating the carrying capacity of plains

It has been assumed that the stock considered is a mature bullock weighing 300 kg liveweight and that the requirement of such an animal is 2.5 kg DM of herbage for every 100 kg liveweight (Boudet, 1975b). Thus, for this animal, the daily requirement is 7.5 kg DM. It is also assumed that at any time the proper use factor of the grassland is 50 per cent of the potential production. Hence the monthly herbage dry matter yield is halved and considered as that available for the stock.

TABLE 2

Annual Total Dry Matter Yield of the Accra Plains

Site	*Yield*		*Mean yield*
	1990/91	*1991/92*	
1	8.501	7.712	8.107a
2	4.831	4.716	4.774cde
3	1.407	1.181	1.294f
4	7.461	5.653	6.557ab
5	4.723	6.756	5.740bc
6	5.434	5.259	5.347bcd
7	4.171	5.156	4.664cde
8	2.930	3.543	3.227de
9	1.678	5.902	3.790de
10	7.687	4.824	6.256bc
11	2.940	3.163	3.052e
Average	4.706	4.897	4.801
Standard error	2.409	1.75	1.902

Mean yields with different letters were significantly different ($P<0.05$).

TABLE 3

Dry Matter Yield of Grass Biomass of the Accra Plains as influenced by Soil Type (t ha^{-1}y^{-1})

Year	*Clay*	*Sand*	*Average*
1990/91	4.543	4.989	4.705
1991/92	4.797	5.072	4.897
Average	4.670	5.031	4.801

Standard error = 4.768

Results

Due to persistent flooding at some locations in the study area, only data from eleven sampling sites are reported.

The annual total dry matter yields from the various sites for 2 years are presented in Table 2. Significant differences ($P<0.05$) were observed among sites. Site 1 had the highest dry matter yield while Site 3 had the lowest yield. Even though Site 1 had higher yield compared to that of Site 4, the difference was not significant ($P<0.05$). The yield of Site 4 was similar to those of Sites 7, 8, 9 and 11. Sites 8 9, and 11 had similar ($P<0.05$) yields.

The dry matter yield obtained on each of the soil types for the 2 years are presented in Table 3. The yields on the clayey soils were slightly lower than those on the sandy soils by 0.36 t ha^{-1} yr^{-1} or almost 7 per cent. However, the differences were not significant ($P<0.05$).

The average monthly plant biomass yield of all the sites on the Accra Plains is shown in Fig. 2. A clear difference in pattern is observed between years even though both curves show two peak points between May and June (0.82 - 0.86 t ha^{-1}) and September and October (0.34 - 0.38 t ha^{-1}). A third peak which appears unusual may be observed in February of 1990/91. The lowest yields were ob-

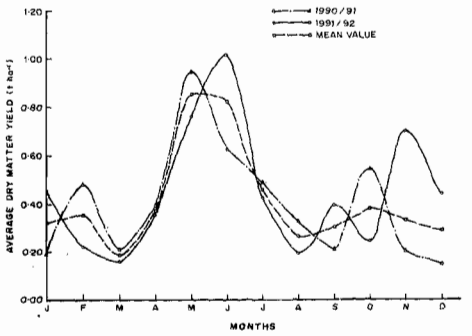

Fig. 2. Average monthly dry matter yield of the Accra plains

served in the months of February-March (0.185 t ha^{-1}) and August (0.265 t ha^{-1}) in both years. Whereas one expected to have had a depression in the dry matter yield in November, there was rather a dramatic increase in the 1990/91 value as a result of the rains in late October. There was quite a large variation in the monthly yields on the different sites. These ranged from 0.013 t ha^{-1} in Site 3 to 3.150 t ha^{-1} in Site 1 (Data not shown).

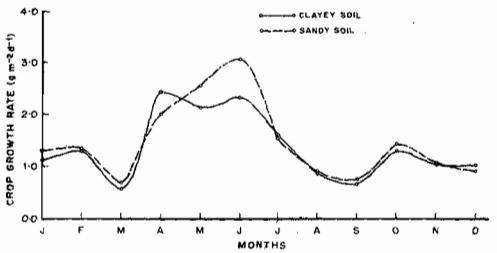

Fig. 3. Crop growth rate of the grass biomass of the Accra Plains as influenced by type of soil

Fig. 3 shows the daily crop growth rate of the grass biomass of the Accra Plains as influenced by soil type. Three major periods could be identified from this graph. These periods were similar for both soils types. These periods were as follows: i) period where yields were intermediate (i.e. October and February) and the yields for the clayey and sandy soils were 1.179 and 1.213 g m^{-2} day^{-1} respectively; ii) periods of least productivity (March and September) with yields of 0.635 and 0.749 g m^{-2} day^{-1} respectively, and finally, iii) periods of highest productivity (April -July) with yields of 2.128 and 2.286 g m^{-2} day^{-1} respectively.

TABLE 4

Estimated Carrying Capacity of different Sites on the Accra Plains

Site	*1990/91*	*1991/92*	*Annual average carrying capacity*
1	2.27	3.22	2.97ac
2	12.53	2.22	7.38b
3	6.73	8.89	7.81b
4	1.28	1.16	1.22a
5	1.48	1.24	1.36a
6	3.22	2.01	2.62a
7	3.21	1.45	2.33a
8	6.87	2.29	4.58ac
9	9.09	1.28	5.19abc
10	0.92	1.09	1.09a
11	3.36	2.36	2.86a
Mer	4.67	2.49	3.58
SI	3.686	2.219	2.366

Annual average carrying capacity of sites with different letters are significantly different ($P<0.05$).

The annual average carrying capacity is shown in Table 4. Wide variations were observed among sites in years. These variations which were significant ($P<0.05$) were largely influenced by the variation in the rainfall pattern and also the soil. For example in 1990/91, the highest value was obtained with Site 2 and the least with Site 10. In the 1991/92, the highest value of 8.89 was obtained with Site 3 and the lowest value of 1.16 with Site 4. The average values of the 2 respective years were 4.67 and 2.49 g m^{-2} day^{-1} but the difference was not significant ($P<0.05$). The average for both years

TABLE 5

Average Monthly Carrying Capacity of the various Sites of the Accra Plains (ha AU^{-1})

	Average monthly carrying capacity		
Year	*1990/91*	*1991/92*	*Average*
Jan	1.64	4.67	3.16
Feb	2.95	3.91	3.43
Mar	7.54	4.29	5.92
Apr	0.74	1.84	1.29
May	1.01	0.77	0.89
Jun	0.68	1.07	0.88
Jul	1.77	1.09	1.43
Aug	4.00	2.02	3.01
Sep	3.53	2.52	3.03
Oct	1.75	2.83	2.29
Nov	24.48	2.38	13.43
Dec	2.04	3.58	2.81
Mean	4.34(1)	2.58	3.46(2)

1) When the extreme value of November is removed, the average value is 2.30 ha AU^{-1}.
2) When the extreme value of November is removed, the average value is 2.56 ha AU^{-1}.

showed that the highest value of 7.81 g m^{-2} day^{-1} was obtained with Site 3 which had high values for both years. Sites 1, 4, 5, 6, 7, 8, 10 and 11 were similar (P>0.05). Sites 9 and 1 were also similar (P>0.05). The overall average was 3.46 g m^{-2} day^{-1}.

The average monthly carrying capacity of the various sites of the Accra Plains is shown in Table 5. Except for the unusually high value for November in the 1990/91 study year, the values obtained for the year ranged between 0.68 and 7.54 ha per animal units (AU^{-1}). In the year 1991/92, the value ranged between 0.77 and 4.67 ha AU^{-1}. The mean values for both years were 4.34 and 2.58 ha AU^{-1} with an average value of 3.46 haAU^{-1}. On the contrary, if the abberant November values were ignored then the average value was 2.30 haAU^{-1}, in which case the average value would be 2.56 ha AU^{-1}.

Discussion

The average annual dry matter yields of 4.67 and 5.03 t ha^{-1} yr^{-1} for clayey and sandy soils recorded in the present work were about twice that reported by Lansbury, Rose Innes & Maybey (1965). The data obtained by Lansbury, Rose Innes & Maybey (1965) was, however, limited to only a period of 32 weeks in the experimental year. On the contrary, Carson (1968) recalculating the data of Lansbury, Rose Innes & Maybey (1965) to estimate the annual net primary production of the plains obtained values of 3.36 and 2.78 t ha^{-1} yr^{-1} for the sandy and clayey soils respectively. These values were still lower than the values of 5.03 and 4.67 t ha^{-1} yr^{-1} respectively being reported in the present work. Ohiagu & Wood (1979) have reported that the annual grass production in Mokwa, Nigeria with a similar grass association ranged between 2.73 and 3.16 t ha^{-1} yr^{-1}. Piot & Rippstein (1975) also have reported that in the Sudano-guinea mountain rangelands of Adamoua plateau of Cameroun, the dry matter yield ranges between 3.43 and 3.71 t ha^{-1} yr^{-1}. Boudet (1975b) indicated that the annual grass production of the southern Sudanian vegetation of West Africa which has similar climate and vegetation of the Accra Plains ranges between 1.50 and 3.00 t ha^{-1} yr^{-1}. This may, however, reach 8.00 t ha^{-1} yr^{-1} in the floodable plains (Boudet, 1975a).

The crop growth rate values reported in the present experiment is higher than the values reported in other areas. Boudet (1975b) indicated that in the southern Sudanian vegetation, the growth rate of the grass phytomass on the floodable terraces may vary from 1.1 g m^{-2} day^{-1} in the rainy season to 0.3 g m^{-2} day^{-1} at the beginning of the dry season and 0.1 g m^{-2} day^{-1} in the mid dry season. On the contrary, in the areas where the soil water regime is better, the growth rate could reach 1.5 g m^{-2} day^{-1}.

The growth rate values obtained in this study are, however, influenced by a combination of factors among which include the grass assocation, the soil type and the rainfall. Similar observation has also been made by Frost & Smith (1991). It does, however, appear that rainfall is dominant among these factors. Indeed, a comparison of Site 1 and Site 3 with similar grass associations on tropical

black earth but with different rainfall regimes clearly demonstrate this point. These notwithstanding, because the data was collected over a limited period of only 2 years, it may be considered a first approximation to the actual grass biomass production on the plains.

Whereas the plains have been used for livestock production for many years, no direct estimate of the carrying capacity of the plains has ever been made. Rose Innes (1977) indicated that carrying capacity of the western section of the plains was about 3.0 ha AU^{-1} (one animal unit is defined as a mature steer weighing 300 kg liveweight), a value later confirmed by Fleischer (unpublished). Other estimates of the plains show 3.6-6.26 ha AU^{-1} yr^{-1} on the sandy loam, 9.12 ha AU^{-1} yr^{-1} on the silty clays and 27.36 ha AU^{-1} on the permanently waterlogged lagoons (Fleischer, unpublished). Thus, although the carrying capacity of the plains estimated in the present work varied between 1.10 and 7.80 ha AU^{-1} yr^{-1}, on the average, it appears that the value has not changed much over the years.

The average monthly carrying capacity of the various sites show that the use of fixed carrying capacity for all kinds of land is undesirable since such an approach could result in environmental degradation when any of the factors that influence the carrying capacity is inaccurately predicted for a season. The dominant factors have included the grass association, the soil and the rainfall which is the most varied at any time. In addition, there are various kinds of losses through such agents as termites, desiccation, wind, fire and trampling which are more difficult to judge so that allowance could be made for them in estimating the carrying capacity.

On the Accra Plains, in 1986, there were 40,041 AU of cattle. According to Ministry of Food and Agriculture (1991), only some 15 per cent of the land is used as unimproved pastures. Thus, it may be estimated that some 42,000 ha of the plains is assumed to be used for grazing. This means an average carrying capacity of 1.05 ha AU^{-1} yr^{-1}. This value is well below the average value for the Accra Plains. It is, therefore, not surprising that inadequate feed supply is a major drawback of livestock production on the Accra Plains. The problem becomes aggravated if other ruminants are considered.

Currently on the Accra Plains, the real problem is that in all the areas where grazing occurs, grazers are limited by the rights given them to move within certain circuits. In most traditional livestock production, the off-take level is very low, and compounding the problem is the refusal of most stock farmers to cull unproductive animals to release pressure on the land. Consequently, overgrazing is scattered and non-uniform.

In conclusion, the study has shown that the Accra Plains with its varied soil type, grass assocation and rainfall pattern has an annual total grass biomass productivity that ranges between 1.20 and 8.50 t ha^{-1} yr^{-1}, averaging about 4.80 t ha^{-1} yr^{-1}. The monthly productivity ranged between 0.68 and 7.54 t ha^{-1}, averaging some 2.43 t ha^{-1}. The annual carrying capacity varied between 0.92 and 12.53 ha AU^{-1} yr^{-1} whereas the monthly values ranged between 0.74 and 24.5 ha AU^{-1}.

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