Water Resources and Dry Matter Production for Livestock in Northern Nigeria

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INTRODUCTION

A MAJOR factor responsible for the comparatively low production of Nigeria's livestock under traditional husbandry methods is malnutrition, particularly during the dry season when the quantity of dry matter available may be insufficient to meet energy requirements. During the wet season good grazing is available, but inadequate feed and shortage of water during the dry season prevent steady growth and normal maturation hence giving low reproductive rates. This situation is aggravated by the challenge of trypanosomiasis and other endemic diseases, the incidence and the spread of which is related to environment.

To overcome these environmental limitations cattle production has developed along pastoral nomadic lines, following the pattern of rainfall distribution in search of pasture and to avoid tsetse fly. Although the role of cattle in peasant agriculture is limited largely to use as draught animals, the farmed areas have very important place in the nomadic system. For three months or more in the dry season (December to March) crop residues from the arable areas are a principal source of fodder. In some areas their utilization is so complete that by the end of March little edible material remains (Van Raay and De Leeuw, 1970.) By mutual agreement between Fulani and farmers the residues are utilized primarily

by Fulani cattle but increasing use is now being made by farmer-owned stock.

Under the present social and economic conditions of subsistence farming and nomadic pastoralism the choice of improvements and innovation that can be applied to raise the level of cattle production is limited. Assuming the first objective to be the improvement of the situation in the dry season the following may be suggested: (a) Encourage partnership between peasant farmers specializing in the provision of grain and fodders (including crop residues) and the Fulani to provide adequate rations for stock throughout the dry season; and (b) greater integration of livestock with arable farming by encouraging farmers to keep livestock to utilize crop residues, surplus grain and conserved fodders grown on the farm. The use of higher levels of inputs, particularly fertilizers, will increase the amount of dry matter in both the above.

Other techniques often proposed for raising production such as increasing herbage production of the rangeland by introduction of improved grasses and legumes, the use of fertilizer and improved management; the setting up of intensive range farming at fattening centres; opening of new grazing areas by fly eradication etc, are much more expensive.

Irrespective of whatever system is adopted an adequate supply of water for fodder and grass production, as well as drinking, is essential. The present paper

therefore assesses the reliability and adequacy of water supply during the rains for crop/pasture production. It estimates the magnitudes of water resources of the Northern States for drinking, supplementary irrigation and extensive irrigation. Finally, it attempts to assess potential productivity of various areas in terms of dry matter under rainfed management.

Water resources in northern Nigeria

General

The main source of water in northern Nigeria is rainfall. Although the river systems are fairly extensive, few rivers sustain permanent flow throughout the dry season. Towards the end of the dry season only the Niger, with its two tributaries, the Sokoto Rima and Kaduna rivers, show a significant flow in the western part of northern Nigeria, while in the eastern part the Benue and its major tributaries flow throughout the year.

Annual Rainfall

There is a high negative correlation ($r = -0.85$) between the annual rainfall (P) and latitude (X). The regression line is $P = 89.3 - 4.7X$, indicating that rainfall decreases by about one inch per 15 miles northwards. The average range in annual amount of rainfall at the southern and the northern boundary of the northern States is about 56 and 28 in respectively. The reliability of annual precipitation at 9:1 confidence limits in respect of latitudinal position (X) is given by the following regressions: Lower limit $P = 65.7 - 3.5X$; Upper limit $P = 118.7 - 6.3X$.

Length of the rainy period

It is clear that the northern states are well supplied with annual rainfall. Drought years of the magnitude witnessed

during the 1973 season, drastically reducing crop yields or causing crop failure due to reduction in the amount of rains or in the length of the rainy period, are very rare. There is a suggestion from an examination of long term records, that severe droughts may have a periodicity of about 30-33 years.

However, in northern Nigeria the distribution of annual rainfall is of greater interest in relation to crop and herbage production than annual amounts. There are very pronounced differences in the length of the rainy period and therefore in the potential production of dry matter under rainfed management, which are closely related to latitudinal position.

Fig. 1 shows the distribution of the length of the rainy period in the northern States of Nigeria.

The correlation coefficient between the latitude (X) and the length of the wet season (L) is -0.914 . The regression line is:

$LP = 367.8 - 20.4X$ days (1)
suggesting that the rainy period increases in length to the south by about 20.4 days per degree latitude. The rainy period ranges from about 90 days at latitude $13^{\circ}N$ (Sokoto-Katsina-Nguru) to about 210 days at latitude $7^{\circ}N$ at the southern boundary of the northern States. This enormous range in the length of the rainy period has obviously a profound effect on the potential productivity of agriculture, as will be described later on in the text.

Evaporation

The average annual evaporation from a fully covered vegetative surface ranges from about 50 in at the southern boundary to about 70 in at the northern boundary. The correlation coefficient between latitude (X) and the annual amount of evaporation (E) is 0.79 and the regression line is $E = 33.6 + 2.5X$. Roughly south of latitude

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7°30" the amount of annual rainfall is greater than evaporation.

Notional water budget

The water resource of the country can be conveniently assessed by means of water budget accounting. This has been reported by Kowal (1972) and here only a brief summary of the notional water budget in the six northern States is reviewed.

The assessment is based on evaporation data obtained from 20 synoptic stations and 148 rainfall stations covering an area of 281,782 square miles. The results are presented graphically in Fig. 2 and Table 1 using Thiessen polygons to demarcate areas of average evaporation. The water balance account is computed for each polygon by comparing the average values of the rainfall data within the polygon with the evaporation data of the centrally situated station in the polygon for each 10 day period of the year.

This procedure makes it possible to distinguish in quantity and time scale the following parameters:

- Et = computed evaporation from a surface fully covered by vegetation not lacking water for transpiration
- P = Precipitation
- WD = Water deficit, difference between Et and P
- WS = Water surplus, difference between P and Et
- IP = Ineffective precipitation, showers with total P of less than 0.5 in in any standard 10 day period at the beginning of the rainy season, which are assumed to evaporate rapidly and are non-effective in hydrology and agricultural

utility

- GC⁴ = changes occurring in the soil water reservoir within the assumed storage capacity of 4 in.
- AW⁴ = components of ground water and surface runoff
- EP = effective precipitation i.e. the amount of rainfall actually available for crops (P-IP-AW⁴.)

RESULTS

These are based on interpretation of Tables 1 and 2.

It will be noted that effective precipitation (EP) is considerably lower than annual rainfall (P), ranging from about 20 to 45 in. This range in the amount of available water to crops is well matched to the length of the rainy period, to evaporation rates and to crop water requirements during the growing period.

The period of water surplus (WS) occurs early in the season, steadily increasing in amount to reach a peak in August/September. This results first in the complete recharge of the soil water deficit in soil profiles, which usually occurs in July or early in August. Secondly, in ground water recharge with a consequent rise in the dry season water table and flow of streams. The range in W.S values is from about 5 in. at Nguru to about 30 in. at Jos.

Of special interest are AW⁴ values i.e. the amount of water lost in runoff and ground water flow. The period during which this occurs represents leaching of the soil with consequent nutrient loss and increased danger of accelerated soil erosion. The AW⁴ values range from about 1 in. at Nguru to about 25 in. at Jos polygon. Catchment basin studies at Samaru show that on the average about 60% of AW⁴ is lost in ground water flow and the remaining 40% in the surface runoff.

Annual values of the mean components of the water budget can be derived from the expression $P - ET - WD + WS = 0$
 Table 1 National water budget (in) of the study area

Polygon	Area (sq. miles)	% of total area	Evapo-transpiration $E_T=0.25$	Precipitation P	Water deficit WD	Water surplus WS	Ineffective precipitation IP	Storage 4.0 in		Rainy period		
								Assumed ground water AW_4	Effect precipitation EP_4	Start	End	Days
Lokoja	13772	4.89	53.77	51.60	21.72	19.58	1.31	15.58	34.71	1-10 IV	21-31 X	210
Makurdi	12810	2.61	54.88	53.66	22.05	20.83	1.03	16.83	35.80	1-10 IV	21-31 X	210
Ilorin	7009	2.49	50.51	49.77	18.49	17.72	1.17	13.75	34.85	21-31 III	1-10 IX	230
Ibi	25400	9.01	60.16	47.86	27.82	15.52	1.78	11.52	34.56	11-20 IV	21-31 X	200
Mokwa	9007	3.20	62.57	43.46	31.05	11.94	0.97	7.94	34.55	11-20 IV	11-20 X	190
Bida	6463	2.29	48.68	50.07	22.80	24.19	1.13	20.19	28.72	11-20 IV	21-31 X	200
Minna	9911	3.52	56.28	55.43	27.33	26.48	0.71	22.48	32.24	21-30 IV	21-31 X	190
Jos	12078	4.29	52.46	56.04	26.07	29.65	0.80	25.65	29.59	11-20 IV	11-20 X	190
Yola	22781	8.08	59.83	38.75	32.89	11.81	0.64	7.81	30.30	1-10 V	11-20 X	170
Yelwa	19371	6.87	22.71	43.63	31.48	19.40	0.92	12.40	27.31	1-10 V	11-20 X	170
Kaduna	10118	3.59	57.28	49.58	31.13	23.43	0.92	19.43	29.23	21-30 IV	11-20 X	150
Bauchi	17977	6.38	57.58	42.22	33.77	18.41	0.54	14.41	27.27	21-31 V	1-10 X	140
Samaru	2916	2.10	57.54	41.04	33.97	17.47	0.72	13.47	26.85	11-20 V	1-10 X	120
Potiskum	17243	6.23	63.47	32.07	40.97	12.57	0.73	8.57	25.77	1-10 VI	1-10 X	130
Maiduguri	29342	10.41	61.59	27.86	41.78	8.05	1.12	4.02	22.49	1-10 VI	21-30 IX	120
Gusau	13604	4.83	57.30	38.48	37.31	16.49	1.15	14.49	22.84	21-31 V	1-10 X	9
Kano	12379	4.39	69.67	31.39	49.36	11.62	0.67	7.62	23.64	1-10 IV	21-30 XI	35
Nguru	10477	3.72	71.45	22.33	54.21	8.09	0.86	1.09	20.38	21-30 VI	21-30 IX	15
Sokoto	17713	6.29	65.79	29.95	44.14	5.30	1.32	4.30	24.33	1-10 VI	21-30 IX	2
Katsina	2108	1.81	63.71	31.08	43.43	10.80	0.93	3.50	23.32	1-10 VI	21-30 IX	9
Total weighted values	281.782	100.00	29.48	41.05	—	—	—	—	—	—	—	161

The AW4 values are a useful guide to the amount of water that can be conserved in average years for dry season use within each polygon. The last column in Table 2 shows the approximate magnitude of the amount of water which can be conserved as a percentage of water deficit (WD). The values are much higher at lower latitudes (with the exception of Mokwa and Ibi polygons, where some 70-98% of the dry season water deficit (WD) could be met by water conservation assuming 100% efficiency of conservation.

At high latitudes the dry season water deficit could be reduced by between 2 and 20% in average rainfall years, or in other words an area of between 2 and 20% in the appropriate polygons could be brought into year-round cropping. It is obvious that at high latitudes water is in insufficient amounts for conservation and subsequent use for very large irrigation areas. At middle latitudes the potential water harvest is within the range of 20-70 of the annual water deficit.

Table 2 Notional water budget (in) in 10-day periods (long-term averages of rainfall and computed ET

Period	EI	P	WD	WS	IP	GC	GC4	AW4	EP4
Jan 1-10	1.48	0.01	1.47		0.01				
11-20	1.51	0.02	1.49		0.02				
21-31	1.70	0.03	1.67		0.03				
Feb 1-10	1.81	0.02	1.70		0.02				
11-20	1.80	0.03	1.77		0.03				
21-28	1.52	0.06	1.46		0.06				
Mar 1-10	1.98	0.13	1.85		0.13				
11-20	1.97	0.19	1.78		1.19				
21-31	2.23	0.28	1.98		0.28				
Apr 1-10	2.14	1.42	1.72		0.42				
11-20	1.99	0.67	1.32						0.67
21-30	1.97	0.81	1.16						0.81
May 1-10	1.95	1.11	0.84						1.11
11-20	1.92	1.23	0.69						1.23
21-31	2.11	1.64	0.47						1.64
Jun 1-10	1.83	1.85		0.02		0.02	0.02		1.83
11-20	1.62	1.94		0.32		0.32	0.34		1.62
21-30	1.59	1.91		0.32		0.32	0.66		1.59
Jul 1-10	1.52	2.17		0.65		0.65	1.31		1.52
11-20	1.42	2.38		0.96		0.96	2.27		1.42
21-31	1.46	3.20		1.74		1.73	4.00	0.01	1.46
Aug 1-10	1.28	2.78		1.50			4.00	1.50	1.28
11-20	1.25	3.06		1.78			4.00	1.78	1.28
21-31	1.28	3.70		2.36			4.00	2.36	1.34
Sep 1-10	1.32	2.98		1.66			4.00	1.66	1.32
11-20	1.40	2.83		1.43			4.00	1.43	1.40
21-30	1.48	2.13		0.65			4.00	0.65	1.48
Oct 1-10	1.52	1.57		0.02			4.00	0.02	1.52
11-20	1.57	0.95	0.62			-0.62	3.38		1.57
21-31	1.78	0.55	1.23			-1.23	2.15		1.78
Nov 1-10	1.53	0.17	1.36			-1.36	0.79		1.53
11-20	1.55	0.09	1.46			-0.79			0.88
21-30	1.56	0.03	1.3						
Dec 1-10	1.43	0.03	1.40						
11-20	1.42	0.02	1.40						
21-31	1.55	0.02	1.53						
Totals	59.53	40.98	31.96	13.41	1.19	—	—	9.41	30.38

Taking the whole 281,782 square miles comprising the area of the six northern States, the average weighted values of the components of national water budget are as follows:

Average precipitation	42 in.
Average water deficit:	32 in.
Average evaporation:	60 in.
Average water surplus:	36 in.
Ineffective precipitation:	1 in.
Seepage + runoff:	9.4 in.
Effective precipitation:	30 in.
Average duration of the wet season:	160 days
Length of growing period with assumed water storage of 4 in.	190 days.
Unproductive dry season,	175 days.

The wettest part of the season occurs during the third 10 day period in August, with 3.7 in. precipitation and 2.4 in. of water surplus. The period of water surplus is 130 days from 1st June to 10th October. The recharge of the assumed 4.0 in. of soil water deficit occurs during the middle of July. The period of leaching lasts for about 50 days from 21st July to 10th October.

Climatic potential for dry matter production

The effect of variation in the length of the rainy period on potential production of dry matter under rainfed conditions can be assessed with some precision.

Thus Kassam and Kowal (1973) have described the crop productivity potential of the Savanna and Forest zones in Nigeria. Their estimates show that mean monthly net photosynthesis during the year, in the savanna zone, has the following values: Low photosynthetic capacity plants (C_3 -species i.e. rice, groundnuts, cowpea, cassava) at full cover may have assimilation rates ranging from 13-19 gm 2^{-1} day. High photosynthetic capacity plants (C_4 -species e.g. maize, millet,

sorghum, elephant grass) at full cover may have assimilation rates ranging from 24-43 g m^{-2} day $^{-1}$. At Samaru, under condition of high fertility and good management, a 117-day maize crop produces 18,600 kg ha^{-1} total dry matter and 6,800 kg ha^{-1} grain. This growth performance of 16g m^{-2} day $^{-1}$ represents energy conversion of 1,300 of the total incident radiation (Kowal and Kassam, 1973). However, during the active growth period in July and August the rate of growth is about 28g m^{-2} day $^{-1}$, equivalent to energy conversion of 2,300. These data illustrate the range in magnitude of dry matter production potential in the savanna areas of Nigeria.

For relative numerical assessment of dry matter production by grassland, forage and grain crops at various levels of inputs i.e. (fertiliser, management, choice of plant material, etc) in respect to the length of the rainy period, data on efficiency of total light utilisation (Σ) are required.

By definition the efficiency of energy conversion (Σ) is the ratio of energy fixed in crop dry matter to total incident energy received. At present few of these data available are tabulated in Table 3.

Quantitative relationships that exist between latitudinal position (X) and certain relevant agrometeorological parameters are described by the following regressions:

$$\text{Length of rainy period in days LP} = 36.78 - 2.04 X \quad (1)$$

$$\begin{aligned} \text{Total amount of incoming radiation} \\ \text{during the rainy period (RLP)} \\ \text{RLP} = 129665 - 6423 X \text{ cal cm}^{-2} \text{ season}^{-1} \quad (2) \end{aligned}$$

$$\begin{aligned} \text{Average daily radiation income during} \\ \text{the rainy period RLP} = 288 + 11.6X \\ \text{cal cm}^{-2} \text{ day}^{-1} \quad (3) \text{ LP} \end{aligned}$$

Assuming the value of 4.0kcal as stored energy content in 1g of plant dry

Table 3. Approximate efficiency of energy conversion for Nigerian grassland calculated from data provided by P. N. de Leeuw

Crop	Fertiliser kg/ha	Ex 10 ⁻⁴	D.M. yields tons/ha
A. <i>gayanus</i>	67 P ₂ 05 0 N	42	6.2
	-do- 100 N	61	9.0
	-do- 200 N	66	9.6
C. <i>gayana</i>	-do- 0 N	43	6.3
	-do- 100 N	63	9.2
	-do- 200 N	77	11.2
D. <i>smutsii</i>	0 0	32	4.7
	0 100 N	39	5.8
	0 200 N	46	6.7
Upland shrub Shika	—	25	3.7
Fadama Shika	—	47	6.8

matter (DM) the efficiency of energy conversion (Σ) in respect of latitudinal position during the rainy period is:

$$\Sigma = \frac{4000 \text{ DM}}{129665-6423X} \quad (4)$$

Choosing the appropriate efficiency of energy conversion value (Σ) the amount of dry matter in $\text{g m}^{-2} \text{ season}^{-1}$ can be calculated for any locality in the Northern

States from equation 4. This estimate of productivity assumes that the rainy period is wholly utilised, and in this respect it probably reflects better productivity of grassland and forage crops than of grain. For estimates of grain production the appropriate correction factor of harvest index must be inserted in the equation and an appropriate variety chosen to match the length of the rainy period (Table 4).

Table 4. Range in efficiency of energy conversion (M)

System Source	Efficiency Ex 10 ⁻⁴	Remarks
Subsistence farming	4-10	average
Ranch Farming	8-20	probable best
	10-10	average
Intensive farming	20-40	probable best
	25-35	large inputs
Samaru experiments	60-130	best over season
	130	(153 t/ha maize)
Maize grain production	230	during active growth
Millet	224-208	Kassam and Kowal, 1973
Sorghum Forafora	190	Kassam and Kowal, 1973
Short Kaura	128	Kassam and Kowal, 1973
NK 300	122	Kassam and Kowal, 1973
Theoretical upper limit	800-1000	

Example

Choosing an efficiency of assimilation of 100 which would entail moderate fertiliser input and good management the expected dry matter production at Samaru (Lat. 11°) would be:

$$\frac{(129665-6423 \times 11) 0.01}{4000} = 0.14753 \text{ g cm}^{-2}$$

season⁻¹ or 14,753 kg⁻¹/ha⁻¹/season⁻¹.

The range of expected dry matter production at the same level of efficiency

(1%) at 13° and 7°N latitude is 11,500 kg/ha and 21150 kg/ha, respectively.

CONCLUSIONS

In general Northern Nigeria is well endowed with water resources for rain-fed agricultural production. Even during exceptionally dry years when agricultural production is drastically affected in the Sahel (800 square miles) and Sudan Zones (93,000 square miles), areas south of 11° 30' latitude is not affected by water shortage to reduce yield of crops significantly (Kowal and Kassam, 1973).

Distribution of rainfall and radiation income during the rainy season is favourable for intensive agricultural production justifying high inputs with acceptable risks. The length of rainy season markedly affects seasonal productivity, which can be estimated in respect of latitudinal position (X) at a chosen input level (Σ) from the following equation:

$$\Sigma (129665-6423X) = \text{DM g}^{-1} \text{cm}^{-2}$$

4000
season⁻¹

At higher and middle upper latitudes the climate lends itself to more intensive grain production since crops and crop varieties may be more efficiently matched to the length of the rainy period and thereby utilizing more efficiently available water and relatively higher radiation income. As the rainy season is short, very large amounts of fodder per unit area would have to be produced and conserved to support food requirement of livestock for the dry season. Water harvest and conservation at higher latitudes is limited in amount for large scale extension of the grazing period

At lower latitudes with a much extended rainy period, a much higher water resources (that can be conserved and utilized in irrigation) and a comparatively much higher seasonal dry matter production, livestock production would be easy to accommodate. Here under a much longer growing period, grass and fodder production are more favourable for efficient utilization of climatic conditions. Obviously much less fodder for dry season feeding has to be conserved thus easing management problems and reducing costs of livestock production during the short dry season. Assuming effective control of trypanosomiasis and other health hazards more prevalent in the southern parts, livestock production at lower latitudes should be less costly, easier to manage and more productive. However, it must be stressed that when these areas are opened to year round grazing, their management must ensure a proper balance between herbaceous and woody species in order to avoid erosion and rangeland deterioration.

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